Neurosurgical forum
Letters to the editor

Simulator for spine pathologies

To THE EDITOR: We read with great interest the paper by Mattei et al.1 (Mattei TA, Frank C, Bailey J: Design of a synthetic simulator for pediatric lumbar spine pathologies. Laboratory investigation. J Neurosurg Pediatr 12:192–201, August 2013). The authors introduced a pilot study synthetic simulator for pediatric lumbar spine pathologies. It is a modular system with a spinal cord pressure detector. It provides great value in surgical training and qualitative evaluation. We have some suggestions, and anticipate even more potential uses for a synthetic simulator in spine diseases.

The synthetic simulator may be not only simulative but also individualized. With a 3D printer and modular materials, it is easy to reconstruct a specific bio-model for each patient. Neurosurgeons can practice the operation repeatedly before undertaking a complicated surgery. Moreover, the significant structures, including spinal cord, nerve roots, and blood vessels, are crucial to surgical results. With sensor techniques, it is feasible to detect the pressure of the spinal cord, traction of the nerves, and injury of the blood vessels. The detected data may be used to evaluate the quality of the procedure and reflect the prognosis of a simulated operation. Neurosurgeons can choose the best surgical strategy according to the results of a simulated operation. For example, once synthetic simulators of a patient with lumbar spinal stenosis are established, a doctor can do a laminoplasty and a laminectomy on two exact simulators with lumbar spinal stenosis are established, a doctor can do a laminoplasty and a laminectomy on two exact simulators. Therefore, a simulated operation. Neurosurgeons can choose the best surgical strategy according to the results of a simulated operation. For example, once synthetic simulators of a patient with lumbar spinal stenosis are established, a doctor can do a laminoplasty and a laminectomy on two exact simulators to compare the outcome of spinal decompression and then choose the possible better way to treat the patient.

Because of their similarity, there are also possible biomechanical correlations between the real spine and the synthetic spine. Biomechanical experiments may also be done on the simulators. Thus, a doctor can get individualized results to choose a proper fixation before the surgery.

In a word, we think that a synthetic simulator for spine may be valuable not only for surgical training but also individualized clinical therapy.

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Reference

RESPONSE: We sincerely appreciate the interest of Drs. Yang and Yin in our research on the development of surgical simulators for spinal pathologies. As was well emphasized in their letter, there is a major trend toward incorporating patient-specific imaging into newly developed simulation platforms.16,20,21 A recent review identified 12 patient-specific virtual reality (VR) simulators in different surgical specialties (one is currently commercially available and the other 11 are still prototypes).20

The most common procedure for obtaining 3D details of patient-specific anatomy is the use of software capable of segmentation, fusion, and volume rendering of cross-sectional 2D fine-slice imaging sequences obtained either from CT or MR images imported in the standard DICOM format.15,20

In the case of synthetic simulation, previous studies have demonstrated the feasibility of using 3D printers loaded with such imaging data in order to build synthetic models with patient-specific morphometric characteristics.9,15 In the setting of VR simulation, it has already been demonstrated that virtual simulation with such patient-specific information may enable surgeons to practice future operations in a VR environment involving the specific challenges posed by the unique anatomy of each patient, possibly transforming the role of surgical simulators from a merely educational resource to one of an adjuvant tool that may have broader applications in the daily surgical practice.20,21

For example, in a recent study testing the value of a presurgical interactive VR simulation technique using a 3D computer graphics model of microvascular decompression for trigeminal neuralgia, 50% of the surgeons who performed the rehearsal of the procedure in the VR simulator prior to the actual operation found that the simulation had “prominent” utility for carrying out the entire surgical procedure.16 The other 50% judged the VR simulator rehearsal as being moderately useful or “supportive.” According to the study, the interactive VR simulation was considered most useful in those cases involving atypical or complex forms of neurovascular compression and structural restrictions in the surgical window.

Another study has also demonstrated the utility of a VR simulator (Dextroscope/Volume Interactions) capable of integrating patient-specific 3D MRI and diffusion tensor imaging data sets as a tool for surgical trajectory planning preoperatively for patients with gliomas invading the primary motor cortex and subcortical motor pathways.17 Similarly, it has also been demonstrated that such technology can be successfully used as a promising educational resource in interdisciplinary meetings and grand rounds for teaching neurosurgical anatomy and operative strategies.11

This article contains some figures that are displayed in color online but in black-and-white in the print edition.
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From a training perspective, patient-specific simulators may also enable the construction of a database containing a library of surgical cases involving challenging pathologies and rare anatomical variants, providing trainees a unique opportunity to have a hands-on experience in interesting surgical scenarios.

In relation to the advantages and drawbacks of each type of simulation, it must be recognized that, although VR simulators have presented very satisfactory results in terms of graphics computation and volume rendering (and at least acceptable results in terms of development of new haptic feedback technologies), the computational strategies for dealing with tissue deformation and collision detection are still in their infancy, and the results presented by current VR simulators are still very far from those that would be required for an educational experience similar to that obtained through the training in synthetic models. For instance, in the laparoscopic literature (the surgical field that has contributed most to the advancement of the field of surgical simulation, as well as the specialty that had earlier incorporated its benefits in terms of surgical education), the vast majority of the training programs still strongly rely on synthetic simulators.

To combine the superiority of synthetic models regarding haptic feedback and tissue deformation with the advantages of the advanced graphic computation provided by VR simulators, some mixed-reality (also called augmented-reality) prototypes have been developed. Such systems usually rely on the advantages of real objects to provide the haptic feedback and tissue deformation while introducing some valuable contributions from technological advances in graphic computation in order to enhance the anatomical details of the surrounding environment. These simulators are able to provide users with the simultaneous perception of both real and virtual digital elements in the same environment, providing the visual illusion that both types of objects coexist in the same space.

A recent study from the general surgery/laparoscopic literature has demonstrated, for example, that it is possible to produce patient-specific abdominal silicone organs with realistic shapes and colors, starting from radiological images. In this model, synthetic organs were assembled in a complex physical simulator and paired with electromagnetic sensors in a virtual environment that simulated the limits of the abdominal cavity. In an attempt to compare the realism, haptic feedback, and didactic value between a laparoscopic simulator, which used exclusive VR tools, and another one employing an augmented-reality strategy, the authors tested both models and measured the reported satisfaction rates for each aspect involved in the simulation procedure. As a result they found that, in comparison with the VR simulator, the augmented-reality simulator was regarded by all participants as a better simulator for laparoscopic skills training on all tested features.

Another interesting augmented-reality simulator has been recently developed for the simulation of the rasping procedure involved in artificial cervical disc replacement surgery. The authors who developed the system first simulated the strain, stress intensities, and critical forces under the various rasp instruments during contact with the intervertebral surfaces and later, using finite element modeling, created a physical model capable of attaining such critical forces. The system composed of both virtual and real objects was tested by 5 different physicians, who considered it a useful tool for both teaching the anatomical details of anterior cervical disc replacement and practicing the rasping procedure.

Similarly, another platform employing augmented reality (ImmersiveTouch) has also been successfully implemented in the simulation of routine cranial and spinal neurosurgical procedures, such as ventriculostomy, bone drilling, percutaneous trigeminal rhizotomy, pedicle screw placement, vertebroplasty, and lumbar puncture.

Regarding the use of synthetic or VR simulators for biomechanical studies, as suggested by Yang and Yin, we were initially skeptical of such an application. As previously discussed elsewhere, even studies in cadavers, which, at