Multimaterial 3D printers create realistic hands-on models for neurosurgical training

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A perforator creates a bur hole in the model of a skull. The model, produced using the latest generation of multimaterial 3D printers, is composed of a variety of materials that simulate the various consistencies and densities of human tissues encountered during neurosurgery. Credit: © American Association of

Neurosurgeons, 2013.

Researchers from the University of Malaya in Malaysia, with collaboration from researchers from the University of Portsmouth and the University of Oxford in the United Kingdom, announce the creation of a cost-effective two-part model of the skull for use in practicing neurosurgical techniques. The model, produced using the latest generation of multimaterial 3D printers, is composed of a variety of materials that simulate the various consistencies and densities of human tissues encountered during neurosurgery. Details on the model are provided in "Utility of multimaterial 3D printers in creating models with pathological entities to enhance the training experience of neurosurgeons. Technical note." By Vicknes Waran, F.R.C.S.(Neurosurgery), Vairavan Narayanan, F.R.C.S.(Neurosurgery), M.Surg., Ravindran Karuppiah, M.Surg., Sarah L. F. Owen, D.Phil., and Tipu Aziz, F.Med.Sci., published today online, ahead of print, in the *Journal of Neurosurgery*.

Neurosurgery is a difficult discipline to master. Trainees may spend as many as 10 years after graduation from medical school developing and honing their surgical skills before they can be designated as proficient in their specialty. The greater the number and variety of neurosurgical training sessions, the better the training experience. However, the authors point out that it is difficult to find suitable simulation models that offer accuracy and realism for neurosurgical training while keeping training costs down.

Three-dimensional printers have been used to create models of normal and pathological human tissues and organs for physician training and patient instruction for some time. Until recently, however, only one material could be used in the creation of models. While useful for display purposes, one-material models have little value for hands-on training. With the advent of multimaterial 3D printers, the sophistication and versatility of the new models that could be created increased substantially, but so did their price.

Waran and colleagues tell us that this situation is now changing. They state that the newest generation of multimaterial 3D printers can aid neurosurgical training by creating models that simulate different diseases in a variety of body tissues, and they can do this in a cost-effective manner.

With the aid of an Objet500 Connex™ multimaterial 3D printer (Stratasys, Ltd.), researchers at the University of Malaya created a two-part model that can simulate pathological conditions in actual patients. The base piece of the model (the "head") consists of one material. It has human features (a "face") and the natural contours of a human skull. This piece is used to train the novice in neuronavigation techniques and can be reused again and again. The second part of the model defines the region in which simulated surgery is performed. This piece contains several different materials, which separately simulate skin, bone, dura mater, tumor, and normal brain tissue. The second piece fits into a slot in the base piece; this multi-textured piece can only be used once and is discarded after the practice session. Fortunately, it is easy to reproduce a steady stream of new pieces.

To make the training session valuable, the trainee must be able to see, feel, and even hear different "tissue" responses to surgical instruments and techniques during simulation surgery. The researchers tell us that the "skin" is designed to be pliable enough to be cut by a scalpel and repaired by sutures, yet sturdy enough to be held by a retractor; the "bone" has to be hard enough for the trainee to obtain experience using bone perforators and cutters; the "dura mater" must be thin and pliable—just like the real thing. The consistency and color of the "tumor" differ from those of the "brain" to simulate actual tissues. The researchers made the "tumor" softer than the "brain" and colored it orange, whereas they colored the brain light yellow.

To test the quality of the model produced by the printer and to make minor adjustments, the researchers from Malaysia were aided by other researchers from the UK. Three neurosurgeons and one expert in surgical simulations performed simulated surgery and assessed the model's "tissue" components. All parts received ratings of "fair" or "good," with most rated "good."

The usefulness of the model in training neuronavigation techniques was also assessed. Since the two-part model was based on data from a real patient, it was no surprise that "neuroimaging" was rated "excellent" by the evaluating team. Two navigation systems were used, and in both cases "registration was accurate and planning possible."

Waran and colleagues state that the reusable base piece of the model costs approximately US $2000 to fabricate and the disposable inset costs US $600. This makes these training models affordable. In addition, model designs are based on actual patient data, providing limitless variety.

The authors note that "as 3D printer technology improves, these machines will provide the possibility for newer, more complex models to be created, allowing an improved training experience." According to Dr. Vicknes Waran, first author of the paper, "3D models of the future may allow the possibility to perform entire operations from start to finish, making for a realistic simulator" to be used in neurosurgical training.

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