The New York Times | http://nyti.ms/1C84z09

SCIENCE

Off the 3-D Printer, Practice Parts for the Surgeon

By KAREN WEINTRAUB JAN. 26, 2015

BOSTON — The surgeon held a translucent white plastic eye socket in each hand. Gently moving them away from each other, Dr. John Meara showed the distance between Violet Pietrok's eyes at birth. He slid the sockets closer to demonstrate their positions 19 months later, after he had operated on her.

Violet, now nearly 2, was born with a rare defect called a Tessier facial cleft. Her dark brown eyes were set so far apart, her mother says, that her vision was more like a bird of prey's than a person's. A large growth bloomed over her left eye. She had no cartilage in her nose. The bones that normally join to form the fetal face had not fused properly.

Her parents, Alicia Taylor and Matt Pietrok, sought out Dr. Meara at Boston Children's Hospital, thousands of miles from their home in Oregon, because the plastic surgeon had performed four similar operations in the previous three years.

Before he operated on Violet, Dr. Meara wanted a more precise understanding of her bone structure than he could get from an image on a screen. So he asked his colleague Dr. Peter Weinstock to print him a three-dimensional model of Violet's skull, based on magnetic resonance imaging pictures.

That first model helped him to decide what might need to be done and to discuss his treatment plan with her family. Three more 3-D printouts closer to the operation allowed Dr. Meara to rotate the model skull in directions he could not manage with a picture and would not attempt with a patient on the operating table. Then he was able to cut and manipulate the plastic model to determine the best way to push her eye sockets more than an inch closer together.

Such 3-D-printed models are transforming medical care, giving surgeons new perspectives and opportunities to practice, and patients and their families a deeper understanding of complex procedures. Hospitals are also printing training tools and personalized surgical equipment. Someday, doctors hope to print replacement body parts.

“There’s no doubt that 3-D printing is going to be disruptive medicine,” said Dr. Frank J. Rybicki, chief of medical imaging at the Ottawa Hospital and chairman and professor of radiology at the University of Ottawa. He is the former director of the applied imaging science lab at Brigham and Women’s Hospital, a few blocks from Boston Children’s.

“It makes procedures shorter, it improves your accuracy,” said Dr. Rybicki, who has used 3-D printing in his work with face transplants. “When bioprinting actually hits, it will change everything.”

For now, the printer extrudes a layer of liquid plastic instead of ink. It adds a second layer, and then another, and a skull or rib cage — or whatever the surgeon dials up — slowly emerges.

The same process can also print layers of human cells. So far, researchers have also printed blood vessels, simple organs and bits of bone. A Utah boy’s life was saved last year by a 3-D-printed plastic splint that propped open his windpipe.

Dr. Weinstock, the director of the Pediatric Simulator Program at Boston

Children's, sees 3-D models as part of a larger program to improve surgical craft. At Children's and a dozen other pediatric centers around the world, he says, the surgical simulation program he developed improves team communication and trust, and lifts confidence before extremely complex operations. He believes it also shortens patients' time under anesthesia.

If the nearly two-year-old program has prevented even one major medical error — and Dr. Weinstock is convinced it has prevented many — it has paid for itself and its $400,000 3-D printer, running nearly full time in the hospital's basement.

The models of Violet's unusual skull allowed Dr. Meara to anticipate exactly what he would find underneath the face that stopped strangers on the street.

Dr. Meara had received printed models of other patients' skulls before, but only after waiting weeks or months for a single replica, at a cost of thousands of dollars. Dr. Weinstock's printer generated four identical copies in a few days, each costing about $1,200 and accurate to within a hair's width.

Experimenting with a model he had cut up, Dr. Meara noticed that in their ideal positions, the bones of the eye sockets would bump into each other, limiting Violet's vision. He modified his cuts to avoid that collision.

"The ability to physically move those segments is huge," Dr. Meara said. "Otherwise, you're doing it for the first time in the operating room."

On Violet's surgery day in early October, Dr. Meara consulted a model a few times in the operating theater. The surgery went as planned.

At Brigham and Women's Hospital, an even more sophisticated 3-D printer replicates flesh as well as bone, and even prints the tools he will use to make the cuts.

"When it comes time to operate, you don't need to fiddle around, it's all

there," Dr. Rybicki said. "You have unprecedented surgical planning, and you have unprecedented accuracy."

Comparing models from before and after surgery also offers clues to why some tissue grafts take hold and some are rejected, Dr. Rybicki said.

As 3-D printers improve, so will surgical outcomes, Dr. Rybicki said. Soon, doctors will thread catheters through replica blood vessels, map out how to bypass aneurysms, and feel the tactile difference between tumors and healthy tissue, for instance.

Dr. Weinstock's mock surgical suite on the hospital's third floor looks, sounds and smells just like the adjacent real one — down to the surgical tools, beeping monitors and oozing red liquid. He has hired a puppeteer and a former film engineer to make the practice sessions feel more real. Noah Schulz, a mechanical engineer who recently joined the hospital's staff after a career in the entertainment industry, uses his theatrical savvy in making 3-D printouts of anatomically precise surgical dummies.

Dr. Weinstock says that neurosurgeons, cardiologists and orthopedic surgeons, among others, regularly used the simulation suite to "keep up their batting practice."

Although there has been little research so far into the benefits of 3-D printing or surgical simulations, Department of Veterans Affairs researchers have shown that teamwork exercises in operating rooms reduced patient deaths or injuries by as much as 18 percent.

"Solve one problem, remove one error, identify one latent safety threat, save one life," and it will reduce both personal and financial costs, Dr. Weinstock said.

The benefits of practicing for routine procedures, for which doctors and nurses can become complacent, are as great as in unusual ones like Violet's, he

Dr. Frank J. Rybicki, a radiologist who works with 3-D printing in face transplants. Dr. Rybicki is chief of medical imaging at the Ottawa Hospital and chairman and professor of radiology at the University of Ottawa; he is no longer with Brigham and Women's Hospital in Boston.

A version of this article appears in print on January 27, 2015, on page D1 of the New York edition with the headline: The Operation Before the Operation.
