



TY BAE PUSHES THE ART
AND APPLICATION OF
COMPUTER-AIDED DIAGNOSIS
BY ELAINE VITONE

VISUAL THINKER

In the 1960s, Korea's postwar capital city swelled with a baby boom and an influx of displaced farmers from the countryside. At one point, a grade school in Seoul was said to have 12,000 students, more than any other on the planet. The children of this rapidly industrializing city often left the classroom for the factories at age 12—that's as far as public education went. There was no roll call. Teachers used a map of the desks to track attendance, each child represented by an assigned number.

PHOTOGRAPH | JIM JUDKIS

Kyongtae (Ty) Bae is an engineer-cum-radiologist-cum-artist. (He's shown here with some of his own paintings.) The visual thinker is now helping other docs decipher the intricate detail revealed by current medical imaging technology (which he helped improve).

Number 98 was Kyongtae Bae.

Against the odds, young “Ty” would excel at his studies. His family could not afford to send him to middle school—Ty Bae is the sixth of eight children, and his father had died when he was a teenager. But merit scholarships enabled him to ultimately become the first in his family to earn a bachelor’s degree (from Korea’s prestigious Seoul National University).

After he graduated, the Baes immigrated to Los Angeles. For a year, Bae worked three jobs—through the days, evenings, and weekends—pumping gas and mopping floors, earning minimum wage.

“Like any other immigrants, we had to adjust to the system. We had no money. We had borrowed to pay our airfare,” he says on a recent fall afternoon, standing at his desk (sitting isn’t really his style) in UPMC Presbyterian South Tower, where he now heads the University of Pittsburgh Department of Radiology, among the largest academic radiology departments in the world.

In L.A., Bae longed to return to academia. He had a chemical engineering degree and wanted to use it. He contacted a professor he knew at the University of Iowa and asked for a reference letter for graduate school. The professor told him to forget the letter and offered him a graduate position.

Bae had always wanted to invent something. Early on, he seemed to understand that if you want to bring something new to a field, it helps to be able to approach it from multiple disciplines. He calls this “learning new languages.” He earned a master’s degree in chemical engineering while holding down a research job in the biomedical engineering department—to prepare himself for a PhD in that field, and then, ultimately, med school.

“As an engineer I’m trained to solve problems,” says Bae. “But I know it’s equally important, if not more important, to define the good problem. Without that, you end up getting a solution you don’t really need.”

“I figured medicine is the engineering of biology.”

As a med student, Bae worked in the University of Chicago’s Rassman Lab, a player in the then-nascent field of computer-aided diagnosis. These early programs aimed to help physicians flag problem areas in 2-D imaging scans like X-rays and mammograms. But Bae’s PhD from the University of Pennsylvania had given him the training needed to take things a step further, into 3-D, using CT scans. “So that’s what I did,” he says. “It was sort

of my pet project. I was working weekends and evenings making a computer program.” This “pet project,” which kept him crafting code through many nights, would result in his first patent; it was filed in his second year of medical school. In 1994, he published the first paper on computer-aided diagnosis of pulmonary nodules from CT images.

It was becoming clear to Bae that radiology was the ticket for him. It married two of his skill sets, technology and medicine. Plus, he was a born visual person. (Laughing, he admits to not having much of an ear for the stethoscope.) He has an art studio at home, and his oil paintings and color photographs adorn the walls of his department. (“I think maybe they are tolerating them because I am

“I figured medicine is the engineering of biology.”

chair,” he says with a smile.) He might have pursued an MFA if it had been less of a financial gamble.

In 1992, as Bae began his residency at Washington University in St. Louis, computed tomography had just taken a giant step forward with the invention of the helical CT scanner. Previously, to create individual cross-section images of the body, the X-ray beam and its sensors were mounted to hardware that made a 180-degree arc across the patient, then paused to allow the patient gurney to move ever so slightly in preparation for the next pass. With the helical model, the scanner and patient could both move simultaneously and continuously, the beam moving through the patient like a spiral slicer through a ham.

“It used to take several minutes to scan a body. You would inject the contrast, wait and have a coffee break, then come back and do the scan. Now it would take seconds. Because the scanner is faster, you get much better quality if you hit it right. But if you miss it, you won’t get good quality.”

Curious about how he might improve upon scanning technology and dynamic contrast agents, he decided to study the literature on the subject. He found little in this new field. Here was a good problem.

Bae’s engineering brain kicked in: You have the blood vessels and organs, and the input moving through them—the contrast agent. Depending on how you move your input through, you get a different product—the

images.

“To me it was like a factory,” he says.

Bae enrolled in a class to brush up on physiology, then conducted a series of experiments on pigs, working out the effect of different rates of IV-contrast input on different rates of cardiac output. Once again burning the midnight oil in his free time, he created a mathematical model that takes all of the variables into account—the patient’s height, sex, weight, age, etc.—and projects how best to image each organ of the body. (After 15 years of work in the field, in 2010 he published a landmark article in *Radiology* describing the state of CT intravenous contrast medium and timing technology.)

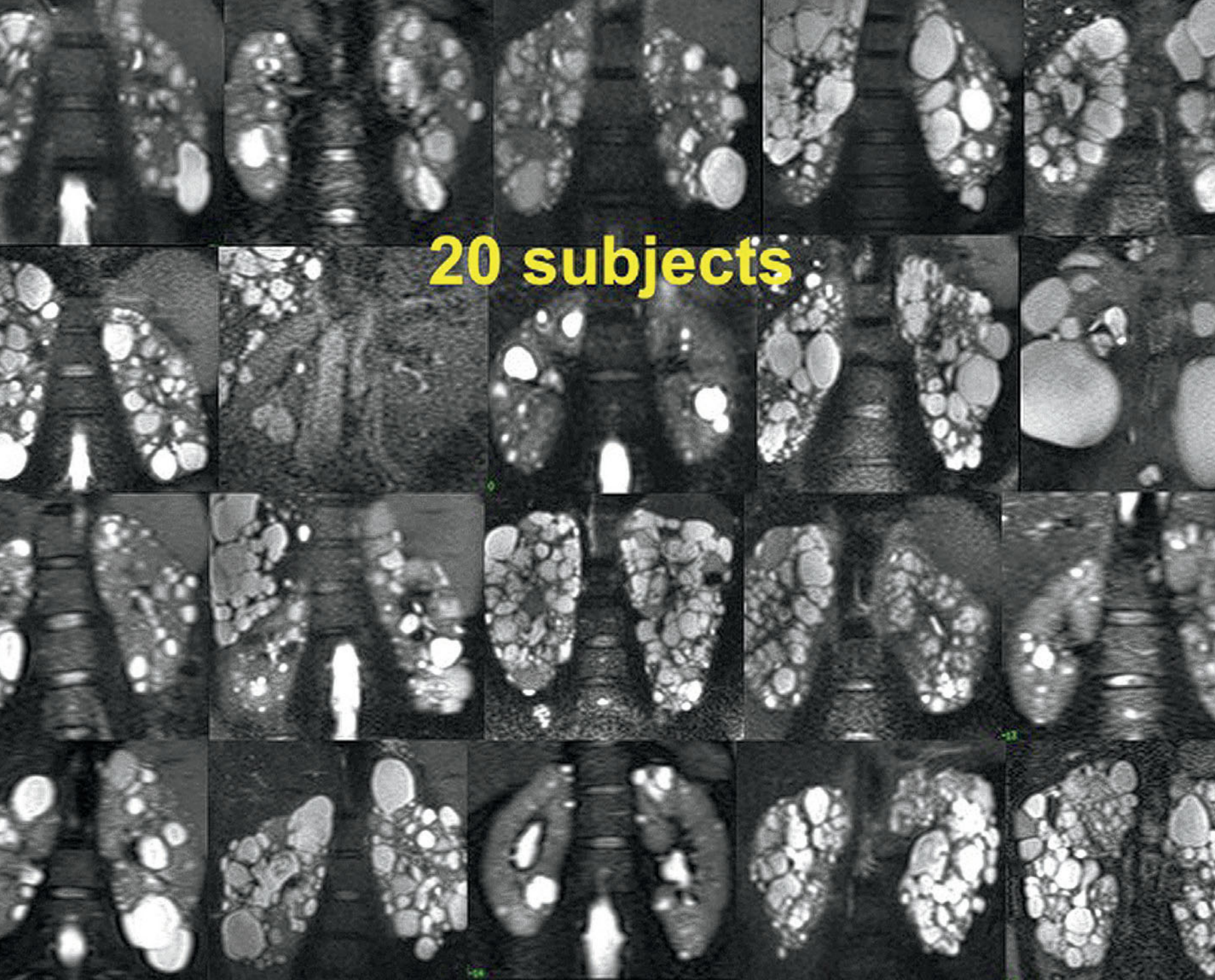
While Bae’s methods weren’t universally

adapted, they did get people thinking about how best to use the tools that were available to get the most detailed information, says Vamsi Narra, professor of radiology at Washington University, who trained alongside him there. “Just like Google was the one that started people thinking about indexing. ... I see things coming out now as an offshoot of [Bae’s] work.”

Bae was invited to join the faculty at Wash. U. and stayed for eight years. Then, in 2006, he joined the University of Pittsburgh as visiting professor of radiology and bioengineering, bringing several of his research endeavors with him. Three years later, he became chair.

It’s an exciting time to be in radiology, Bae says. He reaches over to his computer and opens presentation slides (he’s on the international radiology circuit), comparing the first CT scan from 1972—a single, grainy, gray slice of the brain that took 20 minutes to scan—to the staggeringly intricate 3-D renderings that take seconds to conjure up today. Now we can scan the entire body, head to toe, in less than a minute and scrutinize any organ from any angle. We can spot disease where it lives, as well as aberrations not yet causing any symptoms whatsoever.

Therein lies the rub, and Bae’s next big problem to solve: Yes, we can see the body in stunning detail, but ... now what? At Pitt’s Imaging Biomarker Lab, which Bae directs, he and his colleagues are decipher-



20 subjects

Half of patients with polycystic kidney disease progresses quickly to renal failure, while the other half “is doing fine,” says Bae. Using algorithms on measurements of cyst volume, distribution, density, and other characteristics, he has developed a tool to help doctors determine which path a patient is likely to take.

ing what to do with the massive amount of information that comes with each new imaging technology. They’re looking for new imaging biomarkers—visual indicators of diseases—and also evaluating how best to use the biomarkers that are already known.

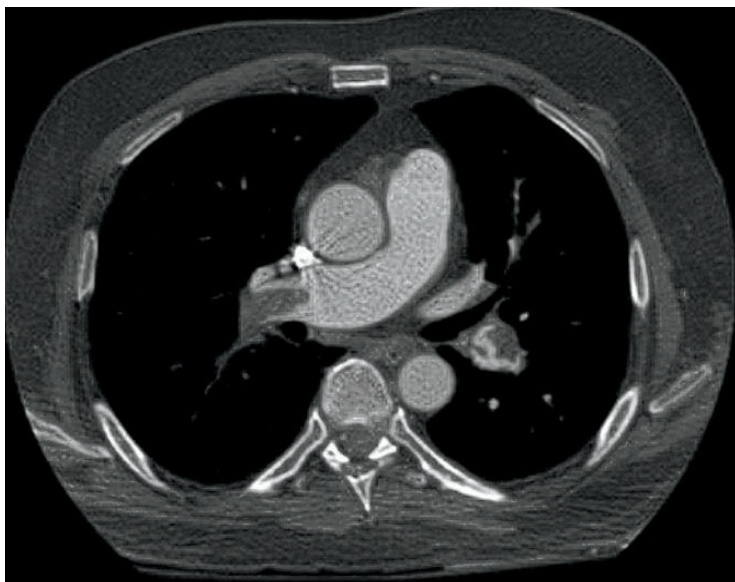
For the past 12 years, one focus of Bae’s research has been polycystic kidney disease (PKD). Characterized by a plague of fluid-filled cysts in the organ, PKD can cause back pain, high blood pressure, and urinary tract infections. And, for about half of these

patients, the cysts eventually overtake the organ and cause renal failure. “But the other half [of the patient population] is doing fine,” says Bae. Right now we have no way to tell at the onset who’s going to be a rapid progresser, and who’s going to be okay.

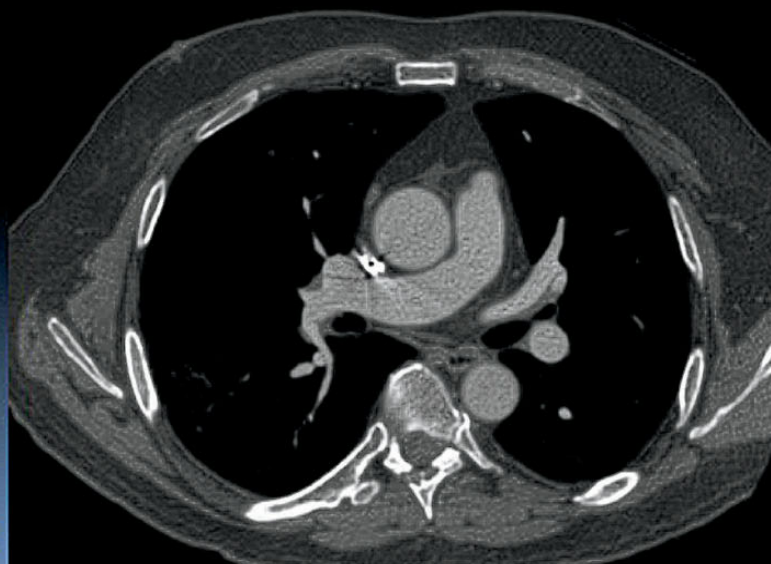
In 1999, the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) formed the Consortium for Radiologic Imaging Studies of Polycystic Kidney Disease (CRISP), a 10-year prospective study. As chief radiologist and PI of the data center for the

study, Bae has been analyzing MR images from sites across the country and developing algorithms that use these images to calculate the volume, distribution, density, and other characteristics of cysts. He’s finding patterns, linking various characteristics of disease progression with their outcomes, and developing a prognostic tool. And in recent years, a spinoff study funded by the NIH has been putting this new tool to the test. Dubbed “Halt PKD,” the ongoing trial applies what has been learned to improving treatments.

Bae is working on similar projects for pulmonary embolism, emphysema, osteoarthritis, lung cancer, prostate cancer, breast cancer, Parkinson’s disease, brain tumor perfusion,



BASELINE



FOLLOW-UP
COMPLETE RESOLUTION

COURTESY BAE LAB

Mark Roberts and Bae are finding that not all pulmonary embolism clots are created equal. The two are developing CT biomarkers to distinguish which patients need less anticoagulant, a potentially dangerous medication. Here, a pulmonary embolism (left) is completely resolved in the follow-up scan two months later.

and multiple sclerosis, as well.

Mark Roberts, MD professor and chair of the Department of Health Policy and Management in the University of Pittsburgh Graduate School of Public Health, calls Bae forward thinking. “I have been involved in some other projects back in Boston, where I came from, where there was this incredible urgency to find the most accurate test, the most robust test—not the impact of the test on decisions doctors were making in real patient care. I personally find that what’s atypical about Dr. Bae is he’s not just a radiologist; he’s a doctor first. What he cares about is how the diagnostic tests he’s using affect patient outcomes.”

Roberts is collaborating with Bae on a CT biomarker project involving pulmonary embolism—blood clots gone rogue.

He explains: When you have an injury, several processes kick in at roughly the same

time. The clotting process, which stops the bleeding; the repair system, which heals the vessel; and the clot-dissolution system, which eats the clot away from the inside out as the vessel heals so that the normal diameter of the vessel remains intact.

Here’s the problem: The body’s strongest signal to produce clot is . . . the presence of a clot. And in the case of a pulmonary embolism, unfortunately, the clot didn’t get there in the first place because it was needed (because the lung is bleeding); the clot got there because it formed elsewhere, somehow became dislodged, and then traveled to this most precarious spot. Yet there it is, stuck and sounding alarms—which, in spite of their best intentions, could cause further clotting that could choke your lung and kill you.

Docs do not take pulmonary embolism lightly. Right now, an extended course of anticoagulants is recommended for all

cases—though exactly how extended, no one can agree. Some say six months, others nine, and still others a full year.

Mind you, anticoagulants don’t dissolve the clot in your lung. They just allow your clot-dissolution process to catch up and prevent further clotting activity. Disabling your body’s clot production for months on end comes with its own risks. (You do not want to cut yourself while you’re on these meds.)

Bae is applying his algorithms to pulmonary-embolism CTs scanned at sites across the country. The tool has increased the team’s ability to predict outcomes by a “non-trivial,” says Roberts, 10 to 15 percent.

With Pitt’s Donald Yealy, professor and chair of emergency medicine, and others, Bae had submitted a new clinical trial proposal to the National Heart, Lung, and Blood Institute; that study will attempt to answer the nagging question of how long these patients should be given anticoagulants. The answer, they suspect, is: It depends. They’re building data stores to prove that not all clots are created equal;

and, therefore, they do not all require the same treatment. In fact, the researchers believe some clots are probably so small they don't need treatment at all.

This is one of the reasons Bae's work is so exciting, Roberts says. "Most of the recommendations we have about diagnostic testing and treatment are pretty blunt. We have to understand ways of making them more tailorable, more personalizable. I think his work can help us do that."

In doing so, Bae's research also stands to help bring down health care costs, improve

patients and runs a very large department. (In addition to 220 clinical and research faculty members, it's academic home to 57 residents and 28 fellows at last count.) Bae is an engaged leader, frequently meeting one-on-one with mentees and reviewing grant applications and manuscripts for junior faculty members. In his relatively short time here, he has overseen the hiring of more than 30 new faculty members.

And in his spare time, just for kicks, he's learning Chinese.

None of this surprises Narra, who likens his friend to "some kind of movie hero."

whelmed, or he's busy. Never! You say, 'Ty, I hear you got this [grant application] out,' and he says, 'Yeah, we took care of it. There was a problem, and we got it out, and we got a paper, and yeah, I got a \$5 million grant from the NIH.' And it's all in the past tense!"

Bae, who, after a two-hour interview still has yet to make use of a chair, shrugs it off.

"For me, working hard is no big deal." He wonders aloud whether his drive stems from being one of eight kids and always wanting to distinguish himself by creating something all his own. Having the chance to do so here in

Bae's next big problem to solve: Yes, we can see the body in stunning detail, but ... now what? He and his colleagues are deciphering what to do with the massive amount of information that comes with each new imaging technology.

reliability and consistency in what happens with diagnostic imaging, and ultimately help patients recover faster.

But research is just one of the plates Bae is spinning at any given moment.

This is a guy who has 10 patents to his name, has secured more than \$16 million in NIH grants in the past 13 years, and still sees

(Apropos of nothing, he mentions that he has seen Bae, who is a lifelong student of martial arts, do thumb push-ups. And one-legged squats.)

"Ty is one of the most brilliant guys I've come across. And he's not only bright, but he also has this unending energy and enthusiasm. It's amazing. You never hear him say he's over-

the States fills him with gratitude. He hopes to return the favor by realizing his ambitions and helping others to do the same.

"I appreciate the opportunity," he says. "There are a lot of people who work in factories doing the same stuff over and over, without any additional creative opportunity. So this is wonderful." ■

NIGHT SHIFT

They have the graveyard hours. Although, considering their line of work, they prefer to call it the nighthawk shift. Whatever the name, 10 UPP (University of Pittsburgh Physicians) radiologists are now staffing a UPMC Emergency and Teleradiology Division during those hours (5 p.m. to 7 a.m.), when most people have already called it a day.

The unit started somewhat modestly back in 2008, but has continued to expand as technology continues to advance. "Obviously, imaging has evolved and become more complex, pushing the need for in-house coverage," says Omar Almusa, an MD, division chief, and Pitt assistant professor of radiology.

The need is about having a trained subspecialist (for example, a neuroradiologist interpreting brain and spinal cord film) taking an active role in a patient's trajectory of care.

In the not-so-distant past, imaging was considered an adjunct to patient management at UPMC. But now with the teleradiology division in place and located on the Presbyterian campus, final reports are available within an hour (as opposed to 15), and radiologists are available for consultations in real time.

Almusa sees the radiologist as the doctor's doctor. A radiologist might also be thought of as the air traffic controller who assists the ER physician or surgeon in charting the right course.

The concept of a 24/7 academic medical center radiolo-

gy division is not a new one. But, says Almusa, UPP was an early adopter. These days, its coverage area extends to UPMC Presbyterian, Shadyside, Magee-Womens, and Mercy, other UPMC facilities (including its urgent care centers, Bedford Memorial, Northwest, and Hamot hospitals), and Trinity Health System in Steubenville, Ohio, as well as Monongahela Valley Hospital.

Typically, the four overnight radiologists on site will handle anywhere from 160 to 480 cases; most are related to car accidents, strokes, and abdominal or chest pains.

"One moment you may have nothing to do," Almusa says, "and the next it's all you can do to keep up." But he has taken note of predictable patterns of behavior, bracing himself for an onslaught of work from 8 p.m. to 2 a.m.; he knows the summer months will keep him busier than any other time of year. (Exceptions are winter days of bibulous revelry: New Year's Eve, St. Patrick's Day, and the Super Bowl, especially if the Steelers are on the field.)

Almusa is looking forward to expanding the division's reach to rural areas and its expertise to include more subspecialties like pediatrics and obstetrics. "It's very rewarding," he says, "to have such an impact on patient care."

—Barbara Klein