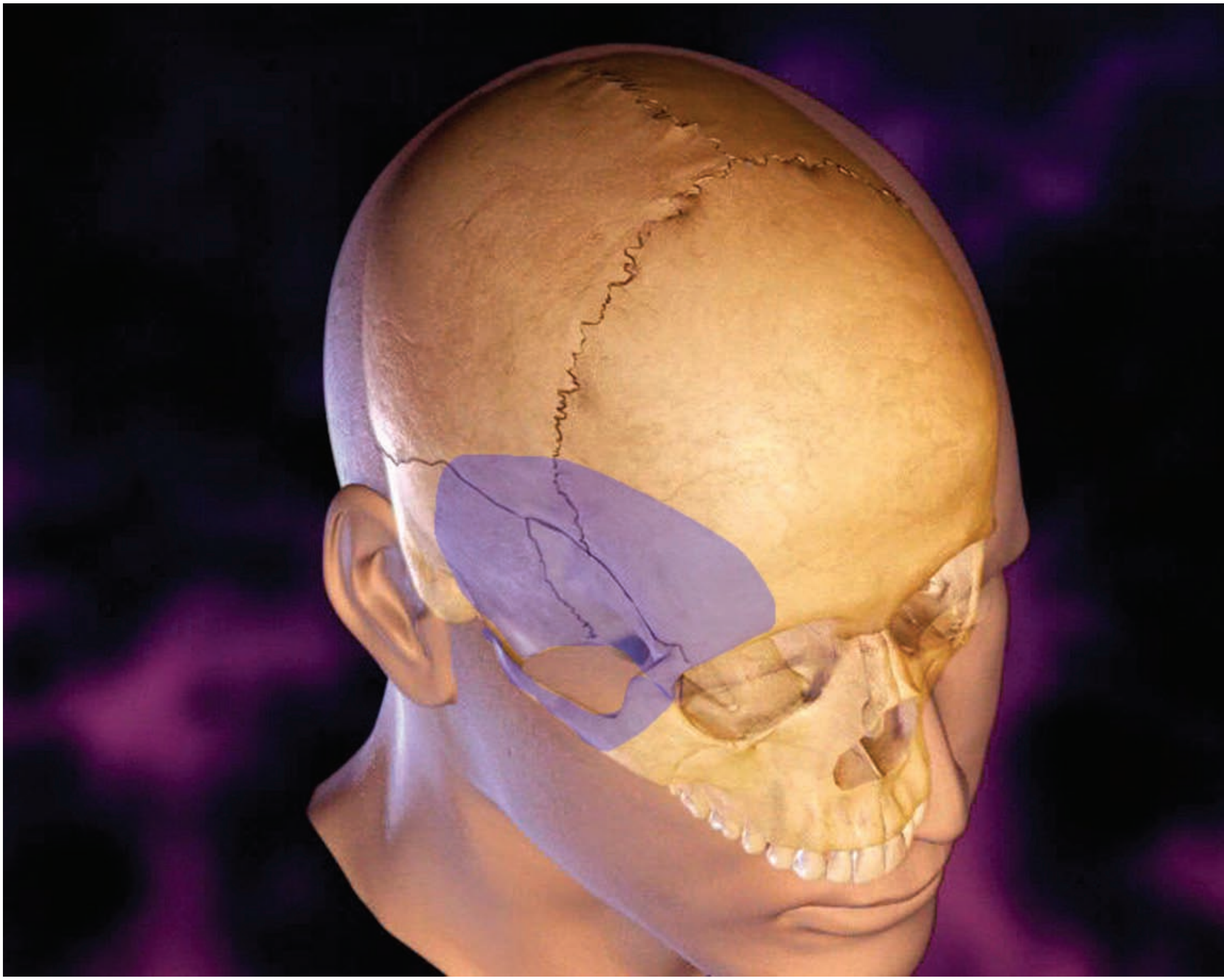
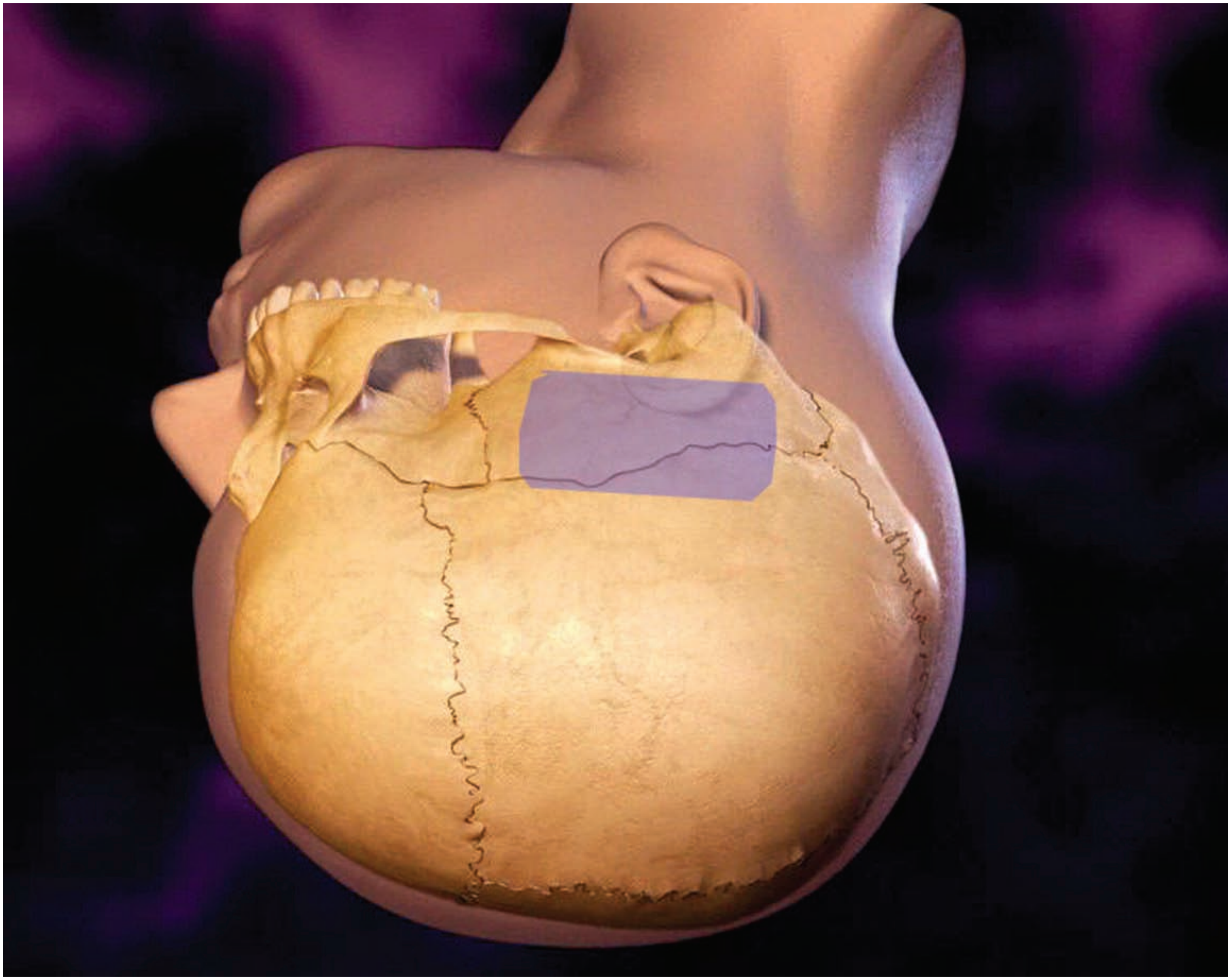


Brain Power

In the Microneurosurgery Skull Base Laboratory, virtual reality gives surgeons a once-unimaginable look inside the body

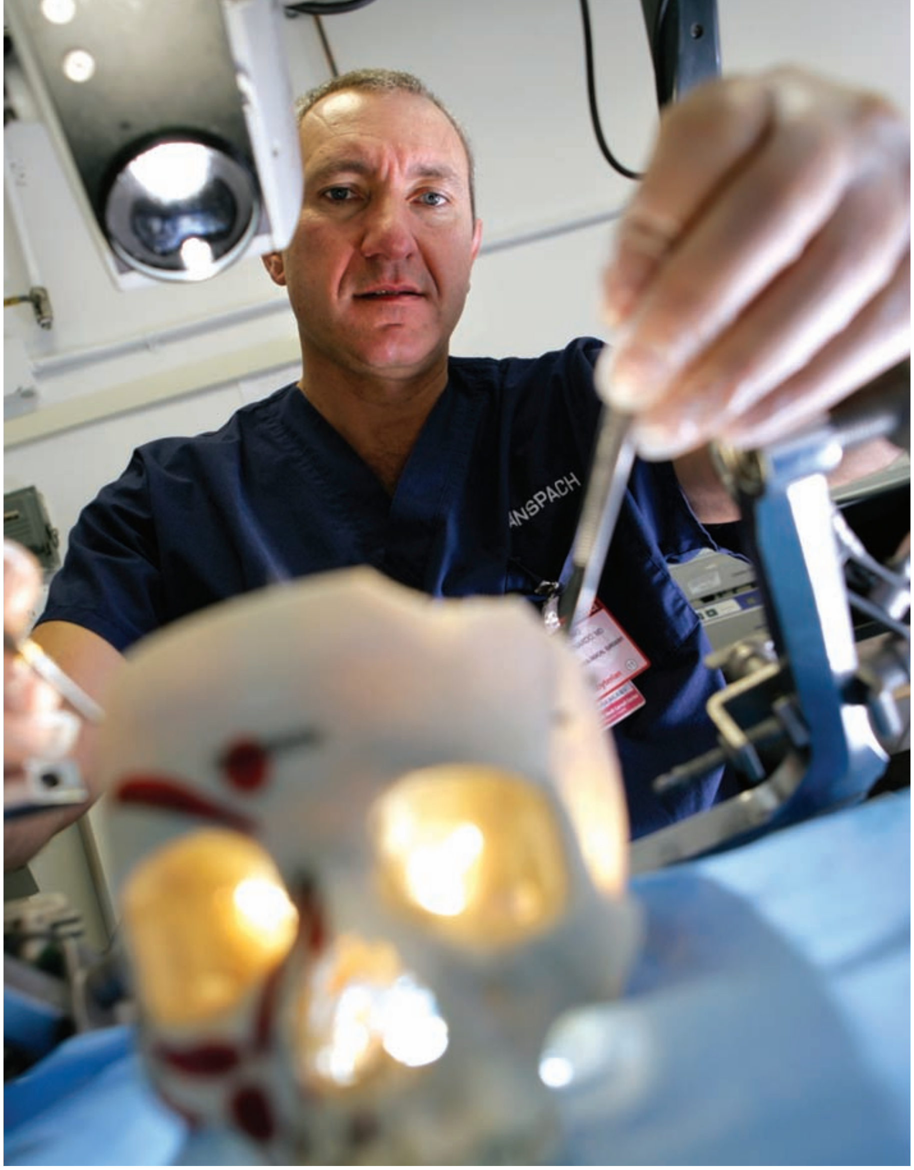


IMAGES PROVIDED BY DR. ANTONIO BERNARDO

By Andrea Crawford

The skull of an anonymous patient, a male born on New Year's Day 1934, appears before you, floating off the computer screen like a hologram. You resist the urge to reach out and touch it, pushing the 3-D stereoscopic glasses up the bridge of your nose. Wearing his own pair, Antonio Bernardo, MD, sits at a computer monitor, a joystick in each hand. The one on the left controls the image, turning the head in any direction. The smaller, pencil-shaped tool in his right hand acts alternatively like a mouse, clicking through tabs in the computer program, and as a surgical tool.

All in your head: The lab offers detailed images of the skull and brain, which can be manipulated and viewed from a variety of angles to plan surgical approaches.



JOHN ABBOTT

Technology and treatment: Antonio Bernardo, MD. Below: One of the lab's 3-D images.

With one click, the bone structure of the skull disappears, revealing the brain. Another click and the spongy pink matter disappears too, leaving only the bright green of a lesion interlaced with a blood-red vascular system. The sudden revelation of this image is stunning—not because of the tumor's ominous presence deep within the patient's brain, but because the vibrantly colorful figure is so beautiful.

These 3-D images are the newest weapon in a neurosurgeon's arsenal—and the forty-three-year-old Bernardo, director of Weill Cornell's Microneurosurgery Skull Base Laboratory, is playing a leading role in their development. A computer fanatic since boyhood—in medical school, he created his own animation programs as study aids—Bernardo first turned to virtual reality technology as a tool for teaching skull-base neurosurgery. Now the work of this lab—which he's directed since 2004, hosting international fellows on three-to-four-month rotations, with a current waiting list of more than sixty—has profound clinical applications as well.

By recording every dissection conducted in the lab into a digital archive, Bernardo is enabling surgeons around the world to learn skull-base surgery, many in areas where cadavers are hard to come by, due to religious or social taboos. He is also creating a vast repository of data to be published in atlases and on the Web, accessible to the entire neurological community; building anatomical teaching models that could be of enormous use to medical students; and helping patients by developing safer routes to the brain's most inaccessible regions.

The field of skull-base surgery emerged as a subspecialty about fifteen years ago, not long before the Italian-born Bernardo began his neurosurgery residency. It is among the most challenging disciplines: the surgeon enters the brain from its base, typically through the face or from behind the ear, areas with complex neurological, muscular, and vascular structures. The benefits of such an approach are numerous; they include making inoperable tumors operable, limiting the amount of brain tissue to be retracted, and enabling better surgical control over aneurysms and tumors.

In 1999, Bernardo—traveling with donated equipment and seven human heads—landed in South America for a year-long volunteer program, funded by the Foundation for International Education of Neurological Surgery, to establish skull-base training centers throughout Peru. While teaching the courses, he realized the difficulty of transmitting information about complex microanatomy while having limited access to cadavers. After a lecture with conventional materials, the surgeons would make many mistakes on the precious few specimens. So Bernardo began using 3-D technology, letting surgeons see the structures first in virtual reality. "With this 3-D projection, people got a good grip on the anatomy before doing the dissection," he says. "The results were phenomenal. They didn't make as many mistakes, and they got the best use of the single specimen."

Back in the U.S., as a fellow at the Barrow Neurological Institute in Phoenix, Bernardo continued to develop the technology. He created a 3-D surgical simulator, the Interactive Virtual Dissection, which allows surgeons to improve visual-spatial skills by simulating surgery—doing the drilling, clipping, and cutting in virtual reality on a computer that shows actual cadaver images. Using the program, surgeons choose a route and instruments, then practice the procedures. Bernardo is now at work adding force feedback, so the tactile sensations of surgery will be replicated as well. While the hardness and roundness of the spine and nerve tissue are easy enough to approximate, he says, brain tissue is more difficult to replicate on a computer program, due to its elasticity.

On the screen before him, Bernardo demonstrates how the 3-D technology can also transform pre-operative planning, as he weighs several options for surgical approaches to removing a tumor. By importing data from CT scans, MRIs, and ultrasounds, the program creates a replica of the patient in three dimensions. Bernardo investigates the skull from every possible angle, zooming in and out. He slices the plane of the skull by increments, seeing the exact contours of the lesion and its relation to the bone and vascular structures. He resects the tumor, which enables him to see where any vessels or nerves lie within it.

Then, Bernardo turns the patient's head into a surgical position and demonstrates the conventional approach through the top of the head—a pathway, he shows, that would make complete removal of the tumor impossible. He turns the head another way, and demonstrates the much shorter orbitozygomatic path. The difference is striking. All options still not exhausted, he turns the patient again and tries another approach, known as a subtemporal with anterior petrosectomy. It too reveals complete access to the tumor, but turns out to have an even shorter trajectory. It's the preferred route. "I used to have to picture the dimensions in my head just by looking at the flat image on the lightbox," he says. "Now I can turn the image around, put the head into surgical position, look at it from various approaches, and see what kinds of structures I'm going to encounter. You can completely extrapolate the depth of the surgical field, see which route takes you closer. It makes everything safer for the patient."

For now, the best way for surgeons to use this knowledge is simply to memorize it. In this case, the surgeon knows he will resect the tumor from top to bottom rather easily and that the task will grow more difficult toward the bottom, where the lesion rests on the carotid artery; by reaching beneath each side of the artery, however, he'll be able to remove it entirely. But Bernardo hopes there may soon be another way to use the data. The 3-D image could be viewed through a visor that allows surgeons to switch between it and the microscopic view of the actual surgical field. In fact, Bernardo is at work on just such a device.

The laboratory was in transition last fall, moving from one space to another during a building renovation. In its temporary quarters, it doesn't look so high-tech. It contains two workstations, surgical bays that—aside from issues of sterility—look just as they would in an OR. On the microscope, Dr. Bernardo has mounted four video and two still cameras to record dissections. In a container on the surgical tray lie two pieces of skull, a visual representation of a two-piece orbitozygomatic craniotomy, one of the most useful skeletal gateways for skull-base surgery.

When each new fellow arrives at the lab, Bernardo offers this surprising piece of advice: Don't study too much. "It sounds paradoxical, and they look at me strangely," he says. "But when you read too many papers you get a bias, and then when you do dissection, you'll do the same dissection that's been done before." So for the months of their fellowship, he tells them, give your brain the freedom to explore. "At the end of the day, 98 percent of the time, you'll end up doing what's been done before," he says. "But if you do this experiment, you've got that 2 percent chance to do something nobody's ever done." ●

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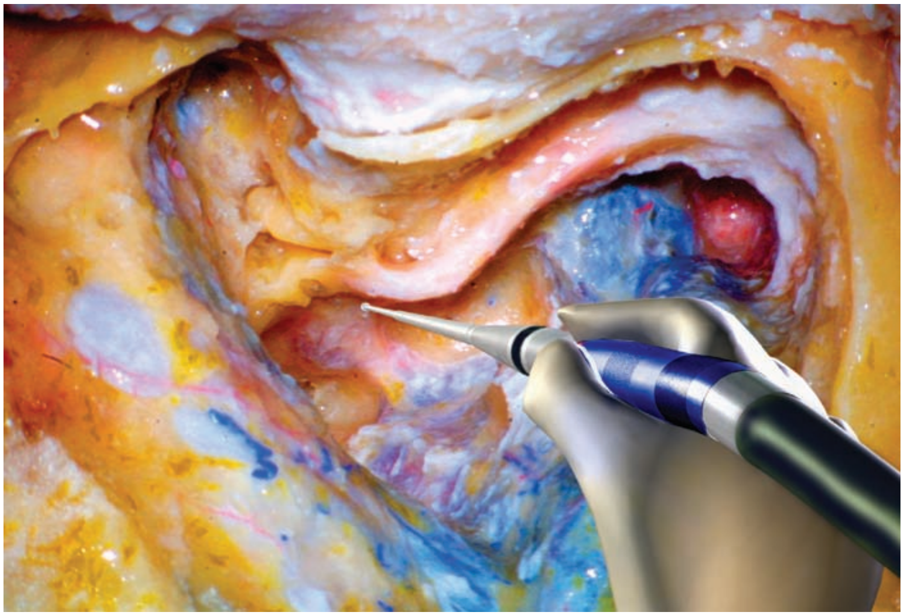

Virtual vision: Surgeons can simulate procedures using images taken of cadavers.

For more information about the Microneurosurgery Skull Base Laboratory, go to: www.cornellneurosurgery.com/skullbasesurgery