

FOCAL SPOT

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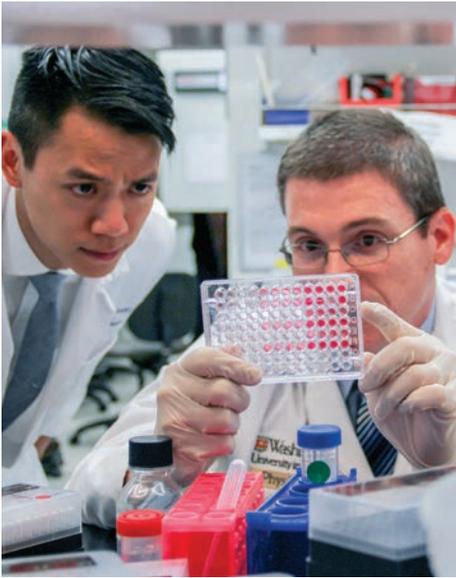


**SPRING/SUMMER 2018** An Inside Look at the New Face of Stroke Treatment  
MALLINCKRODT INSTITUTE OF RADIOLOGY // WASHINGTON UNIVERSITY // ST. LOUIS

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### FOCAL SPOT MAGAZINE SPRING/SUMMER 2018

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**Cover Photo:** Fifteen-year-old Arron Whitt was treated nearly nine hours after his stroke began.



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# 2018 MIR Research Symposium

More than 200 faculty, staff and postdoctoral research associates turned out for the annual Mallinckrodt Institute of Radiology Research Symposium and poster session. The annual event,

held in the Farrell Learning and Teaching Center on April 3, featured 67 posters showcasing an array of ongoing basic and clinical research conducted by MIR investigators.



a.



b.



c.



d.

**a.** Robert Gropler, MD, senior vice chair and division director of radiological sciences, talks with graduate research assistant Parna Eshraghi Boroojeni. **b.** Keynote speaker Markus Schwaiger, MD, professor and chairman of the Department of Nuclear Medicine at the Technical University of Munich, presents “Translational Molecular Imaging: Challenges and Opportunities.” **c.** Joshua Shimony, MD, PhD, professor of radiology, gives the opening lecture “How We Identify Brain Networks at Rest.” **d.** The 2018 MIR Research Symposium, which began at noon, featured 67 posters.

# Co-Clinical QI: Advancing Precision Medicine

Researchers with Washington University's Co-Clinical Imaging Research Resource (C2IR2) are developing quantitative imaging (QI) methodologies in order to advance the science and clinical practice of precision medicine.

C2IR2 is participating in a National Cancer Institute (NCI) initiative to develop advanced QI methodologies in the context of co-clinical trials. These trials are defined as parallel investigations in patients and in human-in-mouse models of cancer that mirror the genetics and biology of the patients' malignancies or pre-cancerous lesions.

"Patient tumors are grown in PDX (patient-derived tumor xenografts) mice," says Kooresh I. Shoghi, PhD, associate professor of radiology and a principal investigator with the C2IR2 project. "The PDX mice are used to test the efficacy of drugs, develop translational QI methodologies, and to inform the clinical trial." For years, genomic signatures have been investigated to predict disease or therapeutic outcome with limited success, says Shoghi. In light of the redundancy in the genomic landscape, QI can supplement this effort by extracting measurable features from medical images, such as MRI and PET scans, to identify disease and to assess treatment response, either alone or in combination with genomic data. "We are looking beyond qualitative images," he adds. The MIR-based initiative crosses multiple imaging disciplines and laboratories, and the imaging informatics group is building a database system to house the images and related data.

In addition to Shoghi, other principal investigators with the project are Richard L. Wahl, MD, the Elizabeth E. Mallinckrodt Professor of Radiology and MIR director; Joseph J.H. Ackerman, PhD, professor of radiology and the

Special procedures technologist Margaret Morris performs small animal preclinical imaging protocols for C2IR2.



William Greenleaf Eliot Emeritus Professor of Chemistry; and Shunqiang Li, PhD, assistant professor of medicine and director of the Human and Mouse Linked Evaluation of Tumors (HAMLET) Core at Washington University.

## More Realistic Animal Models

Unlike many other research studies involving animals, the C2IR2 will not use established cancer cells lines.

"Some established cell lines have been propagated for decades and, as a result, have very little in common with human tumors," says Shoghi. "They're not heterogeneous, and thus offer limited utility in predicting therapeutic outcome or efficacy of drugs in clinical trials." C2IR2 is using more realistic animal models. It will use mice that have been implanted with tumor tissue samples from patients enrolled in a triple negative breast cancer trial. Researchers will generate two types of PDX mice for the study.

## Mouse-to-Man, Man-to-Mouse

"The PDX mice will be used to unify the application of QI across scales and species (from mouse-to-man) and to correlate image features with the biology of the tumor," Shoghi says. All data will be uploaded to a dynamic and modular informatics resource, available to test new algorithms and mine for novel leads integrating imaging and multi-scale analytic data to predict therapeutic response in triple negative breast cancer.

"We built the imaging informatics platform that will be used by the study," says Daniel Marcus, PhD, associate professor of radiology. "It's an open source platform called XNAT that is widely used around the world," adds Marcus, who is chief of MIR's Electronic Radiology Laboratory and a C2IR2 co-investigator. "It was designed primarily for human imaging, so an important part of this project is to adapt it for preclinical imaging."

## First In Class

C2IR2 is the first center of what the NCI hopes will become a network of imaging research resources that will help establish best practices of how quantitative imaging is applied in the context of co-clinical trials. In March, the center completed the first year of a five-year, \$3.2 million combined grant. The resource center brings together expertise in a variety of areas, including preclinical and clinical PET and MR imaging, oncology, animal modeling, informatics and quantitative imaging.

"This is truly a multidisciplinary effort," says Shoghi.

# What's Sex Got to Do With It?

by Tamara Bhandari

Belly fat affects the odds of women surviving kidney cancer but not men, according to a new study by researchers at Mallinckrodt Institute of Radiology (MIR). Half of female kidney cancer patients with substantial abdominal fat at the time of diagnosis died within 3 1/2 years, while more than half of women with little belly fat were still alive 10 years later. For men, the amount of abdominal fat appeared to make no difference in how long they survived.

"We're just beginning to study sex as an important variable in cancer," says Joseph Ippolito, MD, PhD, an instructor in radiology and MIR researcher who conducted the study. "Men and women have very different metabolisms. A tumor growing in a man's body is in a different environment than one growing inside a woman, so it's not surprising that the cancers behave differently between the sexes."

Excess weight is a major risk factor for the development of kidney cancer, but it does not necessarily portend a poor outcome. Rather, the new study — published in the March online edition of *Radiology* — suggests that how long a patient survives after diagnosis is linked not to total fat but to the distribution of body fat, at least for women.

Most methods of estimating body fat rely on just a person's height and weight. But not all fat is the same. The kind you can squeeze, called subcutaneous fat, seems to be mostly harmless. But visceral fat, which lies within the



Joseph E. Ippolito, MD, PhD, and research technician Shanshan Zhang examine a tissue sample.

abdomen and encases internal organs, has been associated with diabetes, heart disease and many kinds of cancer.

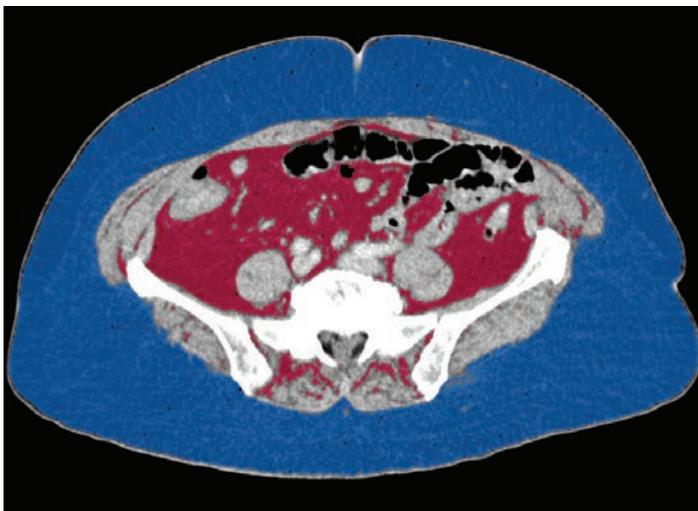
Visceral fat sits too deep inside the abdomen to be measured accurately with a tape measure around a person's waist. Instead, Ippolito analyzed cross-sectional CT scans, which are routinely performed on people newly diagnosed with kidney cancer to measure the size of tumors and to look for metastases. Subcutaneous and visceral fat are located in different areas of the body on a CT scan, making it possible to calculate the proportion of each.

"We know there are differences in healthy male versus healthy female metabolism," Ippolito says. "Not only in regard to how the fat is carried, but how their cells use glucose, fatty acids and other nutrients. So the fact that visceral fat matters for women but not men suggests that something else is going on besides just excess weight."

Using data from The Cancer Genome Atlas, the researchers analyzed the gene expression profiles of tumors from 345 men and 189 women diagnosed with kidney cancer. Both men and women were less likely to survive if their tumor cells had switched on the genes associated with consuming sugar, or glycolysis. Men whose tumor cells exhibited low glycolysis survived an average of 9 1/2 years, whereas those with high-glycolysis tumors survived for only six years on average.

The researchers found 77 women with matched imaging and gene expression data, so they combined their analyses of visceral fat and glycolysis.

For women with kidney cancer, the amount of visceral fat (shown in red) matters when it comes to survival.



About a quarter of the women had a high amount of visceral fat and tumors whose glycolysis genes were significantly active. Those women survived only two years after diagnosis on average. Strikingly, of the 19 women who fell into the low visceral fat and low glycolysis category, none died before the end of the study, which covered a span of 12 years. There was no group of men with a similarly favorable prognosis.

“Our data suggest that there is a potential synergy between the patient’s visceral fat and the metabolism of their tumor. That can be a starting point to figure out how to better treat women with kidney cancer. We would not have discovered this if we had been looking at men and women together,” says Ippolito.

“Sex differences in cancer metabolism is a new paradigm in oncology.”

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## ATTRACT Trial Results Mean Patients Spared Risky Treatment

by Tamara Bhandari

Not all patients with a condition known as deep vein thrombosis (DVT) need to receive powerful but risky clot-busting drugs, according to results of ATTRACT, a large-scale, NIH sponsored multicenter clinical trial.

“What we know now is that we can spare most patients the need to undergo a risky and costly treatment,” says Suresh Vedantham, MD, professor of radiology at MIR and the study’s principal investigator. Vedantham is referring to a procedure where doctors insert a thin, flexible plastic tube through a tiny incision in the leg and navigate it through the veins using X-ray and ultrasound guidance, until it rests within the clot. They instill a drug known as tissue plasminogen activator through the tube, give it time to digest the clot, and then suck out or grind up any remaining fragments using specialized catheter-mounted devices. The procedure is costly and often requires a hospital stay.

The findings, published in *The New England Journal of Medicine*, showed that routine use of the procedure did not reduce the chance of developing post-thrombotic syndrome (PTS). The researchers also noted a worrisome increase in the number of people who developed major bleeding after undergoing the procedure. However, the procedure did reduce the severity of PTS, easing patients’ long-term symptoms. It also alleviated pain and swelling in the early stages of the disease, when patients are often very uncomfortable.

“We are dealing with a very sharp double-edged sword here,” says Vedantham, who also is an interventional radiologist. “None of us was surprised to find that this treatment is riskier than blood-thinning drugs alone. To justify that extra risk, we would have had to show a dramatic improvement in long-term outcomes, and the study didn’t show that.”

While the study showed that most patients should not undergo the procedure, the data hint that the benefits may outweigh the risks in some patients, such as those with exceptionally large clots.

“This is the first large, rigorous study to examine the ability of imaging-guided treatment to address post-thrombotic syndrome,” Vedantham says. “This study will advance patient care by helping many people avoid an unnecessary procedure. The findings are also interesting because there is the suggestion that at least some patients may have benefited. Sorting that out is going to be very important. The ATTRACT trial will provide crucial guidance in designing further targeted studies to determine who is most likely to benefit from this procedure as a first-line treatment.”

In March, the ATTRACT study was given a 2018 Top Ten Clinical Research Achievement Award from the Clinical Research Forum. The annual awards honor innovative and groundbreaking accomplishments in clinical research. 

# In To Africa

In August 2017, Robert C. McKinstry, MD, professor of radiology and senior vice chair for the division of diagnostic imaging, traveled to South Africa as part of the Anne G. Osborn ASNR International Outreach Professor Program. The two-week volunteer program is available to senior members of the American Society of Neuroradiologists (ASNR) who are interested in teaching in developing countries.

McKinstry visited five public hospitals while in South Africa, reviewing difficult cases with the consulting physicians and residents, helping refine MR protocols (diffusion, perfusion, MR spectroscopy, cranial nerves), and giving impromptu lectures on a variety of topics. While he says the trip was transformative, it was not without its difficulties.

“I visited the third-largest hospital in the world and they only had two MRI machines,” says McKinstry. He compares that to Mallinckrodt which, combined with Barnes-Jewish and St. Louis Children’s Hospital,

is about one-third the size and has 12. As a result, there can be up to a nine-month wait for a scan. “I’ve never seen anything like this because I’ve never worked in an underserved or resource-limited area.”

McKinstry says the experience gave him a true appreciation for the global gaps in access and subspecialty expertise. “The concerns of the developing medical world are under-investigated,” he adds. “And the developed medical world is not keyed in to what those things are.” Despite the inherent challenges, he says the outreach program was life changing and encourages others to follow suit.

“If you get the opportunity to take your knowledge and understanding to an area where there are resource limitations, an entirely different set of diseases, and the inability to subspecialize, you’ll learn a lot.”



Photos // Robert C. McKinstry

**Opposite:** A 20-foot tall bronze statue of Nelson Mandela, the late president of South Africa, stands in front of the Union Buildings in Pretoria.

**a.** McKinstry with physicians (front row) and residents from Steve Biko Academic Hospital in Pretoria.

**b.** Morning lectures at Johannesburg Hospital Wits University started at 7:30 a.m. **c.** Dr. Jaishree Naidoo, head of radiology at Nelson Mandela Children's Hospital in Johannesburg. **d.** McKinstry and Dr. Victor Mngomezulu; the day's cases included a MR spectroscopy diagnosis of a Glutaric Aciduria Type 1. **e.** Physicians, residents and staff at Rahima Moosa Mother and Child Hospital in Johannesburg.



# DAWN

## of a New Day in Stroke Treatment

by Holly Edmiston

**Fifteen-year-old Arron Whitt had no way of knowing that his first day of football practice at O’Fallon Township High School would end with his collapse and transfer via helicopter to St. Louis Children’s Hospital. But it wasn’t extreme heat or exertion that felled Arron that day; there wasn’t even an on-field practice. The Illinois high school junior didn’t know it yet but he had, in fact, suffered a stroke much earlier in the day.**

Thanks to a procedure performed by MIR’s interventional neuroradiologists, Arron Whitt was released from the hospital just one week after suffering a stroke.





After quick evaluation at Children’s, Arron was immediately transferred to Barnes-Jewish Hospital for treatment. As part of an interdisciplinary stroke team, Mallinckrodt Institute of Radiology interventional neuroradiologists performed an endovascular thrombectomy to clear the blockage in his brain. One week later, on June 26, 2017, Arron was released from the hospital, started both occupational and physical therapy, and was on his way to a full recovery.

## A Larger Window of Time

Endovascular thrombectomy is a minimally invasive, image-guided procedure that allows interventional neuroradiologists to gain access to blocked blood vessels in the brain through the leg’s femoral artery. After entry through a small incision in the groin, they navigate this natural tunnel system — using real-time X-rays — to thread a catheter to the blockage. Once in place, a tiny mechanical device is used to break up or remove the clot.

Though not new, the use of thrombectomy has increased recently due to the results of a study that found it to be highly effective in treating stroke patients like Arron. That is, when there is a significant time lag between stroke onset and treatment, and when a large volume of viable brain tissue remains.

Traditional treatment for acute ischemic stroke — the result of blood clots obstructing vessels supplying blood to the brain — is the intravenous administration of tissue plasminogen activator (tPA). The drug breaks up many clots but it frequently fails to dissolve large clots in the major arteries and, to be effective, must be given within 4.5 hours after a stroke begins.

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## The study showed that patient outcomes 90 days after stroke were markedly better with thrombectomy.

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These obstacles led researchers to explore other options. Several studies have investigated endovascular thrombectomy, either alone or as an adjunct to tPA. Building on these studies, the DAWN trial, a multicenter study published in November 2017 in *The New England Journal of Medicine*, indicates that not only is the procedure effective at destroying or removing blood clots, it also can be performed during a larger window of time than other stroke treatments. Perhaps most important, the study showed that patient outcomes 90 days after stroke were markedly better with thrombectomy.

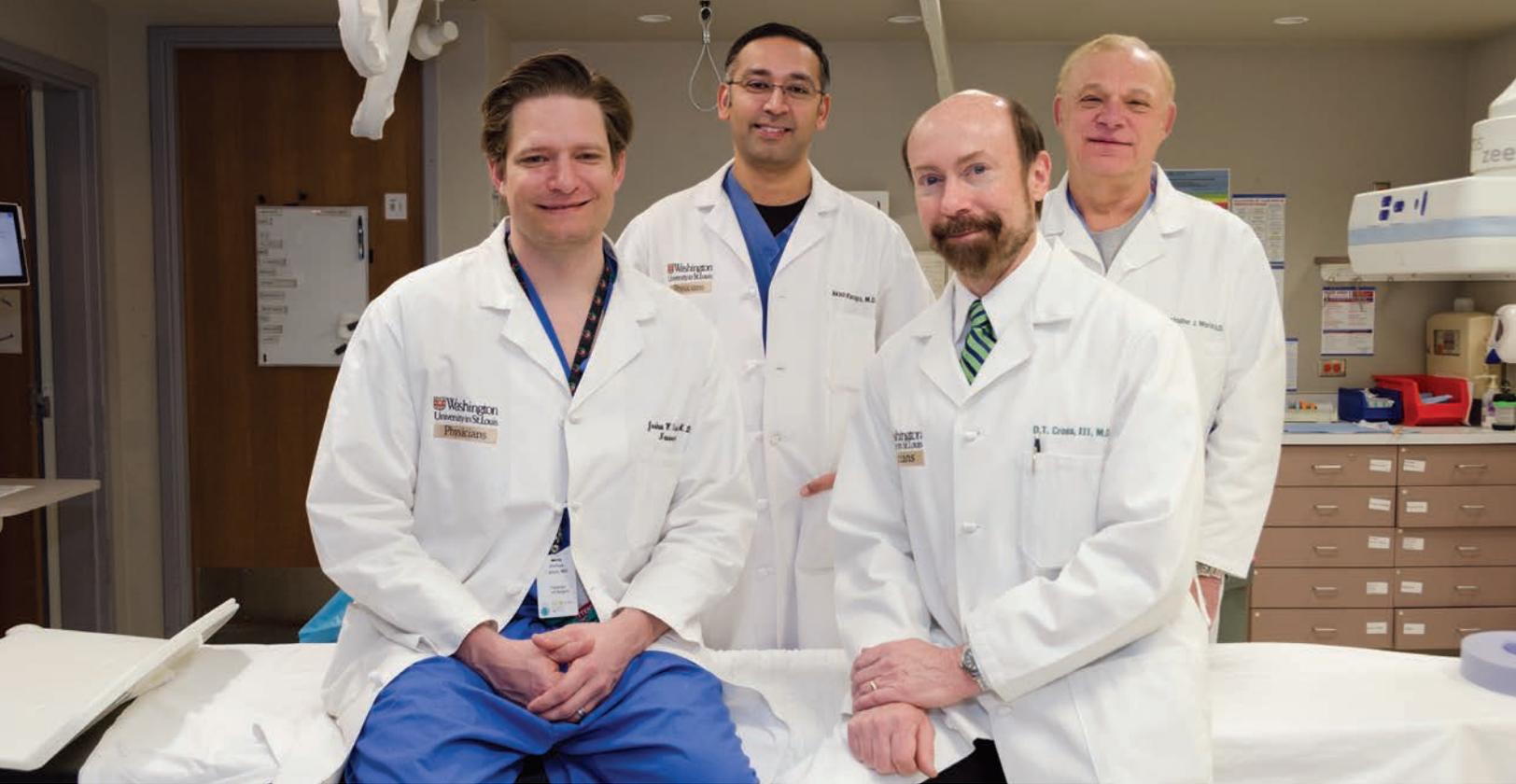
## Expanded Criteria

“In 2015, a series of five landmark trials came out that definitively proved that thrombectomy is extremely effective in a subset of stroke patients,” says Akash P. Kansagra, MD, assistant professor of radiology, neurology and neurological surgery. “The DAWN trial was one of the first to push the envelope by studying thrombectomy in patients in whom benefit was less certain, particularly those further out from onset of symptoms.”

That approach certainly benefited Arron, who was treated nearly nine hours after his stroke began. And like many stroke patients of all ages, Arron didn’t realize he was having a stroke. His initial symptoms — headache, lack of appetite and extreme fatigue — didn’t seem that alarming to the 6-foot, nearly 200-pound teenager or his mother, Tamala Malone, who later that afternoon found him prostrate on the floor. “It felt like a normal headache to me,” says Arron, who just wanted to sleep when he got home after practice.

Because Arron’s initial symptoms didn’t seem that alarming, Tamala Malone had no idea her son was having a stroke.





**Left to right:** As members of the stroke team, Joshua W. Osbun, MD, Akash P. Kansagra, MD, DeWitte T. Cross III, MD, and Christopher J. Moran, MD, regularly perform thrombectomies.

The DAWN trial found that when the amount of brain affected by stroke symptoms is substantially larger than the irreversibly damaged area, there is a very good chance that a patient may benefit from thrombectomy. For physicians, this means they have more time to treat stroke. For patients, it means faster and more complete recovery from the effects of stroke. However, it remains imperative to treat stroke as quickly as possible.

## A Breakthrough Stroke Center

In November 2017, Kansagra was named co-director of the Washington University and Barnes-Jewish Stroke & Cerebrovascular Center. Designated as a Comprehensive Stroke Center by the Joint Commission and the American Heart Association/American Stroke Association, Barnes-Jewish Hospital has been recognized for its team-based approach to complex stroke care. The center was the first of its kind in the region and remains one of a handful today that not only provides patients with the latest in care, but also focuses on research, patient safety and education, employee training, and in creating an efficient hospital infrastructure.

“One of things I value most at Washington University and Barnes-Jewish is the spirit of collaboration,” says Joshua W. Osbun, MD,

assistant professor of neurosurgery, radiology and neurology. Osbun, who was directly involved with patient recruitment and enrollment for the DAWN trial while a fellow at Emory University, considers the trial’s results to be among the most important medical findings in recent years.

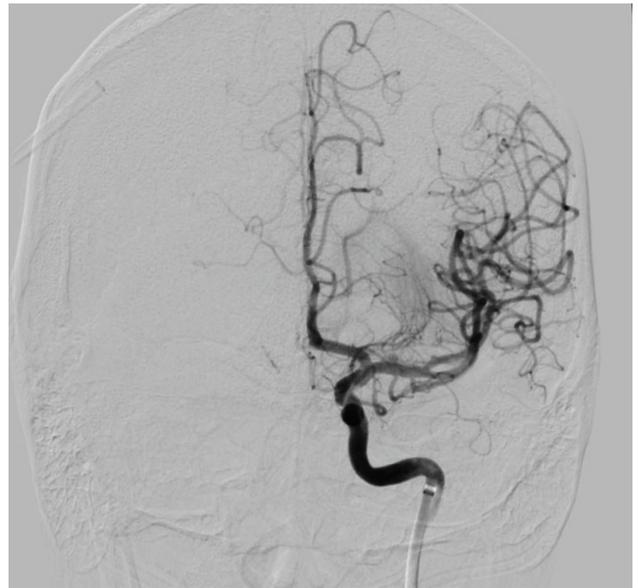
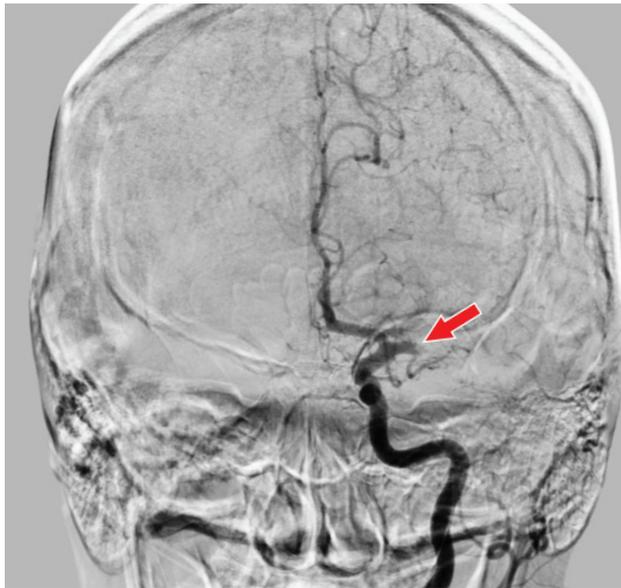
“This research has an immediate impact to the population of the United States because there is actually something we can do to reverse the symptoms of stroke,” he says. “Options that have not been available previously.”

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## This research has an immediate impact to the population of the United States.

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Treating stroke successfully involves coordination between a number of entities. An individual or his/her family members need to be able to recognize the symptoms of stroke, emergency medical responders need to accurately assess stroke and coordinate with admitting hospitals, and emergency medicine physicians need to recognize stroke and quickly alert neurological specialists. And all of that needs to happen quickly. “There are a lot of moving parts, and we have to work effectively across department lines,” says Kansagra.



**Left:** A patient's blocked brain flow in the left-middle cerebral artery (red arrow) resulted in severe speech dysfunction and right side paralysis. **Right:** Immediately after the thrombectomy, normal blood flow was restored and the patient's neurological symptoms improved.

## RAPID Results

When the first set of thrombectomy trials were published in early 2015, the time from arrival to thrombectomy averaged about three hours for a stroke patient at Barnes-Jewish, says Kansagra. But thanks to a massive effort that reinvented the diagnosis and treatment process, that timeline has been shortened to less than an hour. In stroke time, that can mean the difference between minimal damage and severe disability or even death.

Although MRI is more sensitive to the early functional changes of tissue death, its clinical application is limited by difficulties in performing this test quickly. RAPID computed tomography (CT) perfusion allows neuroradiologists to see, almost immediately, blood flow in the brain and which parts of the brain are irreversibly damaged versus those at risk for permanent injury.

"CT perfusion is a really important tool to understand which patients will benefit from thrombectomy," says Kansagra. "Currently, we are the only center in St. Louis, Eastern Missouri and Southern Illinois with RAPID CT perfusion available for routine clinical use."

Four teams work together to take care of stroke patients at Barnes-Jewish. The emergency medicine department recognizes stroke and gets the process started, stroke neurologists evaluate patients and initiate imaging, neuroradiologists interpret the initial brain imaging, and neuroendovascular specialists perform the thrombectomy. In performing

thrombectomies, Kansagra and Osburn are joined by DeWitte T. Cross III, MD, and Christopher J. Moran, MD, both professors of radiology and neurological surgery.

## A Community of Care

Members of the stroke team continuously work on system improvements in an effort to improve quality of care for patients. One way that manifests is in the sharing of stroke patients with Missouri Baptist Hospital, another BJC Health System facility. Individuals having minor strokes (treatable with tPA alone) are sent to Missouri Baptist, accredited as a Primary Stroke Center, while more complex cases are sent to Barnes-Jewish.

According to Kansagra, it's a unique arrangement aimed at doing the right thing for patients. "Keeping resources available for patients at a system-wide level requires a lot of trust and cooperation — two things we have at BJC."

In 2014, MIR's interventional neuroradiology group performed just 27 thrombectomies; by 2017, that number had risen to 115. Kansagra estimates those numbers will continue to increase, as identification and treatment of viable patients (currently about 10 to 20 percent of stroke patients) continues to improve.

"Recent trials supporting the use of intracranial thrombectomy in acute stroke have led to more referrals," confirms Cross, who also is director of interventional neuroradiology at MIR. However,

he cautions that, although the time window has been expanded, “for the great majority of patients, the sooner the clot is removed the better, and thrombectomy is best within the first two hours of symptoms to restore neurological function.”

Study results from DAWN and other trials have been incorporated into American Stroke Association education materials, and Kansagra’s hope is that eventually stroke guidelines and awareness will be as well-known and widespread as those for heart disease are now.

### A New, Happier Ending

“Stroke is a true emergency,” adds Cross. “It is crucial for the public to understand that anyone with stroke symptoms should be evaluated by medical personnel very promptly.”

Those symptoms include facial drooping, arm weakness and slurred speech. But when patients don’t know they’re having a stroke and therefore aren’t treated as quickly, even late thrombectomy might help them to avoid stroke’s worst effects. For Arron, who has moved on from physical therapy to working directly with a personal trainer in preparation for the 2018–2019 football season, thrombectomy greatly mitigated the damage caused by his stroke.

“This is really exciting for patients,” says Kansagra. “Twenty years ago — even 10 years ago — many patients who suffered a major stroke were destined to end up dead or in a nursing home, unable to move or speak. Endovascular thrombectomy offers a real chance to avoid that fate and return to a life that closely resembles the one they had before the stroke.”

With help from his personal trainer and high school coach, T. J. Manning, Arron gets ready for the upcoming football season.



# Game Changing Technologies Help Advance Breast Imaging

by Pam McGrath



**The advent of advanced technologies has revolutionized both the quality of breast imaging and how those images may be used in screening and diagnosing patients. It's an exciting time for breast imaging research and development worldwide, according to Catherine Appleton, MD, chief of breast imaging at Mallinckrodt Institute of Radiology. And the research being done by the section's diagnostic radiologists is contributing to that excitement.**

### **A Spirit of Innovation**

"We have outstanding clinicians, and every one of them has a passion for clinical breast imaging," says Appleton. "That's what we do, day in and day out, in our clinic."

That passion took root in August 1986, when a committed group of radiologists at Mallinckrodt established a screening mammography program, the first of its kind in the Midwest. A component of the program was a mammography van; today, the van service is the longest running of its type in the U.S. and among the most successful.

"Throughout the ensuing years, we have focused on providing our patients with the best possible breast imaging technology. We have been active participants in landmark studies in order to achieve that level of excellence," says Appleton.

The first major transition in breast imaging was from film screen to digital mammography. Mallinckrodt was the top recruiting site for the Digital Mammographic Imaging Screening Trial (DMIST),

**Opposite page:** Steven P. Poplack, MD, and Matthew F. Covington, MD, discuss the image findings of a contrast-enhanced digital mammogram (left monitor) against a traditional 2D mammogram.

**Right:** Steven P. Poplack, MD, believes a robust research program directly influences the quality of patient care.

a pivotal landmark study published in 2006 that proved the benefits of digital mammography for certain groups of women.

"Next was the advent of digital breast tomosynthesis, and again we were a beta test site and early adopter of this technology," says Appleton. Digital breast tomosynthesis uses multiple X-rays and computer reconstructions to produce three-dimensional images of the breast.

"Multiple studies have shown that digital breast tomosynthesis improves sensitivity which, in turn, improves our ability to detect breast cancer," says Appleton, adding that it also improves specificity. "In other words, it reduces the false alarms that can be associated with mammograms."

### **Another First: Contrast-Enhanced Digital Mammography**

In February, Mallinckrodt became one of just a few sites in the U.S. to offer the latest advancement in breast imaging: contrast-enhanced digital mammography (CEDM). As with contrast-enhanced CT or MRI, patients receive a contrast agent before the imaging study begins. Software and equipment upgrades to existing mammography machines produce two sets of images: the standard 2-D digital mammogram, along with the same views enhanced by the contrast agent but with normal breast tissue removed from the images to aid in cancer detection.



“This dual-image capability is one of the advantages CEDM has over contrast-enhanced MRI of the breast,” says Matthew Covington, MD, assistant professor of radiology. “Comparing the standard images with the contrast-enhanced images can help us to better identify cancers that may not have been detected on the mammogram alone, and to better characterize those cancers.”

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## CEDM takes just eight to 10 minutes and appears to be better tolerated.

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Another significant advantage over contrast-enhanced MRI is the comparative brevity of CEDM and its cost savings.

“CEDM takes just eight to 10 minutes and appears to be better tolerated by patients, particularly if they are claustrophobic or have certain pacemakers or other medical devices that makes MRI impossible,” says Covington. “In addition, it’s estimated that CEDM is approximately 25% of the cost of an MRI.”

Currently CEDM is being used for women with known breast cancer to evaluate the extent of their disease and determine if there are additional cancer sites within the breasts. It also is being used to evaluate how patients are responding to chemotherapy by comparing the size of the breast cancer before

treatment and then while they are receiving treatment.

“It’s exciting to have this technology, not only for these two groups of patients but also for the possibilities it has for future uses,” says Covington. “For example, among women who need a biopsy, could a CEDM identify those who could safely forego that procedure if findings on the contrast-enhanced mammogram show nothing suspicious? Or could this technology be a replacement or substitute for MRI for women who have the BRCA or another high-risk mutation, who have dense breast tissue, or who have other risk factors and are unable to undergo an MRI? These are areas of study we hope to pursue in the future in order to maximize the potential of CEDM.”

## The Research Continues

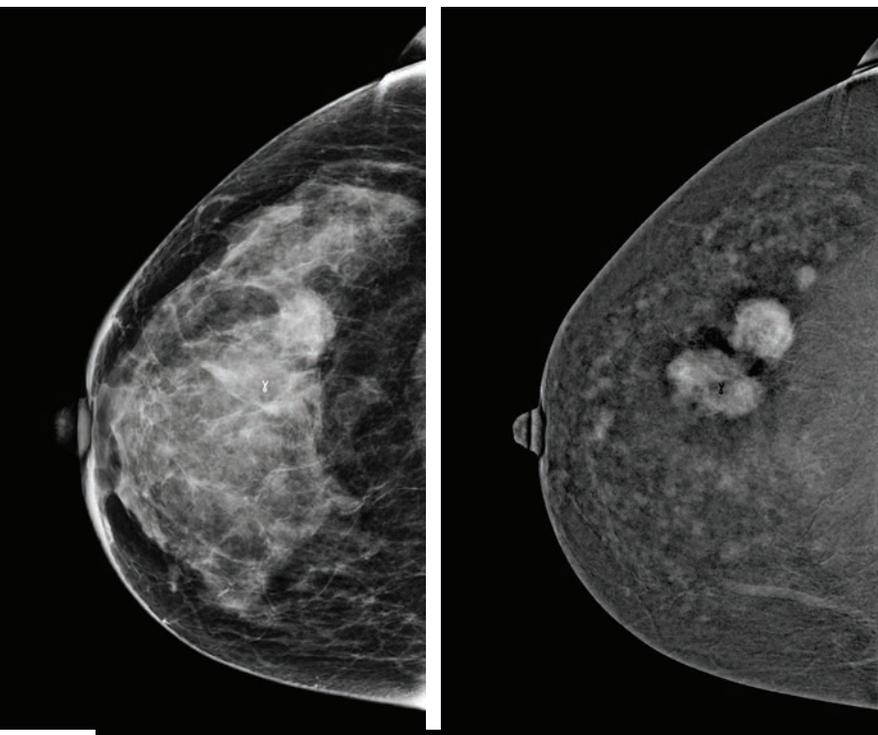
The breast imaging section at MIR currently has more than 35 research projects in various stages of development. Steven P. Poplack, MD, associate professor of radiology, believes this robust research program directly influences the quality of patient care provided by the section’s clinicians.

“It’s absolutely true that as researchers we are able to offer patients diagnostic modalities to which they may not otherwise have access,” he says. “But there’s a cascade effect to it. By performing research, it pushes us to be at the leading edge of the specialty, to be true experts in our field. In turn, it enhances our knowledge and helps inform our clinical practice.”

Several breast imaging research projects currently underway hold promise for advancing that knowledge and clinical practice. Catherine Young, MD, assistant professor of radiology, is the local principal investigator for a vendor-sponsored initial evaluation of the Brevera<sup>®</sup> breast biopsy system. Brevera combines tissue acquisition, real-time imaging, sample verification and advanced post-biopsy handling in one integrated system. Rather than having to move to another room to image and verify a patient’s tissue samples, radiologists obtain and image tissue samples in the procedure room in just a few seconds.

Poplack is the local principal investigator for ECOG-ACRIN 1141, a clinical trial studying abbreviated breast MRI vs. digital breast tomosynthesis in women with dense breasts.

**Left:** A traditional mammogram view shows a metallic biopsy clip within a known breast cancer. **Right:** The enhanced mammogram image shows several additional masses not clearly identified on the traditional view.





Contrast-enhanced digital mammography can help “better identify cancers that may not have been detected on the mammogram alone,” says Matthew Covington, MD.

“Until now, MRI has been restricted to screening women at very high risk for cancer, either because of a genetic mutation or a high lifetime risk based on family history,” says Poplack. “One of the barriers to widespread use has been the cost of and access to MRI. In this trial, the number of MR pulse sequences has been shortened so that the patient spends less than 10 minutes being imaged. If this comes to fruition, abbreviated breast MRI could change the landscape of how we screen patients, making it more affordable and widespread.”

Poplack, Appleton and Young are also collaborating with Quing Zhu, PhD, a professor at Washington University’s School of Engineering and Applied Science. They’re using a fusion of ultrasound and near-infrared imaging modalities to find out if this combination can more accurately determine a patient’s response to neoadjuvant (first step) treatment, such as chemotherapy or endocrine therapy.

“If we were able to determine earlier or more accurately whether or not a treatment is working, it would save patients from receiving additional, potentially toxic treatments, and allow oncologists to tailor individual therapies much more rapidly,” Poplack says.

Additional current and potential research studies include cryoablation, or freezing, of small invasive breast tumors, trends in the utilization of screening mammography among privately insured women in the U.S., and ultrasound to identify patients who may not need axillary surgery.

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### In the United States 40,000 women die of breast cancer every year.

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“Mallinckrodt’s breast imaging section has multiple strengths that support our research efforts,” adds Appleton. Her list includes the talented investigators, the stellar reputations of MIR and Washington University School of Medicine that attracts outside collaborations, and internal collaborations with various departments within Washington University.

“Underlying all that we do is the knowledge that in the United States 40,000 women die of breast cancer every year, and about a quarter million will be diagnosed with the disease,” she says. “We still have a big job to do, and it’s vital for us to be engaged in the research that will help improve outcomes for all women.” 

# ALUMNI SPOTLIGHT

by Kristin Rattini

**John Neil, MD**, is senior vice president and chief physician executive for HonorHealth, a \$1.6-billion health network headquartered in Scottsdale, Arizona. Prior to joining HonorHealth, Neil spent 16 years in clinical practice as a vascular and interventional radiologist at Scottsdale Medical Imaging Ltd. A self-described “lifelong learner,” he has always embraced administrative roles for providing him with the opportunity to “work with exceptionally smart people, continually learn new things, and develop as a professional and a person.”



John Neil, MD, with daughters Sarah and Julia, son Jacob, and wife Shaheen, at El Matador State Beach in Malibu, California, January 2018.

## What attracted you to radiology?

I took a year away from clinical rotations between my third and fourth year of med school at WashU to perform functional brain imaging research under the tutelage of Marcus Raichle. I entered with a strong interest in doing neurosurgery, but under Dr. Raichle’s mentorship I developed an interest in the power and diversity of radiology. At Dr. Raichle’s suggestion I did a radiology rotation early in my fourth year and found that I really enjoyed it. Around the same time, I was deciding whether to get engaged. It was clear that embarking on a neurosurgery residency was probably not the recipe for a successful marriage. Because I enjoyed radiology so much, and thought it would allow for a bit more work-life balance, I changed paths, pursued a radiology residency and decided to get married. Dr. Raichle doesn’t know it but my wife credits him for the fact that we got married.

## Who were some of the people at MIR who made the greatest impression upon you?

Dan Picus had an unparalleled work ethic that I have spent my career trying to emulate. He was incredibly intelligent, incredibly dedicated, and a tireless worker. For Bill Middleton, the ultrasound probe was like a paint brush and he was the artist. In addition to his technical expertise, he as much as anyone taught me the value of hands-on interaction with the patient. Stuart Sagel taught the importance of using every bit of information on the film/image in order to inform the diagnostic opinion. “The history is on the film” was one of his favorite sayings that is embedded in my memory bank. Mike Darcy was no nonsense, to the point of being intimidating to some. I found him to be a fantastic teacher and technically amazing in the interventional lab. He taught me to think my way out of a tight spot, even if it took innovative, outside-the-box thinking. That training paid off innumerable times during my IR practice.

## How did your time at MIR impact your future career?

When I joined the private practice world, I found that I immediately had the breadth and depth of knowledge to practice successfully in that environment and to provide “added value.” Secondly, the environment at MIR taught me to hold myself, and ultimately my colleagues, to the absolute highest standards in terms of patient care. There was simply an unflappable and uncompromising commitment to excellence, and that standard was embedded in me and has stayed with me throughout my career.

**Before HonorHealth you served as chairman of the board of Scottsdale Medical Imaging Ltd., and as a board member for both a regional and national radiology consortium. Is there a common**

## PROFILE

**JOHN NEIL, MD**

**Currently // Masters of  
Medical Management**

University of Southern California

**1998 // Diagnostic Radiology Resident**

Mallinckrodt Institute of Radiology,  
Washington University School  
of Medicine

**1994 // MD**

Washington University School  
of Medicine

**1989 // BS**

University of Kansas

### **thread that runs through all of your administrative roles?**

I am a good listener. That is crucial to leadership, especially physician leadership. If they believe they've been heard and understood, even if the ultimate decision doesn't go their way, then they at least know it was made with an understanding of their perspective.

### **In your position at HonorHealth, you have many diverse departments reporting up to you. Is there a particular area that you are especially excited to be involved with?**

One of the things I miss about clinical radiology is the satisfaction of making diagnoses, answering questions and doing procedures that truly help patients. In this position, our major clinical lines all report up through me. As new technology and approaches to care come into play, I can really work with our various clinical leaders to make sure we're applying those in a responsible way for the maximum benefit of our patient population. It's great to be able to impact care on a much broader level.

### **Academic Affairs is under your purview. What might you draw on from your MIR residency as you shape the residency program at HonorHealth?**

We're trying to enhance the reputational value of our program so that we can attract better medical students, and then retain these talented physicians so they can serve the needs of our community. The biggest thing you can do is get really smart people in the door. We're looking into developing a formal academic affiliation, be it in Arizona or out of state, that will help us attract even better candidates. If anyone at WashU wants to establish a formal affiliation in sunny Arizona, I'll answer the phone for sure!

### **In your rare free time, what do you enjoy doing with your wife, Shaheen, and your children, Jacob, Sarah and Julia?**

We're pretty outdoorsy. We love to snow ski. Two of my kids got better than me this season, so that was a downer. We hike a lot here in Arizona, especially in the Superstition Mountains. We do volunteer work in the community at St. Mary's Food Bank and at Desert Mission, a charity sponsored by HonorHealth. 



John and Shaheen visit Cuzco, Peru, June 2016.

## Honors/Awards

**Samuel I. Achilefu, PhD**, the Michel Ter-Pogossian Professor of Radiology and vice chair for entrepreneurship and innovation at MIR, was named a fellow of the National Academy of Inventors.

**Farrokh Dehdashti, MD**, professor of radiology and senior vice chair and division director of nuclear medicine, was inducted into the national medical honorary society, Alpha Omega Alpha.

**Michael V. Friedman, MD**, assistant professor of radiology, received a 2017 Samuel R. Goldstein Leadership Award in Medical Student Education.

**David S. Gierada, MD**, professor of radiology, was elected a fellow in the American College of Radiology.

**Tamara G. Hershey, PhD**, professor of psychiatry and radiology, and chief of the Neuroimaging Laboratory at MIR, was named co-director of the neuroscience PhD program at Washington University.

**Akash P. Kansagra, MD**, assistant professor of radiology, neurological surgery and neurology, was appointed co-director of the Washington University and Barnes-Jewish Hospital Stroke and Cerebrovascular Center. Kansagra also received an Editor's Recognition Award from the journal *Radiology*.

**Seung Kwon Kim, MD**, associate professor of radiology, received a magna cum laude designation for a poster he presented at a meeting of the Cardiovascular and Interventional Radiological Society of Europe.

**Anup Shetty, MD**, assistant professor of radiology, and **Hilary Orlowski, MD**, instructor in radiology, were accepted into the Association of University Radiologists' Academic Faculty Development Program.

**Suresh Vedantham, MD**, professor of radiology, was elected a fellow in the American College of Radiology. Also, in March the ATTRACT study, a large-scale, multicenter clinical trial led by Vedantham, received a 2018 Top Ten Clinical Research Achievement

Award from the Clinical Research Forum. The annual awards honor innovative and groundbreaking accomplishments in clinical research.

**Richard L. Wahl, MD**, the Elizabeth E. Mallinckrodt Professor of Radiology and director of MIR, will receive the Saul Hertz MD Award from the Society of Nuclear Medicine and Molecular Imaging at its annual meeting, June 23-26 in Philadelphia. Wahl is being honored for his lifetime achievement and outstanding contributions to radionuclide therapy.

**Pamela K. Woodard, MD**, professor of radiology and biomedical engineering, and senior vice chair and division director of research facilities at MIR, was appointed chair of the American College of Radiology's Commission on Research.



MIR chief residents for 2018-2019 are (from left) Maverick LeBlanc, MD, Danielle Summers, MD, and Michael Beal, MD.

## Appointments/ Promotions

**Max Amurao, PhD**

Assistant Professor of Radiology

**Adam T. Eggebrecht, PhD**

Assistant Professor of Radiology

**J. Daniel Giardina, MD**

Assistant Professor of Radiology

**Vincent M. Mellnick, MD**

Associate Professor of Radiology

**Michelle Miller-Thomas, MD**

Neuroradiology Fellowship Program  
Director

**Maria Rosana Ponisio, MD**

Assistant Professor of Radiology

**Thomas H. Schindler, MD**

Associate Professor of Radiology

**Peng Sun, PhD**

Assistant Professor of Radiology

**Richard Tsai, MD**

Instructor of Radiology

**Katie D. Vo, MD**

Professor of Radiology

**Catherine A. Young, MD**

Assistant Professor of Radiology

## Grants

**Joseph J.H. Ackerman, PhD**, professor of chemistry and professor of radiology, received a one-year, \$750,000 grant from the National Institutes of Health for a “Preclinical MRI Scanner Behind a BSL3 Barrier.”

Researchers at MIR’s Neuroimaging Laboratory, **Kevin J. Black, MD**, professor of psychiatry and **Bradley L. Schlaggar, MD, PhD**, the A. Ernest & Jane G. Stein Professor of Neurology, received a five-year, \$2.3 million grant from the National Institutes of Health for “The New Tics Study: A Novel Approach to Pathophysiology and Cause of Tic Disorders.” In addition, Black received a two-year, \$352,283 grant from the Michael J. Fox Foundation for “Dopamine Buffering Capacity Measured by pHMRI as a Novel Biomarker of Disease Progression in Parkinson’s Disease.”

**Charles R. Conway, MD**, professor of psychiatry and a researcher at MIR’s Neuroimaging Laboratory, and **Peter Nagele, MD**, associate professor of anesthesiology, received a two-year, \$228,750 grant from the National Institute of Mental Health for “NMDA Receptor Antagonist Nitrous Oxide Targets Affective Brain Circuits.”

**Joseph P. Culver, PhD**, professor of radiology, received a two-year, \$1,149,794 grant from the Bill & Melinda Gates Foundation for research “Mapping the Effects of Malnutrition on Brain Function.”

**Brian A. Gordon, PhD**, assistant professor of radiology, received a one-year, \$20,400 grant from the Longer Life Foundation for “Examining the Contributions of Obesity and Diabetes to Alzheimer Disease.”

**Robert J. Gropler, MD**, professor of radiology, received a one-year, \$244,700 grant from the National Institutes of Health and Boston Children’s Hospital for “A Novel F-18 PET Myocardial Perfusion Radiopharmaceutical Based on Rhodamine Dyes.”

**Yi Su, PhD**, assistant professor of radiology, received a three-year grant for \$150,000 from the Alzheimer’s Association to study “Amyloid PET as a Biomarker for White Matter Integrity in Alzheimer Disease.”

**Zhude Tu, PhD**, professor of radiology, received a five-year, \$3 million continuation grant from the National Institutes of Health for “PET Probes for Imaging the Vesicular Acetylcholine Transporter.” Zhude, together with **Paul T. Kotzbauer, MD, PhD**, associate professor of neurology, and **Robert H. Mach, PhD**, of the University of Pennsylvania, also received a one-year, \$400,000 research grant for “Developing an Alpha-Synuclein Imaging Agent” from the Michael J. Fox Foundation.

**Suresh Vedantham, MD**, professor of radiology, received a one-year, \$1,376,983 grant from the National Institutes of Health for “1/2 Catheter-Directed Therapy for Chronic DVT (C-Tract Trial).”

**Pamela K. Woodard, MD**, professor of radiology and biomedical engineering, received a three-year, \$2.2 million grant from the National Institutes of Health (NIH) for the “First-in-Human Trial of a Receptor-Targeted Nanoparticle PET Tracer for Atherosclerosis.” Woodard also received a \$2 million grant from the NIH for the “Purchase of a Siemens Next Generation PET/CT.”

## Lectures

**Kevin J. Black, MD**, professor of psychiatry and a researcher at MIR's Neuroimaging Laboratory, presented "The Relationship Between Stimulation Site and Clinical Outcome" at the Radcliffe Institute for Advanced Study in Cambridge, Massachusetts, on September 20, 2017; and "Brain Structure in Pediatric Tourette Syndrome" at the University of Nottingham Institute of Mental Health, in Nottingham, England, on November 8, 2017.

**Kelly N. Botteron, MD**, professor of psychiatry and a researcher at MIR's Neuroimaging Laboratory, presented "Very Early Brain Development and Prediction in Infants at Risk for Autism: Foreshadowing Psychiatric Clinical Applications of Neuroimaging," in Wichita at the University of Kansas grand rounds on December 12, 2017.

**Charles R. Conway, MD**, professor of psychiatry and a researcher at MIR's Neuroimaging Laboratory, presented "Treatment Resistant Definition: Defining a Complex Disorder" and "New Treatments for Treatment Resistant Depression" at the 22nd Annual Central New York Psychopharmacology Update in Syracuse on October 6, 2017.

**Tamara G. Hershey, PhD**, professor of psychiatry and radiology, and chief of MIR's Neuroimaging Laboratory, presented "Tracking Neurodegeneration in Wolfram Syndrome" at the University of Alabama Neuroscience Center in Birmingham, on July 20, 2017. Hershey also presented "Cognition in Youth with Type 1 Diabetes" at a meeting of the Pediatric Endocrine Society and the International Society for Pediatric and Adolescent Diabetes in Washington, D.C., on September 14-17, 2017.

**Akash P. Kansagra, MD**, assistant professor of radiology, neurological surgery and neurology, gave the keynote address "Current and Emerging Interventional Management of Stroke" at a stroke review and update meeting at the Boone Hospital Center in Columbia, Missouri, on February 17, 2018.

**Joel S. Perlmutter, MD**, professor of neurology and a researcher in MIR's Neuroimaging Laboratory, participated in a "Young Onset Parkinson's Disease" webinar sponsored by the American Parkinson Disease Association on October 12, 2017.

**Marcus E. Raichle, MD**, the Alan A. and Edith L. Wolff Distinguished Professor of Medicine and a professor of radiology, presented "Brain Metabolism in the 21st Century" at a symposium organized by the Brain Mind Institute, EPFL, in honor of Professor Pierre J. Magistretti in Geneva, Switzerland, on October 23, 2017.

**Joshua S. Shimony, MD, PhD**, associate professor of radiology, presented "Clinical Resting State MRI" at the 11th annual meeting of the American Society of Functional Neuroradiology in Portland, Oregon, on October 8-11, 2017.



MIR radiologists Vincent Mellnick, MD, and Michelle Miller-Thomas, MD, led a discussion about modern medical imaging techniques on ancient artifacts at the Saint Louis Art Museum on February 16, 2018.

## 3-D Printing Available at MIR

by Mary Konroy

On a routine day in January, one of the four printers in MIR's 3-D printing laboratory was hard at work creating a plastic prototype of a kidney with a malignant tumor. Like many of the other anatomic models it creates, the lab retrieved a scan from a depersonalized image depository.

As the print head moved back and forth, it laid down thin layers of hot plastic. Stacked on top of one another, the layers — each .2 millimeters high — would mirror a kidney in exacting detail. Separated, the layers would align with CT slices from the imaging scan.

An emerging technology in medicine, 3-D printing may lead to more precise medicine and better patient outcomes, especially when complex anatomy is involved.

"We're making negative molds of certain tumors to guide pathologic sectioning," says David H. Ballard, MD, a second-year resident who conducts research in the lab. "It will give us better radiology-pathology correlation."

### An Idea Takes Shape

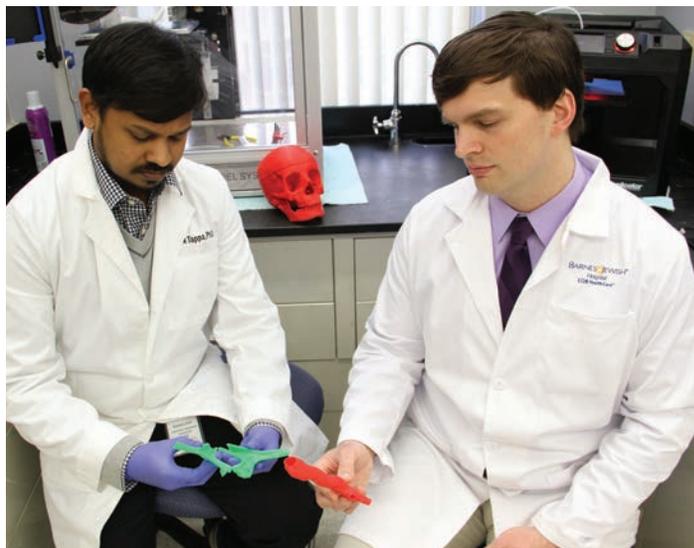
Located on the sixth floor of the Barnard Building, the lab falls under the purview of Pamela K. Woodard, MD, senior vice chair and division director of research facilities at MIR. And unlike other 3-D print labs, MIR's lab offers printing methods that involve bioactive printing.

"Early last year, we were fortunate enough to encounter and hire a team of individuals who not only have 3-D printing expertise," says Woodard, "but also expertise in printing drug-eluting implants and bioprosthesis, essentially taking 3-D printing to the next level."

The lab is staffed by two research scientists — Karthik Tappa, PhD, and Uday Jammalamadaka, PhD — and requests for services are funneled through them. They include: 3-D medical modeling that can be viewed on a computer monitor or be printed into a physical model; customized implants and surgical guides; and training and education on the technology. While the lab does offer some clinical services, most of the models and constructs made there have been research collaborations.

### Customized Creations

Three-dimensional printing is a type of additive manufacturing that produces an object or device from a digital file. It lays down a filament, one layer at a time, to create something out of nothing, says Ballard.



Karthik Tappa, PhD, and David Ballard, MD, examine 3-D printed trachea models from two different patients.

"We call this layering 'segmentation,'" adds Jammalamadaka. "You take data from CT or MR scans and segment [divide] it using segmentation software. We identify the regional features and then start sculpting and drawing around that particular region."

The resulting images are manipulated on a computer and then transferred to a 3-D printer. The time it takes depends on the printer and the size of the model you're trying to recreate, says Tappa. "If you want to print something fist-sized, it may take three hours."

### Research Benefits

For now, most requests come from within the radiology department, and almost all are research based. One research initiative tasks the lab with creating implantable and biodegradable 3-D scaffolds and procedural instruments that can dispense drugs, like antibiotic-impregnated meshes.

"We've developed a new method to incorporate drugs and hormones into biodegradable polymers," says Jammalamadaka. "Drugs such as antibiotics, chemotherapeutics and hormones were successfully 3-D printed and evaluated for bioactivity with promising results. We have also shown the ability to customize these drug delivery devices for patient-specific needs using 3-D printing methods."

"This is an emerging technology where radiologists can take the lead," says Ballard. 

## A LOOK BACK

# The Trailblazing Career of a Nuclear Pharmacist

by Mary Konroy

It was 6 a.m. in Los Angeles when Sally Schwarz's telephone rang. Without any introduction, the caller asked Schwarz why she hadn't completed her application for the PhD radiochemistry program.

"Excuse me, but who's calling?" replied Schwarz, who was half asleep.

The caller was Michael J. Welch, PhD, then associate professor at Mallinckrodt Institute of Radiology, and the year was 1976. Schwarz, who had just earned a master's degree in nuclear pharmacy, told him she didn't know if she wanted to pursue another advanced degree right away.

"Book a flight. Come see us," said Welch," recalls Schwarz. At that point, she had not met him nor had she ever been to St. Louis. But she decided to go and meet Welch, who would later become one of the world's most recognized authorities on radiopharmaceuticals. While there, she also met with Barry A. Siegel, MD, who at the time was director of the division of nuclear medicine. They immediately offered her a combined position as a research associate, working both in clinical nuclear medicine and research.

Almost 42 years have passed since Schwarz, now a professor of radiology and co-director of MIR's cyclotron facility, first came to MIR. In July, following a career punctuated with multiple professional accomplishments and at the age of 70, Schwarz will go part time.

### The Early Years

Diagnostic radiology was exploding when Schwarz, RPh, BCNP, arrived at MIR. Computed tomography was replacing nuclear medicine brain imaging and new camera technology was arriving.

"It was exciting and very different from anything I had experienced," she says.

Schwarz worked 12-hour days — part time for Welch in research, and part time for Siegel making Tc-99m labeled radiopharmaceuticals for clinical imaging studies. About one year into her job, Schwarz was asked to teach radiology residents about radiopharmaceuticals.

"It's the course I still teach today but I kept adding to it throughout the years." Originally she taught five lectures; today there are 19.



### Designing Woman

Despite enjoying the challenges her job provided, after two years Schwarz left MIR to pursue a long held dream: designing women's clothing. It was now or never for the single 30-year-old and she plunged ahead.

"I come from a line of strong women," says Schwarz, whose grandmother was a suffragette.

Although her business was exciting, she found the St. Louis market financially difficult. Schwarz returned to science and MIR in March 1984, married and with a daughter. Her second daughter arrived two years later. In 1988, she began working full time, splitting her time once again between research and clinical nuclear medicine. She was essentially starting over.

### A Return to Research

Schwarz jumped back in full speed, seizing any opportunity that came her way. She labeled antibodies for human use. She published papers. She prepared investigational new drug applications and defended them to the U.S. Food and Drug Administration.

As a member of the Society of Nuclear Medicine, the American Pharmacist's Association and the Society of Radiopharmaceutical Sciences, she was appointed to numerous key committees, often in leadership roles. Membership in these organizations and attendance at

professional meetings, especially international ones, helped Schwarz cultivate a global professional network.

“I had to write abstracts about the work we were doing, submit them, go to the meetings and present the data,” she says. “It was very important because I met a lot of people from around the world through these groups.”

But the turning point in Schwarz’s career came in 1995, when she took over management of Washington University’s PET drug production.

“I wanted an operation that would provide quality PET radiopharmaceuticals for human use. That was my goal,” she says. “It still is.”

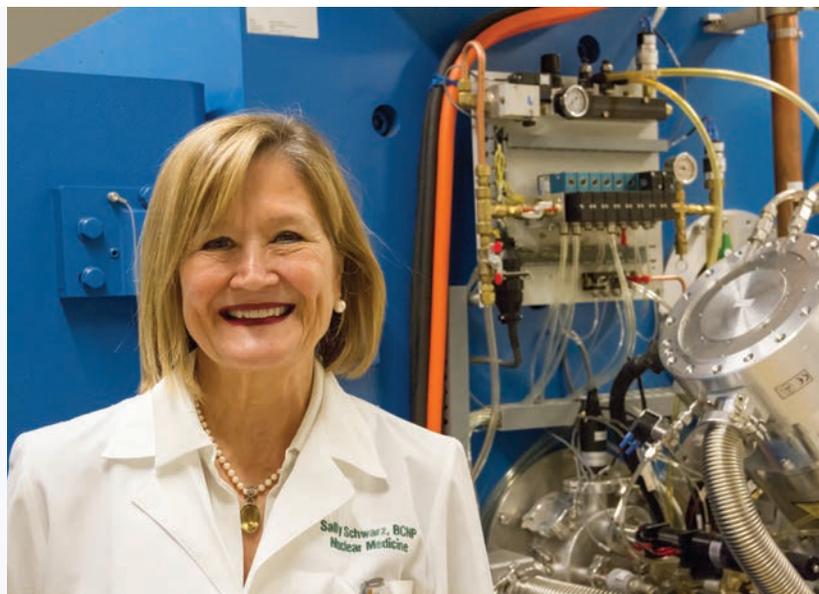
Schwarz began by creating a clean space for clinical PET production in the Barnard Building. When the operation outgrew that space, she helped design the new cyclotron facility in the East Building, which opened in 2000. Additional changes had to be made when the FDA introduced new regulatory requirements initiated in 2012 for PET drug production. In 2015, Schwarz was elected president of the Society of Nuclear Medicine and Molecular Imaging, becoming the first pharmacist and fourth woman to hold the position.

“Sally has helped bring many new PET tracers to patients safely and effectively,” says MIR director Richard L. Wahl, MD.

An expert on regulatory issues involving the production of radiopharmaceuticals for human use, Schwarz has given talks nationally and internationally. She has also served on the U.S. Nuclear Regulatory Commission and as a committee member for the United States Pharmacopeia.

“She has helped craft U.S. and global regulations on the best production practices for PET and other radiotracers, and approaches now used globally,” adds Wahl. “She has greatly elevated pharmacy science in nuclear medicine.”

**Opposite:** Sally W. Schwarz, shortly after she arrived at Mallinckrodt Institute of Radiology, in 1976. **Top right:** Schwarz helped designed MIR’s new cyclotron facility, which opened in 2000. She was named the facility’s co-director in 2013. **Middle:** In the works for more than a decade, the new cyclotron is finally lowered into its vault at MIR’s East Building. **Bottom:** In 2017, Schwarz gives visiting lecturer Lale Kostakoglu, MD, a tour of the cyclotron facility.



FOCAL SPOT

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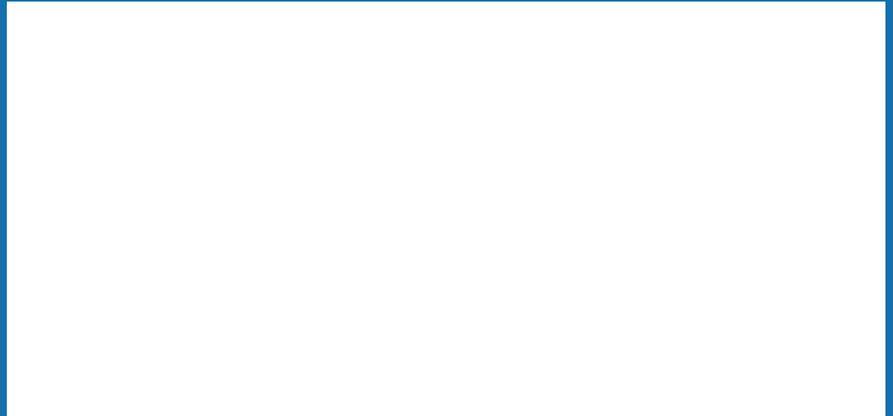
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St. Louis, MO 63110

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