Robotic placement of radioactive seeds in the prostate. Brachytherapy for prostate cancer is a form of radiation therapy in which dozens of tiny permanent radioactive isotopes are surgically placed directly into the cancerous prostate. Brachy means “short” in Greek, and here it refers to the fact that the radiation is supplied a short distance away from the prostate malignancy. Your doctor may also refer to brachytherapy as interstitial (“in the narrow spaces”) radiation therapy, or “seed therapy,” as the procedure is most commonly called, because the isotopes are about the size and shape of a grain of rice.

Here’s how brachytherapy works: The permanently implanted isotopes, placed in close proximity to the tumor, deliver a low dose of radiation over time. Most of the radioactivity is absorbed directly into the prostate. The seeds are never extracted, but their radiation decays until all that remains in the prostate are inert titanium casings.

Think of brachytherapy as radiation treatment that is applied from the inside out, rather than from the outside in, as with traditional radiation therapy. Brachytherapy’s delivery differs significantly from external beam radiation treatments, where powerful but short bursts of radiation are given in several sessions. This slow delivery reduces side effects.

On the day of the brachytherapy procedure, after the patient is sedated, a template with holes is placed over the perineum (the area between the scrotum and anus) to guide approximately 30 thin needles. Computer dosimetry (the calculation of appropriate doses of radiation) is used to decide how much radiation should be used. The plan may be prepared preoperatively (based on CT or MRI images of the prostate), but the procedure is typically done under transrectal ultrasound guidance. The radioactive seeds are finally loaded into the needles and positioned in the prostate according to the dosimetry plan.

Radiation oncologists are always looking for perfection with this procedure, but that’s not always easy to achieve. That’s because prostates differ in size and density from man to man. In addition, the prostate moves. When pierced with needles, it can shift, rotate, and swell. The thin needles may bend, so the implanted seeds don’t always end up where they are supposed to go. Once the radioactive pellets are placed within the prostate, they are not readily visible via ultrasound,
so if the seeds shift or migrate during the procedure, this may go undetected, and it can’t commonly be corrected in the operating room.

If the seed distribution does not exactly match the dosimetry plan, the resulting distribution will have “hot” and “cold” spots within the prostate. Improper placement away from the tumor (cold spots) may lead to cancer recurrence, while overdosing (hot spots) can lead to bladder or bowel side effects.

This is where the use of a robot and image-guided intervention can be a great help. The focus of our laboratory over the past five years has been the development of a robot for real-time image-guided urological interventions. We have created a robot that is able to operate precisely within the closed tube of a high-field MRI scanner. To be MRI-compatible, the robot had to be free of metal components, so we developed a new pneumatic motor made of nonmagnetic materials—plastics, ceramics, and rubber—that do not conduct electricity. The robot is encoded with fiber optics so that it is electricity-free, operated exclusively through pressure and light. Creating this special motor took us over three years of hands-on, trial-and-error iterations.

No other fully MRI-compatible robot exists today. Several other academic and industry research groups have made robots for MRI interventions, but none of these have yet achieved the combined precision, image noninterference, and safety required for medical interventions.

Our goal is to perform the first fully automated prostate brachytherapy under real-time MRI guidance, using the robot to place seeds into the prostate. As the seeds are placed, the gland will be constantly imaged and evaluated for adequate dosimetry. If a seed shifts, it can be immediately recognized and treated. This is not possible with current techniques.

Our URobotics laboratory is quite unique, and no one else in the urology field—or the medical field, for that matter—has this sort of engineering capabil-
ity as part of a clinical department. We are able to design and simulate devices on computers in our laboratory, and when we’re happy with the results, take the design to the workshop next door where sophisticated machining tools (typically found only in high-tech factories) are used to create the parts.

We have already tested our robot on animals and cadavers, and it works nicely, placing the seeds exactly where we want them. After we have collected enough data, we hope to begin testing the device on human subjects within a year or so.

The Crystal Ball: From Prostate Cancer Diagnosis to Immediate Treatment. We have come a long way over the past three decades, making giant strides in our understanding of how cancer progresses at the genetic, molecular, and cellular level. In the future, using powerful computers, sophisticated software, and newer imaging devices that will be able to view tissue on the molecular level, we hope to identify prostate cancer at its earliest stages and then destroy it with well-tolerated, minimally invasive therapies.

Here’s how this might work: Based on PSA score, a man undergoes an MRI image-guided biopsy with robotic assistance. The ultra-sophisticated imaging shows precisely where tumors are in the prostate, and then the robot delivers the needle to those spots to take core samples for biopsy. Based on the biopsy results, the cancer is then treated—during this same procedure—by delivering radioactive seeds, gene therapy, thermal ablations, or other local therapies directly to the tumor using the robotic device. Minimally-invasive, image-guided biopsy and therapy methods have the potential to revolutionize prostate cancer management and care, helping men achieve cancer cure in a more effective and less disruptive way than ever before.