TMC PULSE

NEWS OF THE TEXAS MEDICAL CENTER — VOL. 6 / NO. 5 — JUNE 2019

THE INNOVATION ISSUE

Think innovation.

Our mantra.
Our culture.
Our pride and joy.

Harris Health System places a high priority on giving our patients an especially positive, healthy experience. We encourage our teams to share their insights and talents to make improvements at every touchpoint.

Congratulations to this year's winning innovators.
And thank you, one and all.

PRESIDENTIAL AWARD
Marketplace Insurance Coverage

PHYSICIAN AWARD WINNERS
Ben Taub Oral and Maxillofacial Surgery
Ben Taub and Lyndon B. Johnson Hospital House Calls
Lyndon B. Johnson Hospital Emergency Services

PAVILION AWARD WINNERS
Patient Medication Assistance Program
Pediatric Telepsychiatry
Ben Taub Hospital Eating Assistance Team (E.A.T.)
Lyndon B. Johnson Hospital Fall Prevention

SYSTEM AWARD WINNERS
Healthcare Financial Decision Support

HARRISHEALTH SYSTEM
ONEFORALL harrishealth.org

EVERY 40 SECONDS someone in the United States has a STROKE

CAN YOU SPOT THE SIGNS OF A STROKE?

Take our **Think F.A.S.T. Quiz** to test your stroke knowledge at **CHIStLukesHealth.org/Stroke**.

At CHI St. Luke's Health, we offer comprehensive care for even the most complex stroke cases. Our Comprehensive Stroke Centers have the capability to quickly intervene to stop the progression of stroke damage and prevent permanent impairment through the use of thrombolytic medications and minimally invasive techniques.

CHI St. Luke's Health

WHERE TO FIND HELP

Comprehensive Stroke Center
Baylor St. Luke's Medical Center
6720 Bertner Avenue, Houston, TX 77030

Comprehensive Stroke Center
CHI St. Luke's Health–The Woodlands Hospital
17200 St. Luke's Way, The Woodlands, TX 77384

Primary Stroke Center
CHI St. Luke's Health–Brazosport Hospital
100 Medical Drive, Lake Jackson, TX 77566

Mark Mulligan/© Houston Chronicle. Used with permission.

WILLIAM F. McKEON
President and Chief Executive Officer, Texas Medical Center

As I read through the pages of this issue, I continue to be struck by the innovations created and implemented in the Texas Medical Center. Seeing so much innovation in a single issue highlights the talent, creativity and dedication to patients that make this place unlike any other.

When I first arrived at the Texas Medical Center six years ago, the incubation of new technologies, medical devices and therapies was occurring independently at each institution. In many cases, physicians, engineers and researchers pursued their work in cramped facilities, often with little funding and support available to nurture their early-stage ideas and prototypes.

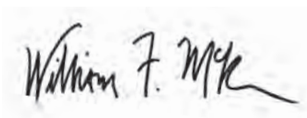
At the same time, a different story played out in places such as Boston, San Francisco and Chicago. In those cities, innovators enjoyed access to critical resources such as high-end facilities, dedicated staff and venture funding. Creative public-private partnerships supported the development of these hubs.

Here at the Texas Medical Center, we recognized we had enormous talent, including more than 120,000 employees dedicated to advancing clinical care. We knew our greatest opportunity to foster innovation was to centralize our efforts. We provided our partners with the resources they needed to unleash their talent. They were empowered to cultivate and accelerate new products and therapies to advance care.

First, we identified the ideal place to build the TMC Innovation Institute. With millions of dollars of investment, we transformed a Nabisco cookie factory into the largest life sciences incubator in the United States. Next, we recruited a talented team to support entrepreneurs on their journey to advance care. Then, we established the $25 million TMC Venture Fund, which bolsters the very best of these companies and helps them move to the next stage of development.

But that wasn't the final step. In fact, there is no final step at all. Fostering our innovation ecosystem is an ongoing process. Every day, we work to position our community as the worldwide destination for the development of next-generation treatments.

The Texas Medical Center is proud to have mentored and supported more than 250 companies since undertaking this effort. The momentum continues to build as we attract the very best companies from around the world.



TMC | PULSE
Vol. 6 No. 5
June 2019

President and Chief Executive Officer
William F. McKeon

Communications Director
Ryan Holeywell

Pulse Editor
Maggie Galehouse
mgalehouse@tmc.edu

Assistant Editor
Cindy George
cgeorge@tmc.edu

Staff Writers
Alexandra Becker
Britni R. McAshan
Shanley Pierce

Photojournalist
Cody Duty

Contributing Photographer
Nick de la Torre

NEWSROOM
713-791-8812
news@tmc.edu

ADVERTISING
Felicia Zbranek-Zeitman
713-791-8829
newsads@tmc.edu

DISTRIBUTION
Wallace Middleton
distribution@tmc.edu

READ US ONLINE
tmc.edu/news

FOLLOW US
@TXMedCenter
@texasmedcenter
@thetexasmedicalcenter

TMC Pulse is an award-winning monthly publication of the Texas Medical Center in Houston, Texas.

Table of Contents

ON THE COVER: A breakthrough bioprinting technique developed by bioengineers at Rice University and the University of Washington uses a water-based gel architecture to mimic the structure and movement of human lungs. The actual size of the model is smaller than a penny. *(Photo by Jordan Miller and Daniel Sazer)*

How Do We Define Innovation?

UST's Beena George ponders the big question

By Maggie Galehouse

Beena George, Ph.D., will become chief innovation officer at the University of St. Thomas on July 1.

Starting in July, Beena George, Ph.D., will become the first chief innovation officer of the University of St. Thomas.

How does she plan to define innovation in her new role?

"We are going to think innovatively about innovation itself," said George, the current dean of UST's Cameron School of Business. "To me, at this university, innovation means doing something better, doing something different to meet the needs of our current students, our future students—even our alumni."

As part of her current role in the business school, George has overseen the birth of several programs, including the Master in Clinical Translation Management (MCTM), which teaches the commercialization of life science discoveries—how to turn basic laboratory findings into medical devices, drugs or clinical processes.

"We did the MCTM program in collaboration with Houston Methodist Research Institute," she said. "They approached us and we felt that this was the type of innovation that really helps humans in this city. We had this program up and running in a year."

A Catholic university in the Basilian tradition, UST seeks to enrich the lives of students intellectually, spiritually, morally, socially and physically. Community is the key to growth.

> "When people think about innovation they are often thinking about technology or entrepreneurship. They're using the word 'innovation' as a synonym for 'entrepreneurship,' but you could innovate in the processes you currently have. Those kinds of incremental innovations help organizations become more efficient and free up resources."
>
> — BEENA GEORGE, PH.D.

"Often, when we think of innovation, we think of an individual effort—a person working alone against the current," George said. "But I think academic innovation has to be of a community. It's important to break down the silos so that everything and everyone comes together."

The university is poised for growth. In April, UST announced the creation of a satellite campus in Conroe, Texas, slated to open in 2020 at Deison Technology Park. The university plans to launch a nursing program there, along with an accelerated bachelor of science nursing program for second-degree candidates.

UST's five-year roadmap for the future, known as "The Call Toward Tomorrow," states that innovation must be learner-centered. In part, that innovation goal translates to new student opportunities, but it also means revisiting the programs and processes already in place.

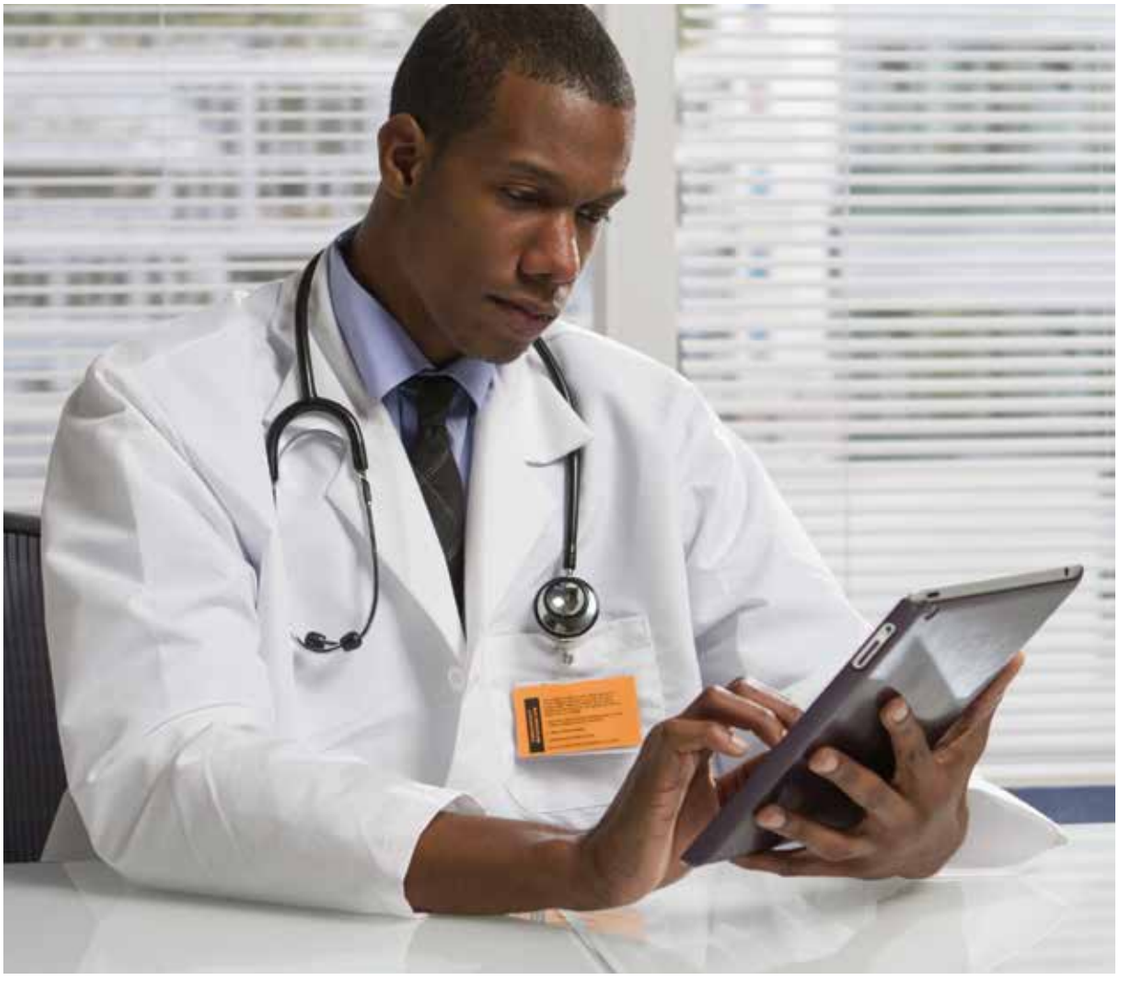
"In the last year, we have started six different programs, and some of those are in technology—including a Master of Science in Applied Data Science," George said. "We have three associate degrees, in cybersecurity, electrical technology and network technology. When people think about innovation they are often thinking about technology or entrepreneurship. They're using the word 'innovation' as a synonym for 'entrepreneurship,' but you could innovate in the processes you currently have. Those kinds of incremental innovations help organizations become more efficient and free up resources."

And we cannot assume that all innovation is positive, George added.

"Everybody tries to make sense of their world," she said. "We have a conference every year in November at the business school and last year the symposium was on the ethics of innovation. We always assume that innovation is good, but you just have to think about it. That conscious thought is important. People like to have luxuries, but I think people don't realize what a luxury it is to have time to think—to learn new things and to build on what you learn."

Universities offer students the time and space to ask difficult questions and seek answers, George said. And that's a perfect proving ground for innovation. ■

We're learning more about mental health every day. So can you.



Join more than 100,000 medical professionals who get free CME with Texas Health Steps Online Provider Education. Choose from a wide range of courses relevant to your practice, including short tutorials and podcasts on topics like Medicaid guidelines, ethics and mental health — all available 24/7.

Learn more at TXHealthSteps.com.

TEXAS Health and Human Services | *Texas Health Steps*

FEATURED COURSES

ADDRESSING ACEs:
Learn how to identify, treat and reduce the effects of trauma and toxic stress and reinforce resiliency in young patients. Earn ethics CME.

INTERPERSONAL YOUTH VIOLENCE:
Implement proven strategies to identify, intervene in and prevent behaviors such as bullying, self-injury and suicide, dating violence and sexting. Earn ethics CME.

AUTISM SPECTRUM DISORDER:
Learn to recognize autism spectrum disorder (ASD) in children and adolescents and provide guidelines for diagnosis, referral, and continuity of care.

Content on the Texas Health Steps Online Provider Education website has been accredited by the Texas Medical Association, American Nurses Credentialing Center, National Commission for Health Education Credentialing, Texas State Board of Social Worker Examiners, Accreditation Council for Pharmacy Education, UTHSCSA Dental School Office of Continuing Dental Education, Texas Academy of Nutrition and Dietetics, Texas Academy of Audiology, and the International Board of Lactation Consultant Examiners. Continuing Education for multiple disciplines will be provided for some online content.

When Your Great Escape is *Simply Going Home!*

MUSEUM DISTRICT

Historic Birdsall Briscoe on Approximately One Acre in Broadacres - One of Houston's Finest Neighborhoods

ED WOLFF
713-446-9205

1324 NORTH BLVD.

BELLAIRE

Almost 5,000 Sqft. with Marble Floors Throughout First Floor, Full Garage Apartment, Pool and Spa

ALDO DI VECE
713-470-8241

4928 MIMOSA

RIVER OAKS SHOPPING AREA

New Construction Features Walls of Glass Overlooking the Backyard, Contemporary Finishes Throughout

CINDY COOK
281-948-1344

1810 W BELL

SOUTHAMPTON

French Country, Wine Room, Summer Kitchen, Cocktail Pool

LAUREN WALKER · 832-428-8237

2320 BOLSOVER

MED CENTER AREA

Custom Home Zoned to Bellaire High School

ASHLEY MANDOLA · 281-989-0678

4006 NEWSHIRE

MED CENTER AREA

Willow Meadows 4/3 on 17,700+Sqft. Lot, Pool & Summer Kitchen

CINDY COOK · 281-948-1344

4314 LEMAC

THE WOODLANDS

Nature Reserve, Easy Access to The Woodlands Medical Center

STEPHEN SHEFFER · 281-658-0172

26 ORCHARD PINES

MEYERLAND

Never Flooded! One Story Contemporary, Open Concept

SHELLEY GREEN · 832-443-0773

5331 RUTHERGLENN

Serving Houston

SINCE 1978!

BETH WOLFF REALTORS
RealLiving

713-622-9339 BETHWOLFF.COM @BETHWOLFFREALTORS

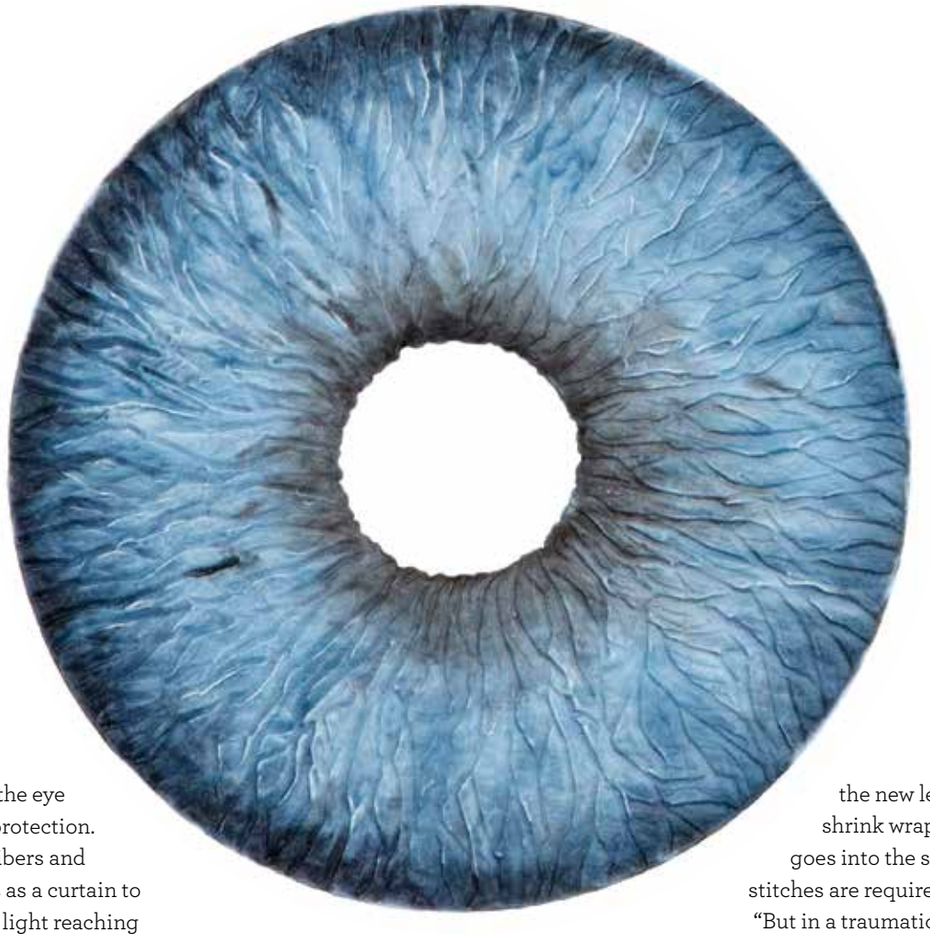
FIABCI LUXURY

NEXT MED

New technology and techniques

By Maggie Galehouse

Building a durable, flexible iris



In addition to giving the eye color, the iris offers protection. Composed of tissue, fibers and pigments, the iris acts as a curtain to restrict the amount of light reaching the retina.

For someone born without an iris or living with a damaged iris, glare can be debilitating.

"These are people who can't drive in the daylight," said Marshall Bowes Hamill, M.D., a professor of ophthalmology at Baylor College of Medicine's Cullen Eye Institute. "So much light is coming in that they're glare-disabled."

Congenital or traumatic aniridia—the absence of an iris—creates cosmetic concerns, as well.

But technology offers a solution. The CustomFlex Artificial Iris is a prosthetic made of thin silicone and produced by German company HumanOptics. Each prosthetic is individually sized and colored for each patient.

The device comes "in two flavors," Hamill said. One is a silicone sheet—"very soft, very pliable"—and the other is a silicone sheet embedded with fiber mesh, strong enough to be sewn to an eyeball.

For a patient outfitted with the device in combination with cataract surgery, surgeons perform a standard cataract operation. They remove the lens of the eye and replace it with an artificial lens, leaving the original back surface of the eye's natural lens—the "posterior capsule"—and fitting the new lens into this natural shrink wrap. The artificial iris goes into the same wrapper, so no stitches are required.

"But in a traumatic injury, if you've lost your lens and part of your iris, we don't have any support structure, so now we have to support that iris implant by actually sewing it to the eyeball," said Hamill, who participated in the clinical trials leading up to the U.S. Food and Drug Administration's approval of the device in May 2018.

The CustomFlex Artificial Iris costs $7,700, according to the manufacturer, and is not yet covered by insurance. Hamill said he hopes insurance companies will sort out reimbursement soon.

"This, in my opinion, is a significant advance in both reconstruction function surgery and reconstruction aesthetic surgery," he said. "It's a game-changer."

LEVERAGING YOUR DATA

Applied Data Science at UST

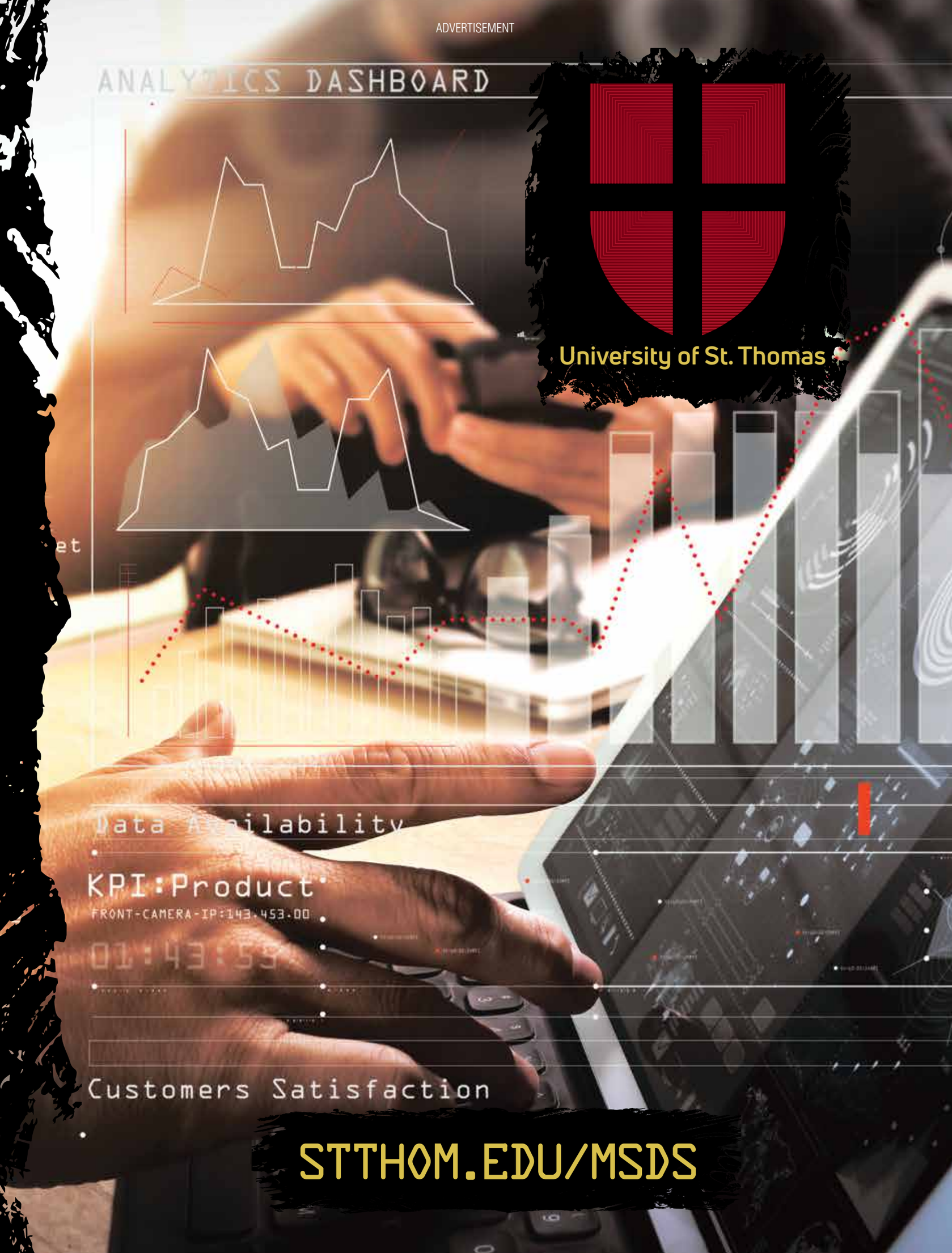
By Jack Follis, Ph.D., Master of Science in Applied Data Science Professor at UST

The world is being flooded with vast amounts of data of every imaginable type, and organizations need to be able to convert this data into actionable knowledge if they wish to stay afloat and ahead of the curve. Because of this need, data scientists are in high demand, and, according to Glassdoor, is the best job in America in 2019. To meet the growing demand for data scientists, the University of St. Thomas has introduced a Master of Science in Applied Data Science.

This program will provide you with the necessary skills to become a data scientist by expanding your horizons by learning to use Python and R for preparing, managing, visualizing and modeling data, as well as communicating results to stakeholders. In addition, you will also learn to use cloud-based services for implementing these methods. Your learning will be strengthened with collaborative projects working on data-driven solutions to real world problems. Consistent with the mission of UST, the program will emphasize the ethical and socially responsible analysis of data, and encourage using data science for social good.

We value intellectual diversity and welcome individuals from any academic background or industry. This program has been designed so that individuals with minimal technical/quantitative backgrounds will be able to develop the necessary skills to pursue a career in data science. Proficiency courses in computer programming and statistics are offered if you need to learn or refresh those skills and can be taken concurrently with other courses.

The program is offered in a format that is convenient for working professionals. Courses will be offered in the evening in either traditional lecture or hybrid (part-online, part in class lecture) format. You can progress through the program at your own pace, as either a part-time or full-time student.



Bioengineered Lungs: How Long from Pigs to People?

Joaquin Cortiella, M.D., and Joan Nichols, Ph.D., examine a bioengineered lung at The University of Texas Medical Branch at Galveston.

By Shanley Pierce

UTMB bioengineers successfully created and transplanted lab-grown lungs into pigs

In 2001, pediatric anesthesiologist Joaquin Cortiella, M.D., arrived at The University of Texas Medical Branch at Galveston for a job interview. Over lunch at the Galveston Yacht Club, he fell deep into conversation with Joan Nichols, Ph.D., a UTMB professor of internal medicine, microbiology and immunology.

As Cortiella and Nichols grew more and more impassioned about possible research opportunities, they started to scribble down ideas on a used napkin and came up with a bold plan: to create viable organs in the lab. In between the food stains, they sketched out a diagram for potentially infusing a combination of stem cells from Nichols' lab with lung-derived cells on a scaffold—a DNA-free, blank-slate structure—and, subsequently, transplanting the lung into an animal.

"When we first wrote this out, it was like science fiction," said Cortiella, who directs the tissue

engineering and organ regeneration lab at UTMB. "A lot of things there didn't happen until much later. We really thought outside the box at that time. … It's still kind of science fiction-y now."

More than a decade after their first meeting, Cortiella and Nichols took one large step toward turning science fiction into reality by creating and subsequently transplanting four lungs into adult pigs—with no medical complications.

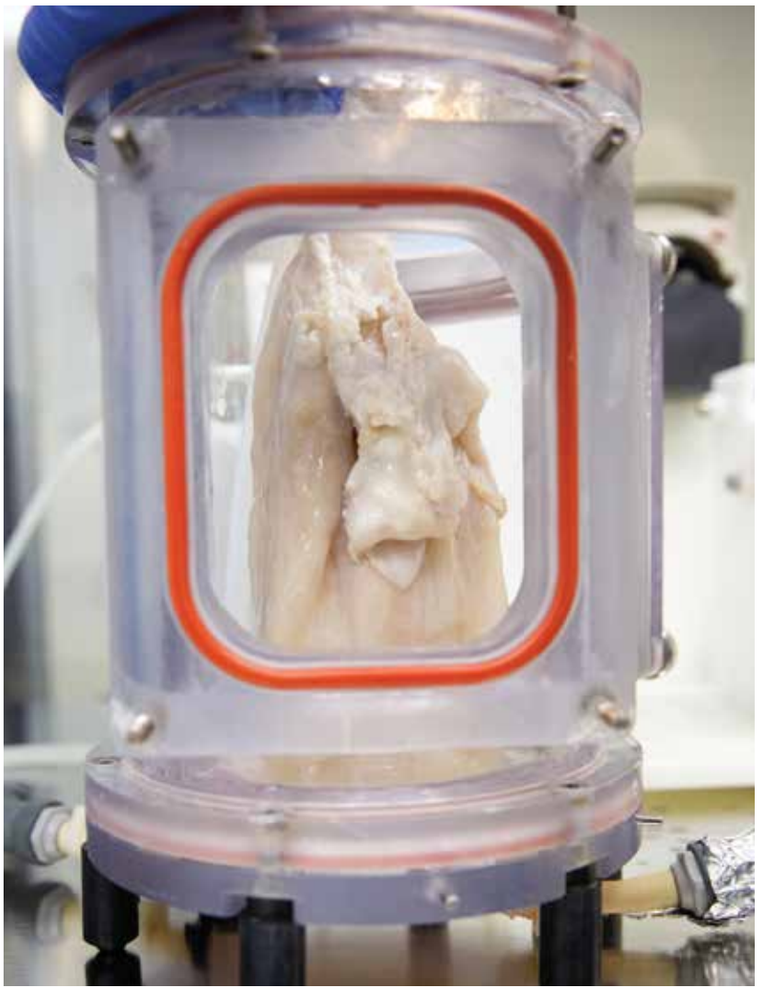
Oreo cookies

Cortiella and Nichols hope to quell the national shortage of donor organs with bioengineered organs.

More than 113,000 patients are listed on the national transplant waiting list, according to the U.S. Department of Health & Human Services. Unfortunately, the organ shortage in the country continues to grow, as the number of patients in need exceeds the number of donors. Another person is added to the waiting list every 10 minutes, while 20 people die each day waiting for a lifesaving organ transplant.

Yet a large number of less-than-perfect donated organs are discarded because they don't meet the strict federal criteria for transplantation. In 2016, nearly 5,000 donated organs were thrown out—including 221 lungs—because they were deemed "unsuitable" for transplantation due to "disease, injury to the organ, and the lapse of too much time between recovery and transplantation," according to a 2017 report from the National Academies of Sciences, Engineering, and Medicine.

"There are more lungs that are being thrown away than there are being transplanted, so there are a lot more people also waiting on a list to be transplanted. Unfortunately, the majority of them don't get it," Nichols said. "This was a way to look and see if we could take a lung that they're going to throw away or put somewhere, isolate the cells, take the scaffold and then start again."



A bioengineered lung hangs in a bioreactor, where it is infused with nanoparticles delivering a special concoction of growth factors.

Throughout the entire study, the pigs were trained exclusively with Oreo cookies, which allowed the researchers to perform tests and checkups without the pigs squirming. The team's veterinarian wrote an actual prescription with strict instructions to feed the pigs with Oreos for "pre- and post-transplant enrichment," according to Nichols.

In total, the researchers harvested and transplanted four lungs. As the lungs stewed in the bioreactor for a month, Nichols treated each of the pigs and each lung like a patient awaiting a transplant.

"I'd come in in the middle of the night and check on them," Nichols said. "We've got a lung for a pig, and the pig is waiting to receive the lung, so we'd better have a lung to give them. … They were all important to us. They were our transplant patients, and they gave us everything to do this research. We couldn't have done it without their involvement."

To create the scaffold, the team took a single lung from another pig and stripped the cells—a process called decellularization—using a detergent and sugar solution. The detergent removes all traces of blood and cells, while the sugar protects the collagen and elastin proteins from deteriorating. What is left is an off-white, gauze-like ghost of a lung. Washed clean of all traces of DNA, the lung scaffold is translucent, with only its branching arteries visible. ➠

The scaffold is then hooked up to tubes and placed in a bioreactor, where it is infused with nanoparticles delivering a special concoction of growth factors—including platelet-rich plasma, fibroblast growth factor 2 (FGF2) and keratinocyte growth factor (KGF)—for 30 days. (The team handmade their first bioreactor in 2013 from a Petco fish tank and nuts and bolts from the local Home Depot hardware store.)

The team also reconstituted an immune system in the new bioengineered lungs by replenishing it, pre-transplant, with alveolar macrophages—which clear out infectious and toxic particulates that pollute the respiratory tracts—and infusing it with a serum made up of the pig's blood cells.

"As an immunologist, I understood that if you just put in a sterile lung, you're going to get an infection," Nichols said. "Without an immune system in the lung as it developed, we don't get past 15 days. You get a fungal contamination overgrowth."

Where other researchers tried to transplant bioengineered organs and failed—because the animals suffered complications—Nichols and Cortiellas had four pigs that thrived. The bioengineered lungs developed a fully functioning network of blood vessels and lung tissues without additional infusions of growth factors within two weeks of being transplanted. All of the pigs remained healthy, but were euthanized post-transplantation after 10 hours, two weeks, one month and two months, respectively, so the team could assess how well the bioengineered lungs adapted to their new host environment.

While the animals' blood oxygen levels were holding at 100 percent because each pig still had one of its own fully functioning lungs, the bioengineered lungs were not developed enough for the researchers to allow the animals to breathe exclusively with the lab-grown organs.

'All of these little pieces'

Determining how well animals fare with only bioengineered lungs is the next challenge for Nichols and Cortiella.

As a byproduct of all their work with bioengineered organs, the researchers have made interesting and important discoveries that could impact science in a variety of ways.

By learning how to revascularize and rebuild the vascular system, for example, they've developed a way to enhance tissue development, which has positive implications for wound healing.

"When you look at it that way, all of these little pieces that we've come up with don't just impact what we're doing for bioengineering lungs. They could be used to help in wound healing, other surgeries, transplantation and the development of other organs," Cortiella said.

But the big question looms: When will they be able to develop a lung to transplant into humans?

Even with adequate funding, Nichols said it would take at least five to 10 years before they could produce a lung for compassionate use, a designation by the U.S. Food and Drug Administration that allows patients with immediately life-threatening or serious conditions to access investigational treatment.

"Although we worked as hard as we could and as fast as we could, there will always be people who hear about our work and say, 'I'm willing to be a guinea pig because I need a lung today.' That's really hard," Nichols said. "I spend weekends and holidays in the lab doing this work. You can never work fast enough … to get it to where it needs to be, but you always have to do it well."

It's a commitment Nichols and Cortiella are passing on to the next generation.

"We've made big advances within my lifetime. Definitely within my students' lifetime, they'll see clinical application," Cortiella said. "Like a relay race, it's their turn now."

In the Lab with Doris Taylor

By Alexandra Becker

The regenerative medicine and cell therapy pioneer shares her latest breakthroughs and the future of mending hearts

Doris Taylor, Ph.D., director of regenerative medicine research at Texas Heart Institute, stands in her lab.

A small human-sized heart hangs suspended in a bioreactor behind a maze of locked doors in Doris Taylor's lab at the Texas Heart Institute (THI). It is void of color, drained of blood and cells. All that is left is its natural scaffold of extracellular matrix, fully intact.

Taylor, who is the director of regenerative medicine research at THI, has already created more than 100 of these "ghost hearts"—and she intends to keep going, pumping each of them full of hundreds of millions of stem cells, hooking them up to artificial lungs and a blood pump, then watching them grow. Eventually, she believes, scientists will use this technique to create tailor-made organs for human heart transplants using a patient's own stem cells. This could mean an end to organ shortages and anti-rejection drugs, as well as a revolution in cardiovascular surgery.

But bringing one bold new idea to fruition means finding solutions for all the large and small problems that arise along the way.

"Ten years ago, when we discovered the concept of building a ghost heart, I thought stem cell biology had advanced enough that we would be able to just take stem cells, put them in the heart, and do something cool. It's taken us 10 years to develop methods to just generate enough stem cells to transplant a meaningful number in the heart," Taylor said, adding that they have now developed the ability to grow over two billion human-induced pluripotent stem cell-derived cardiomyocytes a week.

"Which is unheard of," Taylor said.

Cardiomyocytes are heart muscle cells. Induced pluripotent stem cells (iPSCs) are adult cells that have been genetically reprogrammed to mimic embryonic stem cells, though iPSCs have not yet been differentiated, meaning they have not started the process of becoming specialized cells. In other words, iPSCs are cells with an opportunity for a fresh start, which is necessary for growing new, healthy organs.

Generating the sheer number of cells required for each heart is just one of the many hurdles Taylor and her team have faced. They have also had to design and create their own methods for sterilizing the tools and environments to keep the hearts clean and healthy as the stem cells mature. But they worked through that, too, and can now keep a heart going for 60 days—a cap she's had to implement because of the availability of resources. Each custom bioreactor set-up is expensive, so her team must stop one in order to start a new one.

But, she said, they are exceptionally close to successfully building a working, human-sized heart. And in the meantime, the knowledge they've gained pursuing this goal has led them to the doorstep of many other medical challenges.

Location, location, location

"We've learned that if we put the same stem cells in the atrium or the ventricle, they become different cells, so the matrix seems to have cues that drive differentiation and maturation, which is really cool," said Taylor, a scientist with a Ph.D. in pharmacology. "In human hearts where heart failure is present, and where different kinds of heart failure is present, the scaffold is different. So all of a sudden, we're learning at an intriguing level what we already knew kind of a priori, which is that stem cells respond to their environment to become what they find themselves surrounded by."

Taylor hypothesized that one of the reasons cell therapy has yielded only modest results in repairing damaged hearts is because the stem cells are being placed in unhealthy organs. ➠

"We're taking these immature cells, stem or progenitor cells, and we're putting them in a scar. And we're saying, 'Hey, grow up and become a healthy heart,'" Taylor said. "But what if we put them in a matrix before we put them in the heart and allow them to mature first?"

Her lab has been working on a cardiac patch that may be more successful than traditional cell therapy techniques. Currently, they are pursuing two different methods: the first involves taking a piece of decellularized healthy heart, cutting it out, then sewing it onto the surface of the heart as a patch; the second involves grinding up one of the ghost hearts and creating a powder that they then convert into a gel that is injected into the scarred or damaged area of the heart.

"It's really about putting things in the right environment and letting them do their thing," Taylor said. "I call it the real estate approach to cell therapy. Location, location, location."

A step further

There's more—in fact, potential applications for the team's discoveries are vast.

After noticing that individuals with heart failure seemed to have different matrices than those with healthy hearts, Taylor wanted to compare the matrices in the hearts of animals. What her team found was that in young animals, the matrices of the heart, liver and kidneys of females were stiffer than those of their male counterparts.

Taylor was puzzled. Why would that be?

"I started thinking about the fact that when women get pregnant, their blood volume goes way up," she said. "And if your heart has to pump against that blood volume, you need something that's tougher. We also found out that if we look in older males and females, the males catch up with the females later in life."

Taylor took it a step further, aware that a disproportionate number of women suffer from a type of heart failure called preserved ejection fraction systolic dysfunction, in which the heart muscle contracts normally, but the ventricles do not relax as they should.

"It's the ultimate irony," she joked. "Women can't relax as well."

It turns out, there is a protein in the heart muscle responsible for that stiffness.

"We've recently found that the extracellular matrix determines how much of that protein you have," Taylor said. "This type of heart failure is three times more prevalent in women, and I think it's because the matrix is different, so we've developed a treatment that we hope to try over the next year in preclinical studies that we think will reverse that."

Currently, Taylor said, there are no treatment options for this type of heart failure.

"It's all because we looked at the matrix and saw that there is this underlying structural difference that tells cells how to behave. Again, it's about environment—location," she said.

Taylor's lab is also learning that lifestyle can impact the health of a person's stem cells.

"We've found that smoking, diabetes, hypertension—all of those things change your bone marrow, they change the cells that are there. They will increase inflammatory cells and decrease positive cells, and we've been able to show ... that if you look at the onset of heart disease and the loss of some of these stem cells, they absolutely mirror each other," Taylor said. "And so I say that aging, and a lot of the diseases associated with aging, are a failure of endogenous repair, and a failure of your stem cells."

Taylor applied these lessons to her own life.

"I was involved in a clinical study that shows when you exercise you increase the number of stem cells in your blood," she said. "And I did a study with a colleague in California where we studied acupuncture. It was a small number of women, but in the women who got acupuncture versus sham acupuncture, the number of circulating progenitor cells went up—so all these things we've been told to do to decrease stress, it actually does increase the number of circulating cells."

On this page: *Taylor holds a ghost heart over a bucket containing a solution that is used to wash the cells from the heart scaffold. The attached tubing delivers this solution to the heart.*

> “It’s very different building a biologic device than it is building a mechanical device. Biology is variable, and if you build a mechanical device, you assume it’s going to act the same way every single time you build it. But if you build a biologic heart, you have to prove it’s going to act similarly, with a certain degree of variability.”
>
> — DORIS TAYLOR, PH.D.

Go for the home run

Despite naysayers, Taylor has always believed she could rebuild an organ from the ground up. She believes in the complexity of “nature’s tools” and that pre-existing structural compositions are far superior to any designed by the human hand.

One of the things Taylor is most proud of is that her lab’s more mature hearts are now growing fat on the outside of the muscle.

“It’s real,” she said, adding that at this point, creating an organ is now just a matter of money and time.

“It’s about slogging through it right now, doing it over and over and over and improving a little bit every time,” Taylor said. “But that is expensive. … Right now, building a small, pediatric-sized humanized heart costs us sixty to seventy thousand dollars.”

With the right funding—Taylor said her research isn’t eligible for the usual types of National Institutes of Health funding because it’s not technically hypothesis-driven—Taylor could envision the technique moving quickly to preclinical studies. Still, she emphasized how grateful she is that THI has supported her high-risk, high-reward research.

“There’s a 50 year history of trying to build solutions for heart disease here,” she said. “That’s why I came here and that’s what has enabled us to get to this point.”

Taylor said that her work is on an exponential growth curve, and that she and her team feel like they are more in a process at this point than an experiment.

“It’s a good problem to have, but it’s a hard scientific place to be,” she said.

It doesn’t help, she added, that she chose to pursue such a complex challenge.

“It’s very different building a biologic device than it is building a mechanical device,” Taylor said. “Biology is variable, and if you build a mechanical device, you assume it’s going to act the same way every single time you build it. But if you build a biologic heart, you have to prove it’s going to act similarly, with a certain degree of variability. … Not only do we have to figure out how to build a heart, but we have to figure out how to measure building a heart, which nobody’s ever done before, so there aren’t tools out there to do it. It’s really about constantly having to rebuild everything around you, because none of it exists.”

In the end, Taylor is working to help keep people and their hearts as healthy as possible.

“My approach to science has been: go for the home run, and if it works, great, and if it doesn’t, everything you learned along the way is going to open new doors,” Taylor said. ■

VITALS

Trending topics in health, science and medicine

By Shanley Pierce

What to expect from a doctor's visit in 2039

A lot can change over 20 years, especially in medicine. Health care experts predict technology will transform the doctor's visit in four significant ways by 2039.

Telemedicine

The delivery of health care services online and via mobile devices is fundamentally changing the patient-physician interaction and enabling health care providers to reach more people in communities with limited access.

"Today, how we 'visit' a doctor is transforming," said Roberta Schwartz, Ph.D., chief innovation officer at Houston Methodist Hospital. "We are moving from a world where you see the physician face-to-face to a world where you can visit a physician through telemedicine, whether you're at the hospital or home, and you can even have a text visit with a physician."

More than three-quarters of hospitals in the country currently connect patients with health care experts through video to virtually consult, diagnose and treat conditions in real time, according to the American Hospital Association. Since telemedicine has proven to increase access to care, reduce health care costs and improve outcomes, it is poised to become a standard of care.

More automation with AI

Thanks to artificial intelligence (AI), doctor visits will be likely become more automated. Routine paperwork, such as verifying insurance and manually inputting patient information, will be done by machine—reducing redundancies and eliminating paper forms.

"Patients will fill out automated surveys prior to or upon arriving to appointments, be assisted by kiosks or robots to complete, and then find a room," said Emily Reiser, Ph.D., innovation strategist at TMC Innovation Institute. "All together, the upfront automation and automatic entry of conversation into EHR [electronic health records] will enable higher volumes of patients per provider and more quality time with patients."

PricewaterhouseCoopers estimated that health care organizations could see 15 to 20 percent gains in productivity through the use of AI technologies as early as 2021.

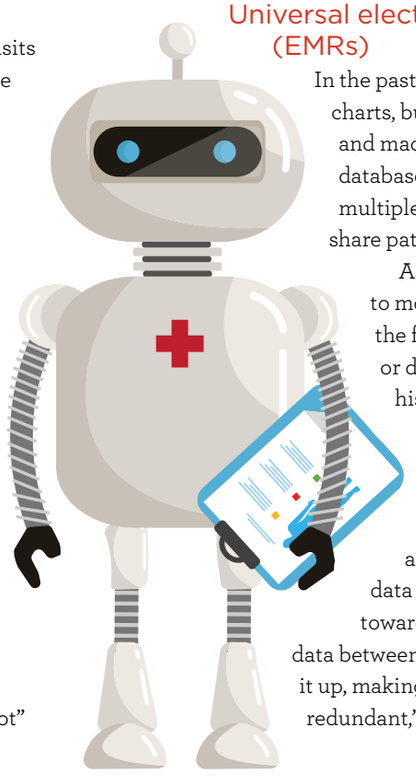
While AI will most likely serve as a "co-pilot" for doctors, some experts believe replacing the role of the physician is not outside the realm of possibility.

"As the AI gets trained and gets the opportunity to show that it is superior to clinicians with outcomes, then there may be human [clinician] pushback on it since it jeopardizes their role," said Albert Huang, M.D., innovation strategist at the TMC Innovation Institute. "Eventually, AI may reasonably be able to take over radiology and pathology, since those are both image recognition-driven fields. Clinical decision-making systems may be close behind."

Wearable tech and the quantified self

Smartphones and wearable devices track our every step, calorie intake, heart rate and sleep pattern, generating huge amounts of data. Doctors in the future will likely collect this information from patients to help anticipate, diagnose and treat different conditions. When doctors see patients in person or via telemedicine, all that data will be at the ready.

"We are rapidly moving to a world where your health status can be monitored from home, uploaded and tracked by health professionals using sophisticated software to proactively identify patients at risk of certain health issues," Schwartz said.



Universal electronic medical records (EMRs)

In the past, medical records were handwritten on charts, but now patient information is digitized and made easily accessible via electronic databases, such as Epic and MyChart, allowing multiple providers to securely access and share patient data.

As a result, EMRs are going to continue to move towards universalization. In the future, when patients enter a hospital or doctor's office, their entire medical history will be immediately accessible across multiple locations and multiple providers.

"Be it everyone on Epic or via interoperability, as much as hospitals are trying hard to hold onto their patient data as an institutional asset, the pull towards more open transmission of patient data between hospitals is going to eventually open it up, making patient care more efficient and less redundant," Huang said. ■

Going *Through* the Motions

The motion analysis center at Shriners Houston calculates therapeutic and surgical interventions

By Cindy George

Navigating a runway seems natural for Madilyn Jenkins.

She walks. She runs. She jumps.

The 9½-year-old places a hand on her hip as she prances, expressing her personality and even humming a song.

Yet on this walkway, she's a superstar and a patient—the center of clinical attention—and the beneficiary of innovative technology that will determine how to improve her movements despite the effects of cerebral palsy.

As she advances along a path of mint green force plates at Shriners Hospitals for Children - Houston, data is collected from her steps while 3D motion capture cameras record numerous aspects of her movements.

"This is basically a computer lab. We use computers to quantify motion and movement," said Annabelle Relf, D.P.T., one of several physical therapists who work in the motion analysis center. "When someone has a full motion analysis study in centers like ours and we do all the data collection, we can say, yes, we think these muscles are tight, these bones are rotated and you should do this and you shouldn't do this."

The MAC

Using data beyond a clinical exam to evaluate children with movement disorders began at Shriners Houston in 1978. At that time, the lab used a basic video camera to capture locomotion and electromyography, or EMG, to test the electrical energy of muscles.

Today, the motion analysis center, known as "the MAC," uses the same technical special effects employed by animators in movies and video games to calculate potential therapeutic and surgical interventions for children ages 4 to 18.

The MAC features foot pressure analysis mats reminiscent of kiosks in drug stores that sell shoe inserts, and a mask for metabolic testing to measure how much energy is expended in movement. Instead of creating Hollywood blockbusters, the center uses this suite of computers, cameras and other specialized equipment as a collective diagnostic tool.

The lab is staffed by physical therapists, a biomedical engineer, a lab coordinator and a technician. This team runs the motion studies, spends weeks crunching the data and then shares its findings in formal reports for "interpretation sessions" with orthopedic surgeons.

"The complication that the children with cerebral palsy have is that sometimes the walking problem is very complex and you need all the data to be able to make decisions," said physical therapist Rebecca Case, the hospital's administrative director of rehabilitative services, which includes the motion center. "We want to improve their lives now, but we are aiming at when they graduate from Shriners that they're as functional as they can be and that they can be successful adults."

Most of the children examined in the lab for major studies, which take 2 to 3 hours, have cerebral palsy—the most common childhood movement disorder, according to the Centers for Disease Control and Prevention.

Beyond gait

A surgical plan can change based on gait analysis, which can clarify the complexity of a case and lead to less trauma for the patient.

"For an experienced individual in gait dysfunction in a child with cerebral palsy—for example, for me—I would say that the motion lab changes what I would plan to do 20 to 25 percent of the time," said pediatric orthopedic surgeon Douglas Barnes, M.D., the MAC's medical director for the last two decades and the Shriners Houston chief of staff. "For me, it is invaluable."

Innovation at the lab has advanced beyond legs, he added.

"We are developing capabilities of refining

Madilyn Jenkins makes her way across force plates that capture data during a post-operative gait analysis exam at Shriners Hospitals for Children - Houston.

trunk motion, neck motion and upper extremity motion. There are a lot of problems with that because they are not repeatable like gait cycles, where you go through certain events such as stance and swing," said Barnes, who performed Madilyn's latest surgery. We are also interested in capturing spine motion—especially in some of the neuromuscular disorders."

This expertise earned Shriners Houston national recognition by the Commission for Motion Laboratory Accreditation. The MAC is one of 14 gait laboratories accredited in the country and the first in Texas to receive the distinction.

Improvement and a love of slime

"She was walking on her toes," Madilyn's mother, Latonia Jenkins, explained. "I ended up going to Shriners in Shreveport. I didn't know they had a Shriners here in Houston and I'm from Shreveport. I went home to get her some help. … I was going back and forth."

Madilyn was born premature in 2009. She weighed 1 pound, 6 ounces and had bleeding on her brain. At different intervals throughout her life, she's had surgery and therapy to loosen up her left side, where her leg remains stiff and her arm hangs at an angle.

Madilyn had casts on both legs during treatment in Louisiana and was referred to Shriners Houston three years ago.

A previous gait analysis prepared Madilyn for surgery in 2018 on her left arm and legs.

During a three-hour, post-operative exam in May, she showed more control on the walkway with her leg braces and wasn't standing up so far on her toes.

"She's a lot better compared to what she was," Latonia Jenkins said.

Madilyn's testing included marching and twirling, easy for someone who loves to dance while she sings.

> "This is basically a computer lab. We use computers to quantify motion and movement."
>
> **— ANNABELLE RELF, D.P.T**
> ***Physical therapist at Shriners Hospitals for Children - Houston***

On an exam table, physical therapist Melissa Howard took measurements and manipulated Madilyn's limbs. A discussion about her favorite things teased out Beyoncé, Nicki Minaj and playing with slime.

At one point, Howard asked Madilyn to hold her muscles tight.

"I'm looking at how strong she is," the physical therapist explained. "Can she move one leg without the other? Can she move just her knee joint or do all her joints move?"

Howard also wanted to know what Madilyn thought would improve her gait.

"I would like these muscles to go down," Madilyn said, pointing to the tightness in the back of her legs.

"Yep, the hamstrings," Howard said.

Latonia Jenkins chimed in.

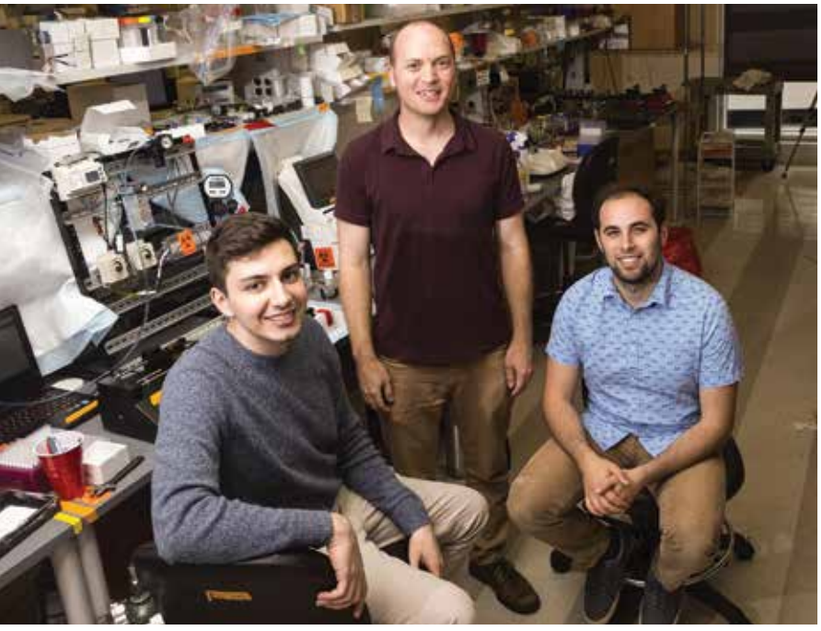
"The knee. That's my concern," she said. "After we stretch out that hamstring, I think she'll be OK. The arm is a lot better. It's still a little stiff, but it's a lot better."

The prize for finishing a gait analysis is a trip to the reward closet. Skipping over the dolls, makeup, puzzles and a purse, Madilyn chose the slime kit. Of course.

ONE STEP CLOSER TO PRIN

Bioprinting fully functioning human organs would help address the organ donation shortage in the United States

By Shanley Pierce



Rice University bioengineers Bagrat Grigoryan, Jordan Miller, Ph.D., and Daniel Sazer worked with collaborators to create a bioprinting technique that could accelerate technology for 3D-printing replacement organs and tissues.

A breakthrough technique developed by a team of bioengineers at Rice University and the University of Washington brings 3D-printed organs one step closer to reality.

One of the biggest challenges in bioprinting has been recreating the complex architecture of vascular networks that supply blood and nutrients to densely populated tissues.

"In biology, you have this idea that form follows function. The form of a biological structure is an evolutionary consequence of its function," said Jordan Miller, Ph.D., assistant professor of bioengineering and founder of the Advanced Manufacturing Research Institute at Rice University. "In bioengineering, we're asking the converse question: Will function follow form? What we're trying to do is build living tissues that can replicate some of the architecture that we observe in the body."

To do that, scientists needed to get creative.

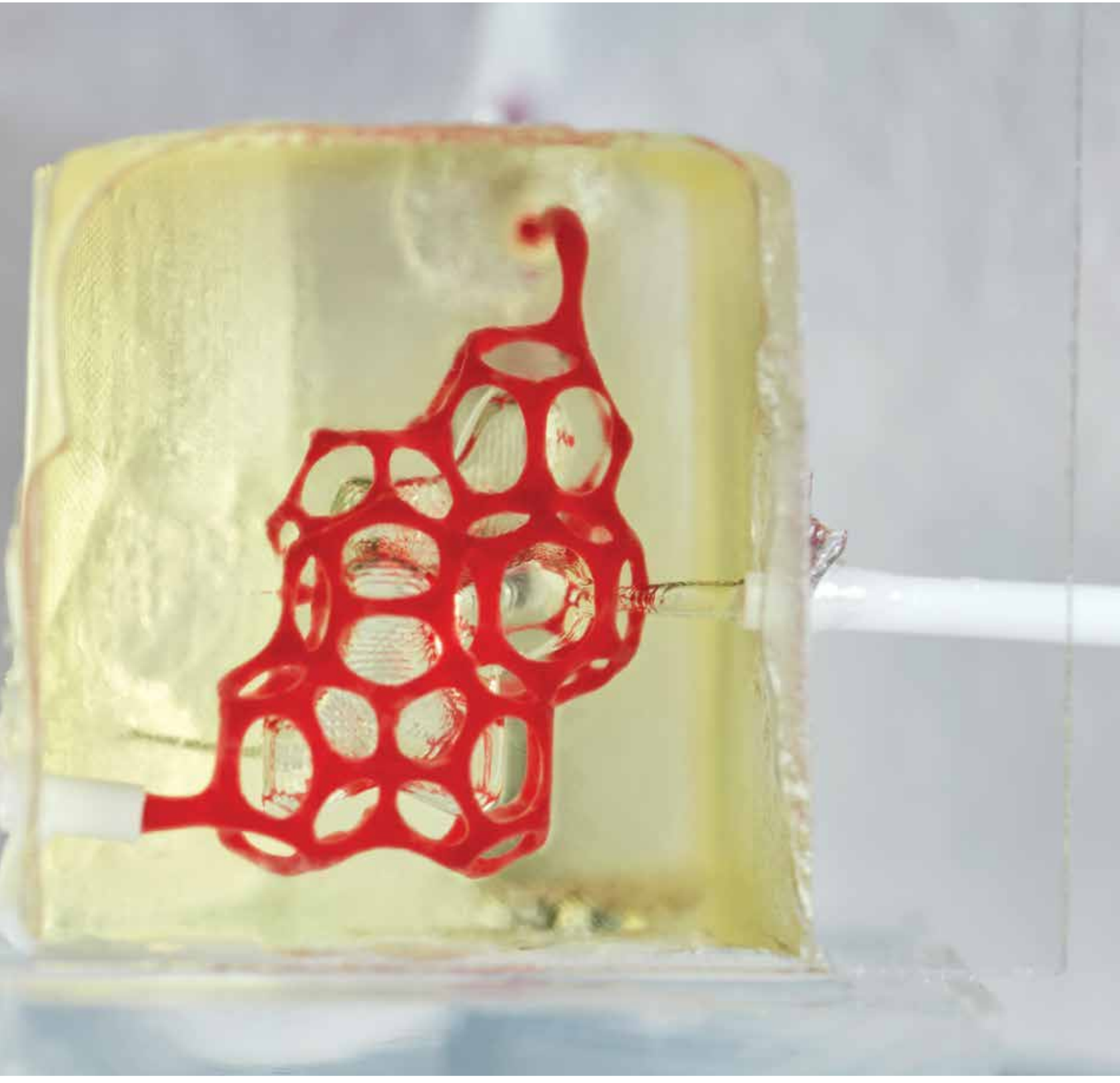
Developed by a team of bioengineers led by Miller and Kelly Stevens, Ph.D., assistant professor of bioengineering at the University of Washington College of Engineering, this new bioprinting technique—"stereolithography apparatus for tissue engineering," or SLATE for short—enables scientists to create intricate multivascular networks that mimic those found in the body that are essential to delivering blood, oxygen and nutrients to organs and tissue.

"This is a much more accurate representation of human tissue because some of our organs are more complicated in terms of their architecture," Miller explained, citing the lungs, liver, kidney and pancreas. "They don't just have one vessel architecture; they have multiple independent vessel architectures that are occupying the same organ but never touch. It's important that they never touch. If that happened in your lung, you would get blood in your airway or air in your bloodstream. Both of those are fatal."

One recent prototype, a lung-mimicking air sac made of a hydrogel material, measures 4.5 millimeters at the widest point—smaller than a penny—and contains blood vessels 300 microns in diameter that do not touch. ➟

Credit: Left, Jeff Fitlow/Rice University; Right, Bagrat Grigoryan and Jordan Miller

TING REPLACEMENT ORGANS



A breakthrough bioprinting technique uses a water-based gel architecture to mimic the structure and movement of human lungs. Bioengineers are trying to replicate vascular structures within the human body using materials in which they can grow cells.

The team decided to create a prototype of that size to focus on the smallest functional microtissue architecture that repeats its pattern throughout the tissue.

"If we could study a distal lung subunit and make that very efficient—if we build more and more of them into a 3D gel volume in a way that they can be interconnected and plumbed correctly—then that could allow us to build functional mimics of human lung tissue," Miller said.

The proof-of-principle model made the cover of *Science* magazine on May 3.

Bioprinting fully functioning human organs has been a goal for bioengineers since the advent of 3D printing. Success would help to address the organ donation shortage in the United States. As of January 2019, the national transplant waiting list contained more than 113,000 names, according to the U.S. Government Information on Organ Donation and Transplantation. Only 58 percent of adults are registered donors.

This new technology could allow doctors to bioprint replacement tissue and organs using a patient's own cells.

A U.S. penny is shown next to a scale model of a lung-mimicking air sac with airways and blood vessels.

Credit: Brandon Martin/Rice University

"In the shorter term, we definitely need a lot more people to register to be organ donors. This is a continued need in the medical space. Organ transplant is still the best and, in some cases, the only treatment for some conditions," Miller said. "As we look longer term, we're very excited about the potential for building human tissue replacement made from [a patient's] own cells."

Miller believes 3D bioprinting will play an integral role in medicine over the next 20 years. Although it will still be several years before doctors implant a bioprinted organ in a patient, the team has made the technology available to help other researchers.

"We've used a lot of open-source technologies to further our work and we're contributing back to the open-source community the designs of our 3D printer and all the designs of our hydrogels that we fabricated in this work," Miller said. "We're very excited to see other people try to pick up this technology and hope these vascular architectures could be useful for other people in their research." ■

> "What we're trying to do is build living tissues that can replicate some of the architecture that we observe in the body."
>
> — JORDAN MILLER, PH.D.
> *Assistant professor of bioengineering, founder of the Advanced Manufacturing Research Institute at Rice University*

The Early Bird

An innovative device uses electrodes to detect internal bleeding

By Alexandra Becker

Eleven years ago, while driving along Interstate 45, a spark of ingenuity hit Mehdi Razavi, M.D.

The electrophysiologist was leaving one hospital and heading to another when he received a call that the patient he'd just left was experiencing complications, including a sudden drop in blood pressure. Razavi feared the worst—in this case, internal bleeding. It was something he dealt with in his line of work, testing and treating electrical activity and rhythm problems of the heart, and he was perpetually frustrated that there were no tools to detect bleeding complications until symptoms appeared. When that happened, it usually meant treatment was urgent, blood transfusions would be required and hospitalization would be extended.

And that's if the patient survived.

But what if, Razavi thought, his eyes fixed on the road, there was a way to discover bleeding before symptoms manifested? What if it was as simple as creating a sheath outfitted with electrodes that could detect impedance—a term used to describe electrical resistance. The electrodes, Razavi speculated, would probably measure extremely low in an area pooling with blood.

It turns out, that is exactly what happens.

"In my subspecialty, we look at electrical impedance all the time, but that's because we're looking at ablation catheters and not for other reasons," explained Razavi, the director of electrophysiology, clinical research and innovations at Texas Heart Institute (THI). "This idea came from the right combination of need and background."

Razavi worked out his concept and initial design, then brought it to Maria Oden, Ph.D., a professor of bioengineering and director of the Oshman Engineering Design Kitchen (OEDK) at Rice University, a workshop where undergraduate students interested in engineering, math, science, technology and other related fields design and create prototypes to help solve real-world challenges. There, Razavi and a group of students refined what would soon become The Early Bird Bleed Monitoring System. Not long after, Razavi founded a new company to develop the device—Saranas—and brought some of those same undergrads on board as summer interns.

Credit: Courtesy Texas Heart Institute

Mehdi Razavi, M.D., director of electrophysiology, clinical research and innovations at Texas Heart Institute, holds The Early Bird Bleed Monitoring System.

Saranas' Early Bird Bleed Monitoring System detects and monitors bleeding complications associated with vascular access procedures by employing a special plastic tube, or sheath, much like the ones commonly used for keeping arteries and blood vessels open during surgical procedures so that catheters and other devices can be inserted. The Saranas sheath is fixed with sensors designed to measure the impedance across a blood vessel. When the sheath senses a change in the vessel's electrical resistance, the device responds with audible and visual notifications to alert the clinical team of a potential bleed. The device is able to detect bleeds almost as soon as they begin, allowing health care providers to avoid what can be costly and sometimes life-threatening complications.

"It's the canary in the coal mine for cardiologists," explained Zaffer Syed, president and chief executive officer of Saranas. In fact, the company's name itself is derived from the Latin word for the Atlantic canary—serinus canaria.

The name Early Bird followed easily from there.

"There is no technology out there that does real-time detection of internal bleeding during these transcatheter types of procedures," Syed said.

Bleeds can occur for a number of reasons related to a patient's condition and the type of procedure performed.

Usually, procedures that create a larger hole in the vessel are more difficult to close and can cause more disruptions farther up—including deploying transcatheter valves, percutaneous heart pumps, even thoracic stents. With these procedures, the risk of bleeding can be as high as 20 percent, on average, Syed said.

By the time symptoms of the bleeding appear, the patient often requires a blood transfusion and will likely have a longer stay in the hospital. At that point, the risk of mortality has already increased.

"A single unit of blood actually changes the course of when a patient is going to get out of the hospital, and it can generate a whole host of other problems," said Kenneth Bueche, chief operations officer of Saranas.

"That's the problem we're trying to address," Syed added. "Our thesis is that by being able to monitor the bleed status of the patient, both during and after the procedure, and being able to inform the clinician early of a potential bleed complication, they're going to be able to mitigate some of those downstream consequences of the bleed, both from a clinical perspective as well as a health economic perspective."

Since the company's founding in 2013, the technology has been patented, the company has participated in the TMCx accelerator program, joined TMCx+ and raised capital. The device has run through clinical pilots across multiple centers throughout the United States, including two in the Texas Medical Center. And in March 2018, the Early Bird Bleed Monitoring System was approved by the U.S. Food and Drug Administration.

Leading the Saranas team are Kenneth Bueche, chief operations officer, and Zaffer Syed, president and chief executive officer.

The next step is putting the technology into the hands of clinicians.

"As a company, immediately what we want to do is demonstrate the clinical utility of this novel technology. We're excited to have the FDA approval and a new product code that allows us to now market this into health systems where we have heard from doctors wanting to try it out," Syed said. "Our mission is to make these procedures safer, and we think our technology could improve not only the quality of those procedures but hopefully the quality of life of the patients who are undergoing those procedures."

Razavi is proud of the collaborative process that led to the birth of the Early Bird Bleed Monitoring System.

"I think we could almost be a poster child for what the TMC is supposed to be like," he said. "Where one person gets an idea and nurtures it through its earliest stages as a seed, and then the plant starts growing with Rice, and then as it matures you turn around and you are at TMCx, then you do preclinical studies at THI, then you have hospitals such as both Methodist and THI participating in the clinical studies. It doesn't get better than this in terms of process." ■

TMC PULSE WANTS TO HEAR FROM YOU

Tell us what we're doing right, and what we could be doing better.

Take our survey today at
www.tmcpulsesurvey.com

Following your completion of the survey, TMC Pulse will make a donation to your choice of the following charities: Heifer International, World Central Kitchen, Direct Relief or UNICEF.

This survey is being conducted by GfK MRI, an independent research firm. All responses are confidential.

TMC | PULSE

IN THE WORKSHOP

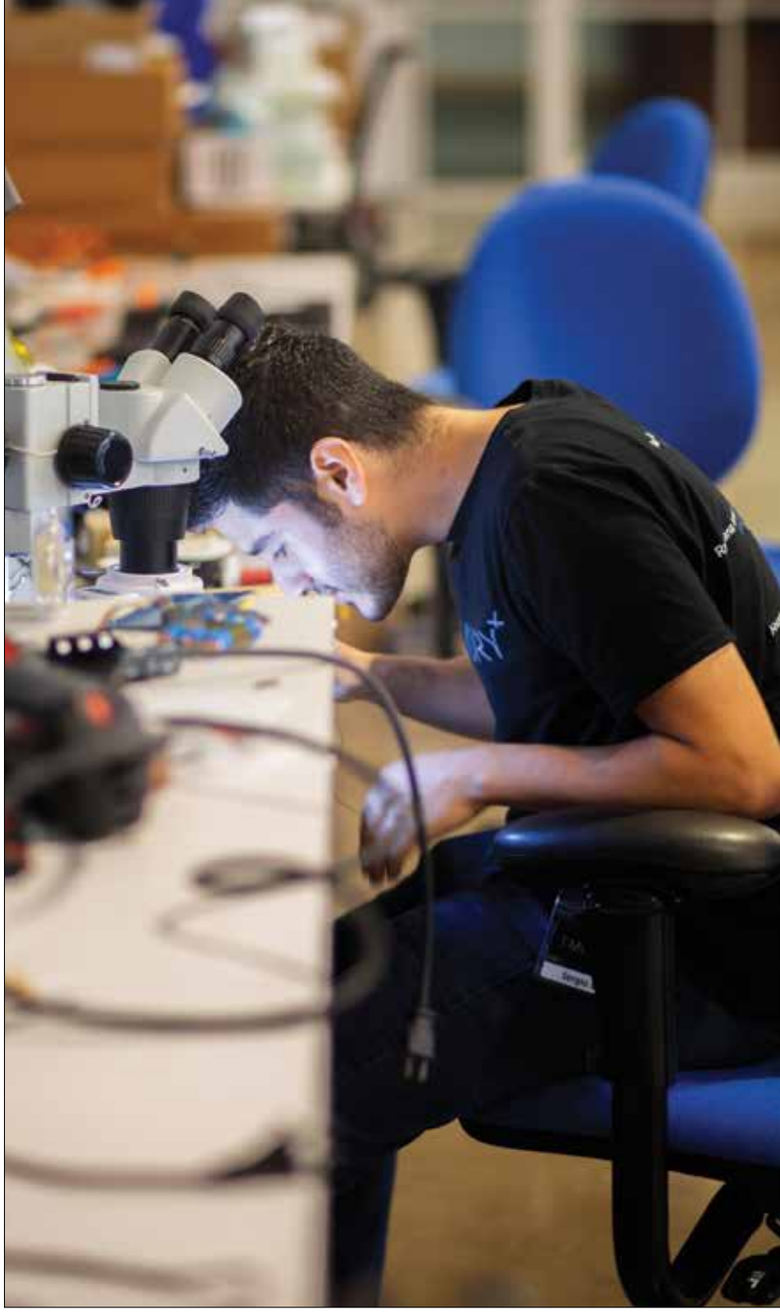
What does it take to transform ideas into realities? Determination, tools and space to tinker. At workshops across the Texas Medical Center, engineers, machinists, researchers and students strive to find innovative solutions to the biggest problems facing health care.

Left: *An orthotist/prosthetist at Shriners Hospitals for Children - Houston, a pediatric orthopedic hospital that is also a research and teaching center, smooths a mold of a patient's limb before creating a brace.*

Right: Welding jackets, helmets and lab coats are stored on a rack at the Center for Device Innovation (CDI @ TMC), a collaboration between Johnson & Johnson Medical Devices Companies, Johnson & Johnson Innovation and the Texas Medical Center. Below: Juan Fernandez, lead machinist at Houston Methodist Hospital, builds and modifies devices in the machine shop located in a Houston Methodist parking garage.

Left: Jeremy Palmer works at Rice University's Oshman Engineering Design Kitchen (OEDK), a space for students to design, prototype and deploy solutions to real-world problems. Palmer graduated this spring with a bachelor's degree in mechanical engineering. Below: Carlos Amaro, operations manager for the CDI @ TMC, uses a laser cutter.

VISIT TMCNEWS.ORG TO WATCH VIDEOS OF TMC WORKSHOPS.



Above: Christine Luk, a master's degree student in bioengineering at Rice University; Karen Vasquez Ruiz, who graduated from Rice this spring with a degree in bioengineering; and Sonia Gomez Parra, who earned her Ph.D. in bioengineering from Rice this spring, examine a cervix model at the OEDK. Above right: Design engineer intern Sergio Lopez works at the AT&T Foundry for Connected Health at the Texas Medical Center, which develops digital health solutions that bridge the gap between the clinical and home setting. Lower right: Tools hang on the wall at the AT&T Foundry.

JOHN and LAURA ARNOLD lead Arnold Ventures, a Houston-based philanthropy developing innovative solutions to some of the country's most persistent problems, from pension underfunding to the high cost of prescription drugs. John Arnold was an energy trader for Enron and then started his own hedge fund, Centaurus Advisors, before retiring at age 38. *Forbes* estimates his worth at $3.3 billion. Laura Arnold is an attorney and former oil executive.

Q | So, you're a husband and wife who work together. Do you have separate offices at your Houston headquarters?

LA | We do, but there's a door between them.

Q | Arnold Ventures, No. 8 on the Chronicle of Philanthropy's list of top donors for 2018, gave away a total of $204,300,000 last year. At the moment, your philanthropy is focused on four areas—health care, education, criminal justice and public finance—though not limited by these categories. How do you decide which issues to take on?

LA | We're interested in market failures across the board. The set of criteria we use to think about where we focus is: Is this an area where we believe there is a systemic failure? Do we believe philanthropy could add value in creating alternatives and developing solutions? Is it a good fit for us—meaning, is it in our skill set? We don't invest in a lot of hospitals, for example. We're not scientists. We couldn't add value in cancer research over and above writing a check. But we believe we could add value to pharmaceutical pricing over and above writing a check, because it's more consistent with our backgrounds and expertise.

Finally, we look at whether or not this is an area where we think bipartisan or nonpartisan consensus could occur from a policy perspective in the near- to medium-term future. The areas in which we're currently focusing are areas where we believe all those criteria are met and we believe we are uniquely positioned to pursue those opportunities given the current political landscape.

JA | Houston's been blessed with a number of very generous philanthropists who have funded the hospitals to provide the facilities we have today. But there's less focus, especially from a philanthropic perspective, on looking at things more holistically: How do we increase access to health care by bringing costs down? We viewed that as a somewhat unique perspective, because health care costs are eating the federal budget. It's the single biggest driver on the fiscal health of this country long term. It's eating employers. It's eating the individual. Compensation is income plus benefits, and the problem is most of the compensation gain has been swallowed up by the cost increase in benefits.

Q | Arnold Ventures is one of three philanthropic organizations that has invested in Civica Rx, a nonprofit hoping to drive down drug costs by collaborating on generics. Catholic Health Initiatives and Memorial Hermann Health System are among the 19 large hospital systems that have partnered with Civica Rx. How will this initiative and others drive down drug prices?

JA | Pharmaceutical pricing is one of the hardest areas because there's a dozen different problems or inefficiencies in the system. We have this difficulty when we're talking to politicians because there's no 'Do this one thing and it will fix all the problems' solution. The market is so bifurcated between generics and branded, between drugs that are unique in their class and drugs that have competition, even by the different types of payers—Medicare is very different from Medicaid is very different from private payers or cash payers or the VA. There are problems throughout that whole structure.

But broadly, there's a whole class of fixes that's trying to increase competition within the sector. How does a drug shift from being branded and having an exclusivity period to being in the competitive space? How does that shift happen more efficiently and more under the spirit of the current rules? A lot of these rules are 35 years old through Hatch-Waxman [1984 federal legislation that established the approval pathway for generic drug products] so some have become outdated. Industry is getting away from the spirit of the regulation and has created a lot of ways to extend the exclusivity period. We have a whole host of policy proposals on that, about six or eight different things.

There's a second group of proposals around trying to get rid of some of the poor incentives in the system. We're talking about the pharmaceutical benefit managers—the PBMs—and some of the bad incentives they have. Maybe they get paid a percentage of the discount between the list price and the net price of drugs, which drives some bad incentives as to how they negotiate and how those

drugs are priced to the individual.

LA | With pharma pricing, there is a consensus that there's a problem. There may not be a consensus on who the culprits are and what the solutions might be, but very few people would argue that the system is optimal. There's a really powerful grassroots movement of individuals who are patients who can't afford their drugs. And one of the things that we're very proud of having done is contributing to galvanizing all those grassroots policies. One of our most powerful grantees and partners in this work is an organization called Patients for Affordable Drugs. It was founded by a cancer patient who has an incurable but manageable form of cancer. He is insured but he saw that his medications cost hundreds of thousands of dollars a year. He started collecting the stories of patients who were similarly situated, of people who had to cut their pills into four pieces because they couldn't afford a full dosage, or who couldn't afford to fill a prescription. People who were forgoing food and rent, cashing in their IRAs just to pay for medications. So those voices—and he has brought those voices to the Senate, to the House of Representatives—really bring home the point that this is *not* a theoretical argument. That this is affecting real people.

> "Most policy ideas that we're working on aren't going to work. But you have to work on problems that are big enough and ideas that are scalable such that when you find something that *does* work, it has a real impact."
>
> — JOHN ARNOLD

Q | What about hidden medical fees? Let's say a woman goes in for surgery. She finds an in-network surgeon so insurance will cover the operation, but after the surgery she receives a $15,000 bill from the anesthesiologist, who is out-of-network. How do you approach that problem?

JA | We started working on this a couple of years ago. We got some of the health care policy experts to focus on this and funded a number of different people to think about what's driving the problem and what are the policy fixes. Our grantees have come up with a number of different options. Some are saying there should be a maximum that an out-of-network doctor can charge. Others have suggested that the out-of-network provider should have to bill through the hospital, so the hospital is forced to negotiate, not the individual. Different ideas are debated and vetted and then the best options are delivered to the policymakers.

Q | Arnold Ventures employs about 85 people in Houston, New York and Washington, D.C. What specific qualities do you each bring to Arnold Ventures? Laura, what does John bring to the table? John, what are Laura's strengths?

LA | John brings a spirit of skepticism. We like to think that the only people who truly are successful here at Arnold Ventures are skeptics, because in philanthropy, most people are super nice and super optimistic, right? It's a spirit of goodness, a spirit of giving, which is a wonderful thing. But when you do the policy-related work that we do, you are faced with certain brutal realities, one of which is that most social programs don't work. Changing human behavior is super hard and much of what you try in terms of policy experiments doesn't really move the needle. So the challenge is to figure out which things do move the needle and why, and to be very clear that you should not devote resources to things that don't work. That discipline is very, very hard for a philanthropist, because it puts you in situations where you're often telling wonderful people, 'No. There's no evidence that your program works.' John keeps us anchored to the vision that we want to do good, but we will only do good if we invest in things that work.

JA | Most medical research doesn't work. Most venture companies don't work. Most policy ideas that we're working on aren't going to work. But you have to work on problems that are big enough and ideas that are scalable such that when you find something that *does* work, it has a real impact.

With Laura, I think we have a great complementary skill set. We look at issues from slightly different perspectives; we have different life and career backgrounds. Our approach to a problem or a proposal is a little bit different, so if it passes both our tests I think it's in a good place.

Beyond that, I'll default into getting deep into the weeds on the very specific technical aspects of a problem. Laura's great skill is understanding how the broader system works. Whether it's, *How does this foundation as an enterprise function day to day?* or *What should we be doing as a foundation to maintain relationships with policymakers?* She's always looking at things from a macro standpoint, where I'm very much micro.

Q | You signed The Giving Pledge created by Bill and Melinda Gates and Warren Buffett, which means you've committed more than half of your wealth to philanthropy or charitable causes. How do you communicate your values to your three children and also ensure that they will recognize the value of hard work?

LA | That's the core of parenting, right? Communicating your values. Making your children productive citizens and people who take pride in their work. We try to establish a standard of excellence in our home in terms of hard work and pairing that with empathy and humility. We do our best to give them context and to keep them grounded.

> "With pharma pricing, there is a consensus that there's a problem. There may not be a consensus on who the culprits are and what the solutions might be, but very few people would argue that the system is optimal."
>
> — LAURA ARNOLD

JA | Our intent has always been to give away 99 percent of our worth. What we want to give our kids is not a pile of cash, because when you look back, historically, that hasn't always led to the best results. What we're giving our kids is opportunity. We're able to use our resources to give them an amazing opportunity in life, so we have high expectations as to what they do with that opportunity.

Q | What are your kids interested in? Anybody want to be a hedge fund manager or a lawyer or a philanthropist?

LA | It's too early to tell. Our one daughter is an artist and an academic. The other two are very athletic and academic—more STEM-oriented.

JA | Our boy has already plotted his career. He's going to play professional baseball, then become the GM and then become the owner. He's 8. ■

Laura and John Arnold were interviewed by Pulse *editor Maggie Galehouse. The conversation was edited for clarity and length.*

Virtual Platforms Help Surgeons Plan Ahead

More thorough preparation means better post-operative results

By Cindy George

Innovation allows surgeons to virtually step inside the human body and prepare for complex procedures, from plotting the precise location of a brain tumor to exploring the intricacies of a child's malformed heart.

Before neurosurgery at Houston Methodist Hospital, physician Gavin Britz dons black wraparound goggles to strategize amid virtual reconstructions that combine CT scans, MRIs and surgical navigation into one 3D visualization platform.

He can start outside the patient's skull, pan inside an eye socket into the brain's soft tissue and locate a tumor amid the tangles of vasculature. Thanks to technology, the tumor appears fluorescent, which makes it easier to find.

The visualization platform, Surgical Theater, is used in about 50 medical centers and academic institutions around the world. Houston Methodist has the only system in Texas, according to Brady Culbreth, the company's Houston-based program lead. Houston Methodist paid about $800,000 for the technology, a hospital system spokeswoman said.

Using a representation of a patient's brain, Houston Methodist neurosurgeon Gavin Britz, MBBCh, MBA, MPH, demonstrates how he navigates the brain using 3D wraparound goggles and the Surgical Theater system.

Britz, a brain and tumor neurosurgery specialist who is chair of Houston Methodist's neurosurgery department, said his field is steeped in tech out of necessity.

"Fifty years ago, a patient presents with headaches. You know they have a tumor. You have to inject into the head or into the spine. You think the tumor is there. You have to operate on the patient not knowing. You think the tumor is on the left-hand side based on the examination. That's guesswork," he explained. "You go in the head and you're probably a couple of centimeters wrong. You can imagine the disaster. So, technology in neurosurgery has really made things safer and is a great equalizer."

For Britz and other neurosurgeons, 3D visualization is a major breakthrough.

"I can get within a few millimeters of where the tumor is," Britz said. "Just because I'm in Texas doesn't mean I'm a cowboy. You have to be a thoughtful surgeon. The more I plan pre-operatively, the better your results are post-operatively. Technology has allowed us to really understand the disease process—where it is and how you can approach it surgically."

The technology also transforms the patient experience.

According to the Ohio-based Surgical Theater, the visualization platform "allows patients and their surgeons to step into the patient's complex diagnosis and to walk together in a 360-degree, virtual reality reconstruction of the

> "Just because I'm in Texas doesn't mean I'm a cowboy. You have to be a thoughtful surgeon. The more I plan pre-operatively, the better your results are post-operatively. Technology has allowed us to really understand the disease process—where it is and how you can approach it surgically."
>
> — GAVIN BRITZ, MBBCH, MBA, MPH
> *Chair of the Houston Methodist department of neurosurgery*

patient's anatomy."

Britz, who has been using the immersion experience with patient anatomy scans for less than a year, said the technology has calmed the fears of patients while offering clarity about surgeries for them and their families.

"A patient terrified of the tumor puts on these goggles and sees what you're going to do," he said. "You can explain that something is going to be a problem because their motor fibers are right here and the tumor is completely engrossed and they can put the goggles on and they can see the problem. They understand what you have to do."

Step inside the heart

For some of the smallest patients, the complex issue is their hearts.

At Children's Memorial Hermann Hospital, pediatric cardiothoracic surgeon Jorge Salazar, M.D., can walk into a room-sized hologram of a young patient's heart prior to surgery and consult a 3D-printed, handheld replica of the child's organ.

Salazar, co-director of the Children's Heart Center at Children's Memorial Hermann Hospital, uses 3D patient-specific models and holograms for biventricular repair and conversions on youngsters whose families are often told that surgery isn't an option and that their children will need transplants when they go into heart failure.

"It's tricky to work inside the heart and to understand the three-dimensional relationships that are necessary to provide normal heart repairs for kids who essentially have a scrambled heart," Salazar said.

The surgeon combines the 3D information from CT, MRI and echocardiogram scans to formulate his surgical plans.

"We use all of those modalities to give us a comprehensive understanding of the heart's internal structures and their relationships to one another, and we are able to pre-plan and pre-map out the actual repair," he said. "With the 3D imaging, we can create 3D models that are both virtual and printed. Now, with the latest technology, we are able to create 3D models with the heart beating—so I guess that's 4D."

Sometimes, when a congenital condition has been complicated by previous surgery, Salazar and his team face additional challenges.

"We have to essentially take the whole heart apart, undo everything that had been done before and convert [it] to normal heart physiology and connections," said Salazar, who also serves as professor and chief of pediatric cardiovascular surgery at UTHealth's McGovern Medical School.

The technology is helping surgeons repair and rewrite young futures.

"We've done 14 conversions of children who were thought to be single ventricles, meaning 'half heart,' and they were thought to be locked into this future of having half a heart with not only restricted quality of life but with restricted longevity of life," Salazar said. "Many of these kids died or had a heart transplant before they got into their 20s. We've had 100 percent success in converting 14 of those children into normal hearts."

New TMC Program Will Streamline Clinical Trials

TMC Institutional Review Board will reduce need for duplicate approvals

By Ryan Holeywell

The Texas Medical Center launched a clinical research initiative this spring that will streamline research at multiple institutions, making the medical center an even more attractive place for industry partners.

The new TMC Institutional Review Board, part of the TMC Clinical Research Institute, will serve as the single "front door" for clinical trials conducted at multiple sites within the Texas Medical Center. This new protocol will minimize administrative complexity and maximize the opportunity for collaboration.

An Institutional Review Board, or IRB, is a committee that ensures clinical research is being conducted in an ethical way. All clinical research must be presented to an IRB before it can begin. Within the TMC, there are currently 29 IRBs, which means that researchers who want to conduct a trial at multiple sites may have to get IRB approvals from each site. Historically, obtaining IRB approvals from multiple TMC institutions can take up to two years.

But the TMC's new unified IRB will change that. Now, instead of going from organization to organization for approval, researchers can get approval from a single body that is recognized by all TMC members. The new program will speed the pace at which some clinical trials can launch in the Texas Medical Center, accelerating the development of lifesaving treatments.

The new, unified TMC IRB includes board members who are clinical experts working within the medical center, as well as Certified IRB Professionals from Western IRB, a commercial IRB with more than 40 years of experience reviewing protocols.

For researchers already on campus, a unified TMC IRB makes it easier to gain necessary approvals when they seek to collaborate with other institutions. It will also be a boon for startups and major companies who hope to take advantage of the vast patient population seeking care at TMC member institutions.

Experts say the TMC IRB could be especially useful for research on rare diseases, where there may be only a handful of patients scattered across Texas Medical Center institutions.

Bert Wilkins, of Western IRB, said the TMC IRB is most likely to be used for phase II and phase III drug trials. "It's far more efficient if you're dealing with an IRB once, instead of up to 29 times," said Wilkins, who serves as the TMC IRB chair. "The ability to tap into that environment and to make this a seamless process will increase the amount of research here."

The program will also grant researchers access to a more diverse set of patients, ensuring their results have broader impact, said Steven Kornblau, M.D., a professor in the leukemia and stem cell transplantation departments at The University of Texas MD Anderson Cancer Center who serves on the new IRB board.

The TMC IRB will also ease logistical challenges for researchers.

"If you're a pharmaceutical company, supervising one trial is less of a headache than supervising multiple trials in separate institutions," Kornblau said.

To learn more about how to work with the TMC IRB, please contact TMCClinicalResearch@tmc.edu.

CURATED

The Intersection of ARTS and MEDICINE

By Britni R. McAshan

Music has always helped humans through their darkest hours. At Houston Methodist Hospital, care providers on the inpatient behavioral health unit are using a sound dome—a directional speaker—to harness the healing powers of music and help patients through times of emotional distress.

Audrey Zybura, a board certified music therapist specializing in acute psychiatry, takes patients to the sound dome after they have created a personalized playlist. While one might assume the songs on the patients' playlists are airy melodies and soothing lullabies, Zybura says it is quite the opposite.

"The playlists are 100 percent patient-selected and patient-preferred music, so there are often heavy metal and rap songs on these playlists," she said. "No matter what Spotify wants us to believe, there is not one type of music that is relaxing."

The behavioral health unit at Houston Methodist, which can house up to 19 patients at a time, treats individuals who are suicidal, aggressive or otherwise unable to take care of themselves.

"These conditions can range from severe depression, an actual psychotic disorder like schizophrenia, or a mood condition like bipolar disorder," said Corinna Keenmon, M.D., medical director of the unit. "Sometimes it might not be about the condition, but it is the circumstance—maybe they lost their job or have a breakup or experience the death of a loved one. Those moments of emotional crisis can produce the same safety problems."

Music therapists like Zybura offer patients a non-pharmaceutical approach to regulating their emotions.

Zybura works with patients on musical self-awareness, using the music they already respond to in ways that are helpful and positive.

"The music selections line up with the emotional process that the patient has outlined with me and the music that they connect with most," she said. "I always recommend using music you wouldn't press skip on. If you are in a moment that you really need something specific from the music, you don't want to rely on the unpredictability of the radio or the next thing that comes up on the shuffle."

Once Zybura and the patient have compiled a list of seven songs—enough for about 30 minutes of play time—the patient can listen to the playlist through the sound dome, located in the day area of the unit, without disturbing anyone else. The sound dome creates audio isolation, offering an intimate listening experience similar to wearing headphones. Those outside the dome can't hear the music; those inside hear the music only, without the disruption of background noise.

"This gives our patients a tool they can control," said Keenmon, who also serves as an assistant professor of psychiatry and behavioral sciences at Baylor College of Medicine. "Once they have made their playlist, we help them identify when they are feeling emotionally triggered and when they sense that coming on. They can use that station at any time, day or night. It is fully open to them and it allows the nursing staff to monitor for safety and make sure the tool is helping—not making the patient more emotionally distressed."

Music therapists, she added, are the engine behind the sound dome's success.

"Our music therapists are so talented and so skilled," Keenmon said. "To be able to take somebody from a moment of crisis and create something beautiful out of it is remarkable." ■

Music therapist Audrey Zybura sits under the sound dome at Houston Methodist Hospital.

1 | **ED EMMETT,** former Harris County judge, speaks at the Salute to Volunteers Awards Luncheon, held annually by the Texas Medical Center Volunteer Services Council. The luncheon honors the volunteers who donate their time to make a difference in the lives of patients, visitors and workers across the TMC campus.

2 | PARTNERS, an organization dedicated to supporting the **CIZIK SCHOOL OF NURSING AT THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON (UTHEALTH),** raised more than $160,000 to advance the school's nursing education and research programs at a recent luncheon. Guests and participants included Paula Cizik, master of ceremonies Ernie Manouse, Sippi Khurana, M.D., Kelli Cohen Fein, M.D., Jan Cizik, Carolyn Jones and Jane Cizik.

3 | **JAMES VERSALOVIC, M.D., PH.D.,** professor of pathology and immunology at Baylor College of Medicine and director of the Texas Children's Microbiome Center, has been elected to fellowship in the American Academy of Microbiology.

4 | **YOHANNES T. GHEBRE, PH.D.,** associate professor of radiation biology in the department of radiation oncology at Baylor College of Medicine, has been nominated by the National Institutes of Health Center for Scientific Review to serve as a member of the Lung Injury, Repair and Remodeling Study Section.

5 | **MICHAEL E. DeBAKEY HIGH SCHOOL FOR HEALTH PROFESSIONS** was ranked the No. 3 high school in Texas and No. 17 high school nationally by *U.S. News & World Report*, the global authority in education rankings. This year's report evaluated more than 17,000 schools nationwide.

6 | Memorial Hermann's Circle of Life gala drew 1,300 guests and raised $8.25 million to benefit **MEMORIAL HERMANN TRAUMA AND CRITICAL CARE SERVICES.** Ann and Clarence Cazalot were honored at the gala for their continued leadership and generosity to Memorial Hermann through the years.

Credit: Nos. 3, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15 courtesy photos; No. 2, Priscilla Dickson; No. 8, Dwight C. Andrews


7


8


9


10


11


12


13


14

15

7 | **CHERILYNN R. SHADDING, PH.D.,** has joined the MD Anderson Cancer Center UTHealth Graduate School of Biomedical Sciences as associate dean for diversity, career development and alumni affairs.

8 | **DAVID SANDBERG, M.D.,** the Dr. Marnie Rose Professor in Pediatric Neurosurgery, a professor in the Vivian L. Smith Department of Neurosurgery at UTHealth and director of pediatric neurosurgery at Children's Memorial Hermann Hospital, has been awarded the 2019 American Association of Neurological Surgeons Humanitarian Award.

9 | **DIANNA M. MILEWICZ, M.D., PH.D.,** the President George H.W. Bush Chair of Cardiovascular Medicine, director of the division of medical genetics and vice-chair of the department of internal medicine at UTHealth, received a $1 million American Heart Association Merit Award.

10 | **W.H. "BILL" EASTER III** has been appointed chair-elect for the Memorial Hermann Health System Board.

11 | Frank Vazquez, medical center director at the **MICHAEL E. DeBAKEY VA MEDICAL CENTER - HOUSTON,** cuts a ribbon to celebrate the opening of the new VA mental health building at 2002 Holcombe Blvd.

12 | **JOSEPH JANKOVIC, M.D.,** professor of neurology, distinguished chair in movement disorders and director of the Parkinson's Disease Center and Movement Disorders Clinic at Baylor College of Medicine, received a Lifetime Achievement Award from the International Neurotoxin Association.

13 | The University of Texas Medical Branch at Galveston named **TIMOTHY HARLIN** executive vice president and chief executive officer of the UTMB Health System.

14 | More than 230 guests attended the annual gala benefiting the **JAN AND DAN DUNCAN NEUROLOGICAL RESEARCH INSTITUTE AT TEXAS CHILDREN'S HOSPITAL,** raising $500,000. Among the attendees were Cynthia Petrello, Huda Zoghbi, M.D. and gala founders Barbara Feigin and Mike Feigin.

15 | Pediatric patients at **CHILDREN'S MEMORIAL HERMANN HOSPITAL** took part in a Spring Celebration Egg Hunt at Fondren Park, hosted by performers from *Disney On Ice presents Mickey's Search Party*.

Do you have TMC photos you would like to share with *Pulse*?
Submit high-resolution images to: news@tmc.edu

June 2019

6/6

TMCx Demo Day

Digital Health

Thursday, 1 – 8 p.m.

TMC Innovation Institute

2450 Holcombe Blvd., Suite X

Register at eventbrite.com

mfier@tmc.edu

713-791-8846

6/10

Nursing Information Session

Monday, noon – 1 p.m. and

5:30 – 6:30 p.m.

Prairie View A&M University

College of Nursing

6436 Fannin St., Room 135

fdsmith@pvamu.edu

713-797-7000

6/11

Rice University Farmers Market

Tuesdays, 3:30 – 6:30 p.m.

Rice University

Parking lot entrance 13B

5600 Greenbriar Dr.

ricefm@rice.edu

6/18

WindSync

Wind quintet performs

Tuesday, noon

Crain Garden

Houston Methodist Hospital

6565 Fannin St.

mjgallop@houstonmethodist.org

346-238-5351

KEEP YOU MOVING

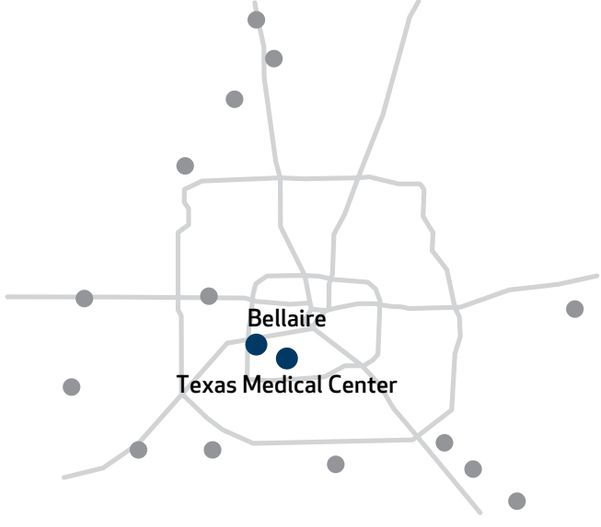
without joint pain

Live life without joint pain.

At Houston Methodist Orthopedics & Sports Medicine, we know that joint pain affects every part of your life. With treatment plans customized for you, our specialists offer a full range of advanced nonsurgical and surgical techniques, including:

- Innovative pain control methods
- Physical therapy to improve mobility and range of motion
- Latest technology, including minimally invasive surgical techniques
- Presurgical education programs for joint replacement

We can help you find relief from joint pain — so you can keep moving.



HOUSTON Methodist®
ORTHOPEDICS & SPORTS MEDICINE

Schedule an appointment:
houstonmethodist.org/jointpain
713.441.9000

Vanderbilt
West University, $4.6+ mil.
Cathy Blum, 713.320.9050

Inwood
River Oaks, $3.5 mil.
Cameron Ansari &
Teresa Byrne-Dodge, 713.942.6811

Westchester
West University, $3.3+ mil.
Cathy Blum, 713.320.9050

Troon
River Oaks, $3.2+ mil.
Cameron Ansari &
Teresa Byrne-Dodge, 713.942.6811

Terwilliger
Briarcroft, $3.1+ mil.
Colleen Sherlock, 713.858.6699

Hunters Park
Hunters Creek, $2.7+ mil.
Colleen Sherlock, 713.858.6699

GREENWOOD KING

3201 KIRBY DRIVE / 1616 S. VOSS RD., SUITE 900 / 1801 HEIGHTS BLVD. HOUSTON, TEXAS

a place to find your home

LUXURY PORTFOLIO INTERNATIONAL®

Leading REAL ESTATE COMPANIES OF THE WORLD®

Aberdeen Way
Braes Heights, $2.4+ mil.
Jan Yardley, 713.882.1885

Marquette
West University, $2.2 mil.
Sharon Ballas, 713.822.3895

Berthea
Rice/Museum District, $1.9+ mil.
Tim Surratt, 713.942.6830

Nottingham
West University, $1.9+ mil.
Rachel Rosson, 713.256.4167

Harvard
Heights, $1.4+ mil.
Amanda Anhorn, 713.256.5123

Robinhood
Rice/Museum District, $560s
Amy Johnson, 832.541.4805