

INSIDE SPRING 2015

3 NewYork-Presbyterian Receives Accreditation for Pediatric Rehabilitation Medicine Fellowship

4 Resident News and Notes

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Innovating Robotic Technologies for Patients with Neural Impairments

Sunil K. Agrawal, PhD, Professor of Rehabilitation and Regenerative Medicine at Columbia University College of Physicians and Surgeons and Professor of Mechanical Engineering at the Fu Foundation School of Engineering and Applied Science at Columbia University, knows all too well the difficulties faced by individuals with neural impairments. “Having seen close family members suffer from Parkinson’s disease, I have observed, firsthand, the debilitating effects of neurological disorders on gait and motor functions,” says Dr. Agrawal, who has devoted his career to developing innovative robotics technologies to help adults and children move more easily or retrain their bodies to regain lost function.

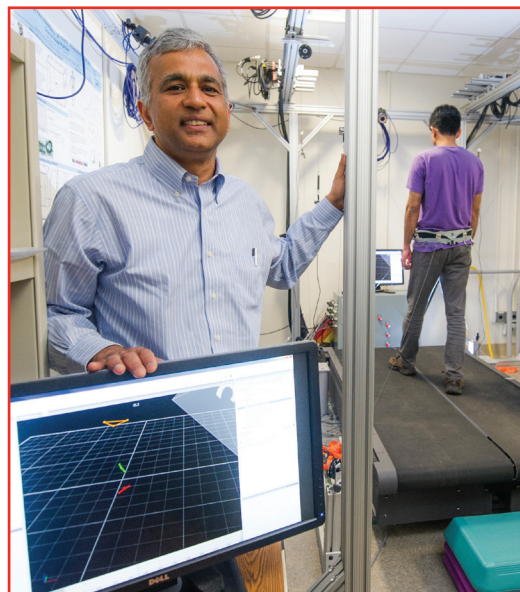
Dr. Agrawal, who is also the Director of the Robotics and Rehabilitation Laboratory (ROAR) and the Robotics Systems Engineering Laboratory (ROSE) at Columbia, pursues pioneering investigations in robotic exoskeletons and robotic interfaces. Prior to joining Columbia in 2013, Dr. Agrawal was a Professor of Mechanical Engineering and Director of the Mechanical Systems Laboratory and Rehabilitation Robotics Laboratory at the University of Delaware. His extensive research has resulted in 10 new U.S. patents in the last five years, with half a dozen additional applications under review. His work in rehabilitation robotics is frequently cited by the research community.

“Robots can be similar to training wheels on a bicycle. They help the user gain proficiency in function until their support is no longer needed.”

— Dr. Sunil K. Agrawal

Research in Dr. Agrawal’s laboratory has helped advance the science of robotic interfaces and exoskeletons. These devices are powered by motors that supplement the forces provided by the muscles and interact with the wearer to help retrain their neuromuscular systems.

“I’m a robotics engineer by training,” says Dr. Agrawal. “Neural disorders limit a person’s



Dr. Sunil K. Agrawal

ability to do things that we all take for granted: reach and raise our arms, walk, and perform activities of daily living. My research is aimed at helping these people accomplish everyday tasks. Having the ability to go to the store or the park and move around as we please is an integral part of our value system. Stroke sufferers are hesitant to cross the street because they are typically slow walkers. They have to worry about losing their balance and falling.”

Over the past decade, Dr. Agrawal and his team, with support from the National Institutes of Health and National Science Foundation, have been pursuing the development of different robotic exoskeletons that individuals could wear with the goal of regaining their walking function. In addition, they are developing appropriate motor learning algorithms within the robot controllers.

“Not only do our subjects learn to walk faster, but they have a more confident stride and balance,” says Dr. Agrawal. “We not only train them in the laboratory, but we assess them at one month, three months, and six months to see if the functions they’ve regained after robotic training translates to

(continued on page 2)

Innovating Robotic Technologies for Patients with Neural Impairments (continued from page 1)



Dr. Sunil K. Agrawal with the Tethered Pelvic Assist Device

their home environment. In many cases, we find that they continue to improve after they've had training."

Technologies that Change Lives

Dr. Agrawal is an inventor of wire-driven arm and leg exoskeletons that can help train limb movements. He has also designed robots that help infants and toddlers as young as six months learn to be mobile in their environment. "I have seen how the robotics technology can change lives," he says.

Pointing to the asymmetrical gait of a person with a neural disorder, Dr. Agrawal explains, "When they are walking, they put more time on the healthy leg during the walking cycle and immediately get off the weak leg. This strategy works for them; however, it's a very unstable way of walking. This makes them more susceptible to falls. If you are placing your body weight on one leg during walking, the other side becomes weaker and will become weaker over time. And the side with excessive load will develop issues such as arthritis."

To address this, Dr. Agrawal and his colleagues have developed the Tethered Pelvic Assist Device (TPAD), a cable robot for studying force adaptation in human walking by applying external forces and moments on the human pelvis. "This device has a belt worn at the pelvis," says Dr. Agrawal. "Several wires are attached to the belt and each wire is controlled by a motor, which regulates tension in the wires. The tensions in the individual wires produce a net external force on the pelvis that influences walking. We can direct this force upwards, downwards, and even sideways to mimic different loading situations."

Dr. Agrawal and his team have been testing TPAD on stroke patients. "The resulting force from these wires is applied along the direction of the weak leg," he says. "Instead of the individuals walking on the stronger side, they are now forced to put more weight on the weak side."

A training session lasts about 40 minutes. "Once the wires are taken off and the force is not present, the person tends to walk more symmetrically," says Dr. Agrawal. "The hypothesis is that after training over multiple sessions, there is going to be a lasting effect. We've performed studies on stroke patients in a single session and are now in the process of tabulating these results. This is giving us preliminary data to prepare a multi-session training study."

"One of the key advantages of these technologies is their adaptability," says Lauri Bishop, PT, DPT, Research Physical Therapist, Department of Rehabilitation and Regenerative Medicine, Columbia University Medical Center. "We can use the TPAD and other devices as platforms to test our clinical hypotheses, and then easily modify the operation of the devices based on the results. I believe as clinicians and engineers work hand-in-hand, we can rapidly develop technologies to make a difference in patients' lives."

Finding the Right Balance

Dr. Agrawal's group is also involved with TPAD in another study that looks at training of elderly fallers using repeated perturbations with TPAD. This study is funded by the Robert N. Butler Columbia Aging Center. In addition, they are about to begin a pilot study using TPAD on children with cerebral palsy. "A lot of children with cerebral palsy are toe walkers," says Dr. Agrawal. "They may have a weak side, but some of them walk on their toes for both legs. We are currently evaluating a strategy that involves applying a downward force that is borne by both the weak leg and the strong leg to see if they can be deterred from walking on their toes."

In the future Dr. Agrawal believes that novel leaps in the field will come from multidisciplinary collaborations with colleagues with expertise in different fields working together on a common problem. "We're also starting to think more quantitatively using sensors built into robots," he says. "Robotics can provide a way of making comparisons to see if a certain treatment is making a difference and in what direction this treatment is leading us to."

Adds Dr. Agrawal, "Rehabilitation medicine has been around for a hundred years or so, but machines and robotics can be used now in innovative ways to study these problems and this can make a tremendous impact on healthcare."

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NewYork-Presbyterian Receives Accreditation for Pediatric Rehabilitation Medicine Fellowship

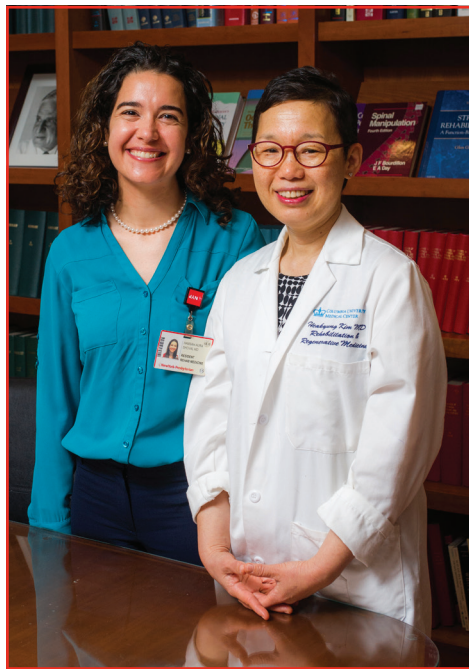
With only some 250 pediatric rehabilitation medicine specialists in the country, it comes as welcome news that NewYork-Presbyterian Hospital will help to increase that number with the establishment of its newly accredited Pediatric Rehabilitation Medicine Fellowship, which is co-sponsored by Blythedale Children's Hospital in Valhalla, New York. The two-year program, which has been accredited by the Residency Review Committee for Physical Medicine and Rehabilitation, under delegated authority of the Accreditation Council for Graduate Medical Education, commences July 2015 with **Hannah Aura Shoval, MD**, as its first fellow.

"We have always had residents who wanted to receive further training here," says **Heakyung Kim, MD**, Chief, Pediatric Physical Medicine and Rehabilitation at NewYork-Presbyterian/Morgan Stanley Children's Hospital, and Chief, Pediatric Physiatry at Blythedale Children's Hospital. "Now with our fellowship program we can provide that training. There aren't enough pediatric physiatrists in communities in other states to work with children with special needs. This program is very important in that regard."

Dr. Kim believes that the shortage of physiatrists throughout the country is due, in part, to a lack of understanding in the medical community of the important role the field plays. "In general, physicians are not educated about physical medicine and rehabilitation in medical school and have little interaction with the rehabilitation doctors as residents," she says. "However, once they get to know what physical medicine and rehabilitation provides for patients, they understand that we can really help improve their care."

Dr. Kim points out that physicians naturally focus on their own specialty and perhaps are unaware of the contributions that physiatry makes to the care of patients throughout the hospital. "This is a great opportunity for us to work with all of the different pediatric departments throughout NewYork-Presbyterian," says Dr. Kim. "We see the patient as a whole person, not just the physical aspect, but the psychological, medical, and social parts of their life as well. It's also a unique field in that we are involved in every specialty, such as oncology, orthopedics, and trauma. If something happens to the patient there are always consequences of physical difficulty, but there are also psychological or cognitive difficulties or dysfunction that come together. We take care of that. The acute medical team can certainly take over disease or acute medical problems, but after that they don't need to worry about what is going to happen to the patient. We take over and care for them to the end and then send them back to their communities."

The aim of the NewYork-Presbyterian fellowship program is to educate and prepare skilled clinicians to pursue successful careers in pediatric rehabilitation, while learning in an environment



Dr. Hannah Aura Shoval and Dr. Heakyung Kim

that is both comprehensive and tailored to the individual. The Hospital's faculty of outstanding clinicians are committed to helping fellows develop skills related to patient evaluation, management, and data collection and interpretation. Fellows receive physical medicine and rehabilitation training for children and adolescents with cerebral palsy, spina bifida and other neural tube defects, brain injury, spinal cord injury, neuromuscular disease, genetic syndromes, musculoskeletal injuries, rheumatic disease, and chronic pain.

The clinical experience is wide-ranging, encompassing inpatient and outpatient training, with rotations at Blythedale Children's Hospital.

"There aren't many accredited pediatric rehabilitation programs in the United States, and there is a huge need for pediatric rehabilitation," says Dr. Shoval, who is just completing residency training in Physical Medicine and Rehabilitation at NewYork-

Presbyterian. "Accreditation is critical for me because it will allow me to do what I'd like to do in the future, especially if I want to pursue academics. I want to be a competitive applicant, and part of that is having accredited fellowship training."

Dr. Shoval looks forward to receiving broad exposure to other pediatric specialties in her training throughout the Hospital. "The rehabilitation piece is so important to maximize the impact and ensure the success of medical or surgical interventions provided to children," she says. "This fellowship will provide me with great experience in the clinical setting, as well as in research."

Dr. Shoval understands the demands of the field, especially the ability to direct all aspects of a patient's care. "There is a lot of coordination between physicians, managing multiple medications, as well as understanding family and social dynamics – but it's needed," she says. "Many of the physicians know that patients who go through rehabilitation do very well. That's also their goal for their patients, so we are all on the same page."

As she begins her fellowship training, Dr. Shoval is grateful for the support and encouragement she has received from physicians and staff. "I have so many doors open right now and there are so many opportunities for learning," she says. "The attending physicians I have spoken to have been very welcoming and also want to involve me in their research. I feel like I literally have the whole world in front of me."

Dr. Shoval says she is certain she has picked the right specialty for herself where she will be able to really help patients. "At the end of the day you want to feel like you've made a difference," she says, "and I will."

For More Information

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Resident News and Notes



Dr. Rachel A. Welbel

Kudos to **Rachel A. Welbel, MD, PGY-2**, who recently came to the assistance of a man she discovered bleeding and unconscious on a New York City subway platform. Dr. Welbel assessed him, found him in cardiac arrest, and initiated CPR. The

Emergency Medical Service eventually arrived and brought him to the Emergency Department at NewYork-Presbyterian/Weill Cornell Medical Center. "There is no question in my mind that Rachel saved this gentleman's life," notes **Nasim Chowdhury, MD, PGY-3**. "Though her humility will probably cause her some embarrassment, I wish to extend my respect and admiration for Dr. Welbel."



Team NYP members Megan A. Frantz, MD, Michael Saulte, DO, Vincent F. Miccio, MD, and Hannah Aura Shoval, MD, are surrounded by faculty and other residents who cheered them on during the Rehab Bowl.

Congratulations to **Team NYP** for winning the coveted **2015 Resident Rehab Bowl Championship**, an annual competition sponsored by the New York Society of Physical Medicine and Rehabilitation for residents from hospitals in the New York metropolitan area. Questions were based on the third edition of *Physical Medicine and Rehabilitation Board Review* by Sara J. Cuccurullo, MD. In addition, Team NYP took home the Spirit Award for the second year in a row.