Simulator for spine pathologies

To The Editor: We read with great interest the paper by Mattei et al. (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 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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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\(^7\) (and at least acceptable results in terms of development of new haptic feedback technologies),\(^2,13\) 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.\(^7,19\)

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 (Fig. 1).\(^1,2,6\) 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.\(^5\)

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.\(^21\) 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.\(^4\) 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 (Fig. 2).\(^36\) 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.\(^1\)

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,\(^14\) even studies in cadavers, which, at