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Experimental study

Role of virtual modules to supplement neurosurgery education during COVID-19

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ABSTRACT

The advent of the COVID-19 pandemic has disrupted all aspects of neurosurgery education, and it is now challenging to conduct routine sessions. Maintenance of essential standard education among novice neurosurgeons during the pandemic is of paramount importance. The aim of this study was the development of virtual modules and validation of its role to supplement the neurosurgery education program. We developed the virtual modules relevant to neuro-anatomy, neurosurgical procedures, instrumentation, and neurosurgical planning. These modules were virtually demonstrated to twenty-seven resident neurosurgeons through Cisco Webex online platform. They provided their rating on the aptness of virtual modules for different neurosurgery applications on various parameters using 10 points Likert scale. The parameters included quality, learning, confidence building capacity, usefulness, and overall satisfaction. The results obtained for each module were analysed and the average score was used for the comparison. The highest rating on quality was obtained by the neurosurgical instrumentation module. The highest rating for learning and confidence building capacity was given to neurosurgical procedure animation. The usefulness and overall satisfaction were highly rated for neurosurgical planning module. The results show that developed virtual modules provide an effective method to supplement the neurosurgery education program in the current scenario involving physical distancing and shift rearrangements. These virtual modules help in limiting the visits to operation room, anatomy and surgical training labs, and allow residents to learn online at their pace.

1. Introduction

As the novel coronavirus (COVID-19) swept across the globe, the pandemic has disrupted all aspects of society including the residency education of neurosurgeons [1–3]. The main impacts of Covid-19 on medical education include physical distancing and shift rearrangements. It has resulted in the cancellation of routine surgeries, outpatient department, in-person medical classes, skills lab training, workshops, and conferences [4]. Major components related to practical aspects of neurosurgery education include neuroanatomy, neurosurgical procedures, instrumentation, and preoperative planning. In the Pre-Covid scenario, education related to neuroanatomy was taught by orientation sessions on embalmed or fresh cadavers [5]. Neurosurgery involves a range of microscopic and endoscopic instruments, and familiarity with these instruments was imparted in the surgical training labs [6,7]. The neurosurgery residency involved apprenticeship assistance of an expert neurosurgeon inside the operating room, which allowed them to observe various neurosurgical procedures [8]. The routine surgical planning was done through physical meetings, in which the radiological parameters and surgical procedures were discussed among the operating team [9].

During this pandemic, the education sessions using cadaver models are adversely affected due to legal, clinical, and safety issues. Also, there are fewer chances for the residents to visit surgical training labs, which results in limited training on the instrumentation. Since the surgical volume has significantly reduced, there is limited exposure for the resident and trainee neurosurgeons to observe live surgeries [10]. In advent to social distancing factors, the repetitive surgical planning meetings are also shifted to online platforms [11]. This has resulted in a gap in the continuing education of neurosurgeons and the aforementioned components of practical aspects. Hence, there is a need of implementing technology-based solutions as urgent measures to provide distance learning to supplement medical education [12]. The virtual modules can play a significant role to provide education on the practical aspects of neurosurgery.

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Virtual modules can be developed with the help of three-dimensional (3D) scanning, reverse engineering, medical image segmentation, computer-aided designing, and animation techniques. 3D scanning allows reconstruction of the surface model of a physical object [13]. Reverse engineering allows the reconstruction of editable 3D solid models from the surface scan data [14]. Medical image segmentation allows the extraction of 3D anatomical structures from medical images such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) [15]. Computer-aided designing (CAD) allows the development of 3D models using direct or parametric modeling [16]. 3D animations make use of various sequences of these 3D models to create motion videos [17].

The aim of this study was the development and validation of 3D virtual modules for neurosurgery education including neuroanatomy, neurosurgical instruments, neurosurgical procedures, and neurosurgical pre-operative planning modules and their role to supplement the neurosurgery education program. These modules were virtually demonstrated to resident neurosurgeons and their rating on various parameters was obtained.

2. Methods

2.1. Neuroanatomy modules

The radiological data was used for the development of virtual models of the anatomical structures. CT provides good contrast for hard tissues and was used for the reconstruction of bony structures. MRI has good soft-tissue contrast and was used for the segmentation of the brain. Simpleware ScanIP software (Synopsys Inc., California, United States) was used for the segmentation of anatomical structures from these images. The virtual models of the scalp, skull, and brain were developed by segmentation. The virtual models of skull bones including occipital, sphenoid, and temporal bones were also developed by 3D scanning of dry bone samples. COMET L3D 5 M Precision Structured Blue Light Scanner (Carl Zeiss, Germany) was used for scanning the bones. Using the scan data from various orientations, the models were developed and exported in the Stereolithography (STL) file format. Fig. 1 shows the 3D models for the neuro-anatomy module.

2.2. Instrumentation animation modules

The virtual models of neurosurgical instruments were acquired from the open-source Virtual Repository of Neurosurgical Instrumentation for Neuro-engineering Research and Collaboration [18]. The functionality of these instruments was animated using 3DS Max/Maya software. It involved applying texturing of the stainless-steel material to the models. Then turntable style animation of the instrument and its function was created. The animation was then rendered at 30 frames per second and exported to standard formats of videos (.mov, .avi). The last step was to label the movie with name and type of the instrument, which was done using compositing in Adobe Premier software. A total of fifty-five animations of microscopic and neuro-endoscopic instruments were developed and stored. Fig. 2 shows the screenshots of the 3D animations of some of the microscopic and endoscopic neurosurgical instruments.

2.3. Neurosurgical procedure animation modules

Hydrocephalus is a condition which causes abnormal accumulation of cerebrospinal fluid (CSF) inside the ventricles. The common surgical intervention to treat hydrocephalus is Endoscopic Third Ventriculostomy (ETV). In this procedure, a burr hole is created on the skull and endoscope is inserted into the ventricles though the brain. An opening is created in the floor of the third ventricle using endoscopic tools and enlarged using Fogarty balloon. This allows flow of CSF into the basal cisterns. We selected this surgical procedure for neurosurgery procedure animation module. The animation was developed with the help of operative videos as reference. The development of animation involved vari-

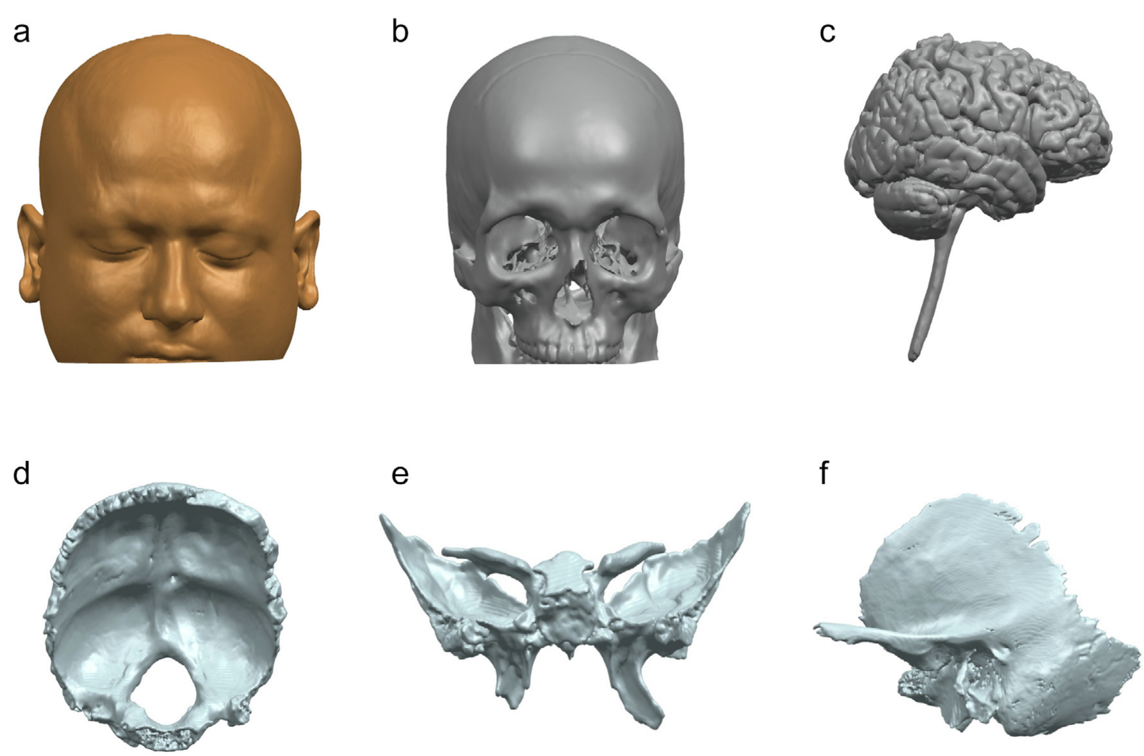

Fig. 1. 3D models of anatomical structures for virtual surgical education, (a) scalp, (b) skull, (c) brain, (d) occipital bone, (e) sphenoid bone, (f) temporal bone.

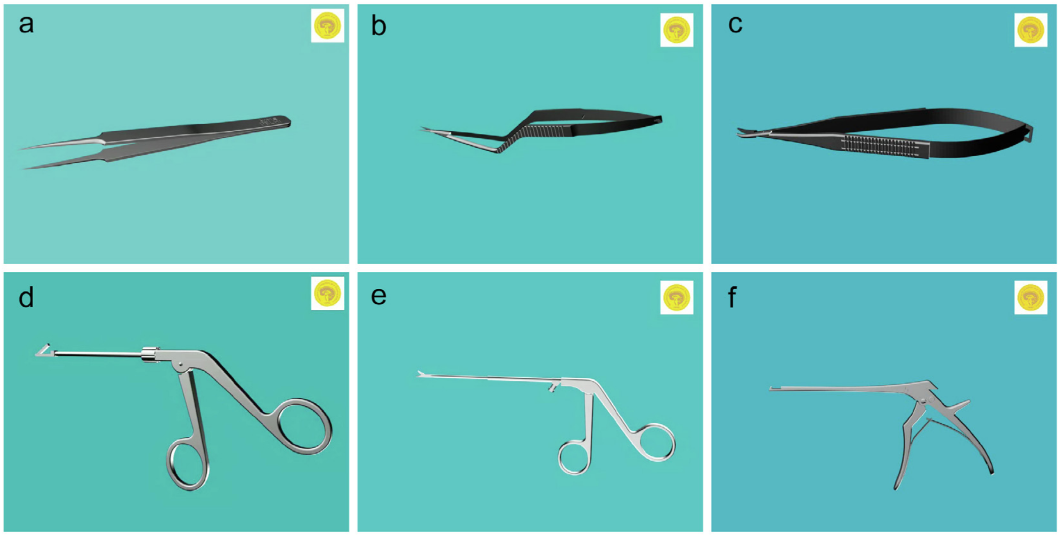

Fig. 2. Animations of neurosurgical instruments, (a) micro-forceps, (b) micro-scissor, (c) micro-needle holder, (d) antrum punch, (e) biopsy forceps, (f) Micro-Kerrison Rongeur.

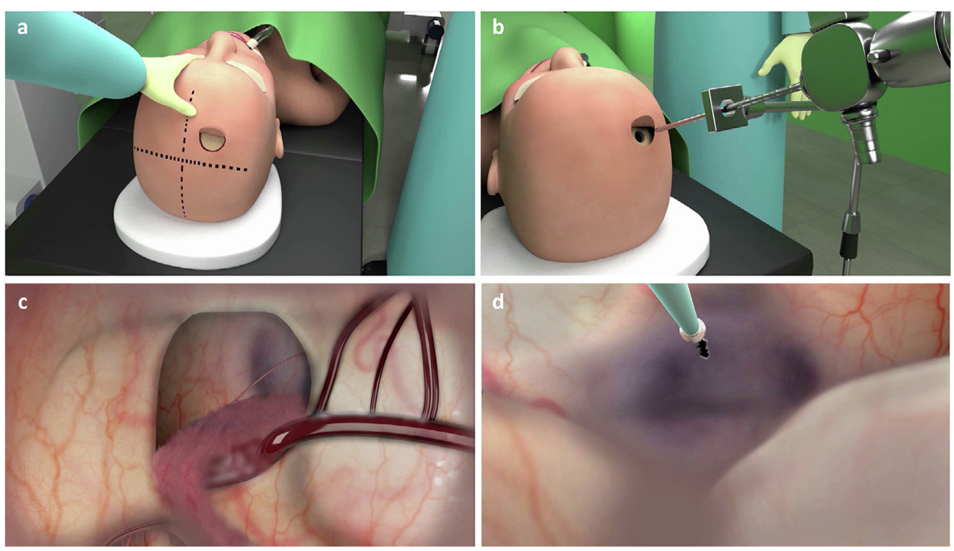

Fig. 3. Animations of Endoscopic Third Ventriculostomy procedure, (a) marking and skin incision, (b) Endoscope insertion through the drilled burr hole, (c) Endoscopic insertion into the ventricular system and (d) enlargement of the puncture created at the floor of the third ventricle using Fogarty balloon.

ous steps including scripting, 3D modeling, surgery tools animations, operation theater room animations, rigging, lighting and rendering. Fig. 3 shows the screenshots of the animation of ETV procedure. The animation was rendered at 30 frames per second and stored in the standard .mov format.

2.4. Neurosurgical Pre-operative planning module

The CT and MRI data were used to model the patient-specific anatomy of an adult suffering from hydrocephalus disease. We registered the CT and MRI images using anatomical land-marking with an accuracy of 0.1 mm using Simpleware ScanIP software (Synopsys Inc., California, United States). The registered data was used for the segmentation of 3D models of the scalp, skull, and ventricles. The virtual models were exported in a single STL file as shown in Fig. 4. This STL was demonstrated to the neurosurgeons using free and open source software Meshlab, which provides various tools for inspecting the anatomy of the patient and allows the operating team to plan the surgical procedure.

2.5. Face and content validation of modules

A group of 27 resident neurosurgeons participated in the study after consent. The modules were demonstrated to resident neurosurgeons and their feedback was acquired. All models and animations were shared with them using WebEx online meeting platform in four sessions for neuro-anatomy, instrumentation, neurosurgical procedures, and neurosurgical planning. They were allowed the remote access to have complete control over the shared content. For neurosurgical planning, groups of neurosurgeons were invited. A questionnaire was devised to acquire their feedback on the virtual modules as shown in Table 1. They rated the virtual modules with scores ranging from 1 to 10, where 1–2,

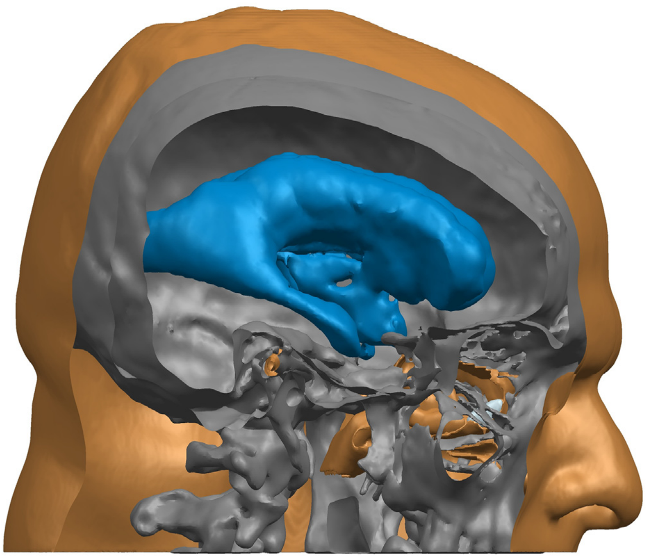

Fig. 4. Patient-specific 3D models of the scalp, skull, and ventricles for surgical planning.

Table 1
Likert scale questionnaire for validation of virtual modules.

S. No.	Questionnaire for performance rating
	Rate the quality of content
	Rate the learning using content
	Rate the confidence-building capacity
	Rate the usefulness of content
	Rate overall satisfaction

no value; 2–4, little value; 5–6, some value; 7–8, good value; 9–10, great value.

The scores provided by the 27 resident neurosurgeons for the virtual modules were tabularized on a Microsoft Excel sheet. The results of the five evaluation parameters were compared using box plots.

3. Results

The validation results provided the opinion of the neurosurgeons regarding the need for virtual modules to supplement neurosurgical education. The scores given by resident neurosurgeons for all five questions were averaged and compared. Fig. 5 shows the distribution of scores using box plots of the validation results for neuro-anatomy, instrumentation, neurosurgical procedures, and neurosurgical planning modules.

Neuro-anatomy modules received an average score of 5.00 for Q1 implying had it had some value in terms of quality of content. For Q2, the average score was 6.07; it was found to have some value for learning the neuro-anatomy. For Q3, the average score was 6.11, which showed that it provided some value for confidence-building capacity. For Q4, the average score was 5.78, and there was some value for the usefulness of the content. For Q5, the average score was 5.63, which related to some value for the overall satisfaction.

The instrumentation animation modules received an average score of 8.25 for Q1, which showed that it provided good value for the quality of content. For Q2, the average score was 6.07, it provided some value for learning familiarity with usage of instruments. For Q3, the average score was 6.22, and it had some value for confidence building capacity. For Q4, the average score was 5.78 implying that it had some value for usefulness of the content. For Q5, the average score was 5.68 and it had some value for the overall satisfaction.

The animation of the neurosurgical procedure module received an average score of 8.22 for Q1, which showed good value for the quality of content. For Q2, the average score was 9.00, which implied that it provided great value for learning approaches related to neurosurgical procedures. For Q3, the average score was 8.37, which showed good value for confidence building capacity. For Q4, the average score was 8.04 and it had good value for usefulness of the content. For Q5, the average score was 8.52 and it had good value for overall satisfaction.

The neurosurgical planning module received an average score of 8.04 for Q1. It shows that this module provided good value in terms of quality of content. For Q2, the average score was 9.00 and it had great value for learning neurosurgical planning. For Q3, the average score was 8.19 and it had good value for confidence building capacity. For Q4, the average score was 8.60 and it had good value for usefulness of the content. For Q5, the average score was 8.97 and it had good value for overall satisfaction.

In terms of quality of the content, neurosurgical instrumentation module was rated highest. Neurosurgical procedure animation received the highest rating for learning and confidence building capacity. Neurosurgical planning module received the highest rating for usefulness and overall satisfaction. The validation results show that the virtual modules were favorable for neurosurgical planning and neurosurgery procedure animations. They have some value for neuro-anatomy and instrumentation.

4. Discussion

Covid-19 pandemic has severely impacted the surgical education and training system of resident and trainee neurosurgeons [19]. One of the possible solutions to solve this problem is by imparting education using distance learning or e-learning [20]. E-learning or electronic-learning uses information technology or internet for learning. It is regarded as an implementation for knowledge delivery and skills in different disciplines to larger student communities scattered across the globe [21–23]. This offers the learner to have control over the content of study, sequence of learning, pace and time [24–26]. There are synchronous and asynchronous learning contents involved in e-learning. The synchronous contents include the real-time teaching and interaction between the teachers and students, coming together at the same time. In this, a group of people can come together to discuss and facilitate interactive learning. In asynchronous learning, the content is uploaded to the learning platform and the student can learn at the own pace [27,28]. Both provide potential solutions for providing medical education [29]. Major components of neurosurgical education include learning neuro-anatomy, usage of instrumentation, approaches related to various neurosurgical procedures, and neurosurgical planning. Basic medical education can be conducted using video conferencing of the cadaveric courses and live surgical sessions from the operating room [30]. However, to teach practical aspects of neurosurgery, these methods lack user interaction and manipulation.

In our current study, we have demonstrated the developed modules for neurosurgery education using a synchronous content mode. All the contents were demonstrated for learning using conference transmission mode and the remote control was transferred for interactive learning. The modules like instrumentation and neurosurgical procedures can also be used in asynchronous mode of learning by including them into learning management systems like Moodle or Massive open online course (MOOC) based course

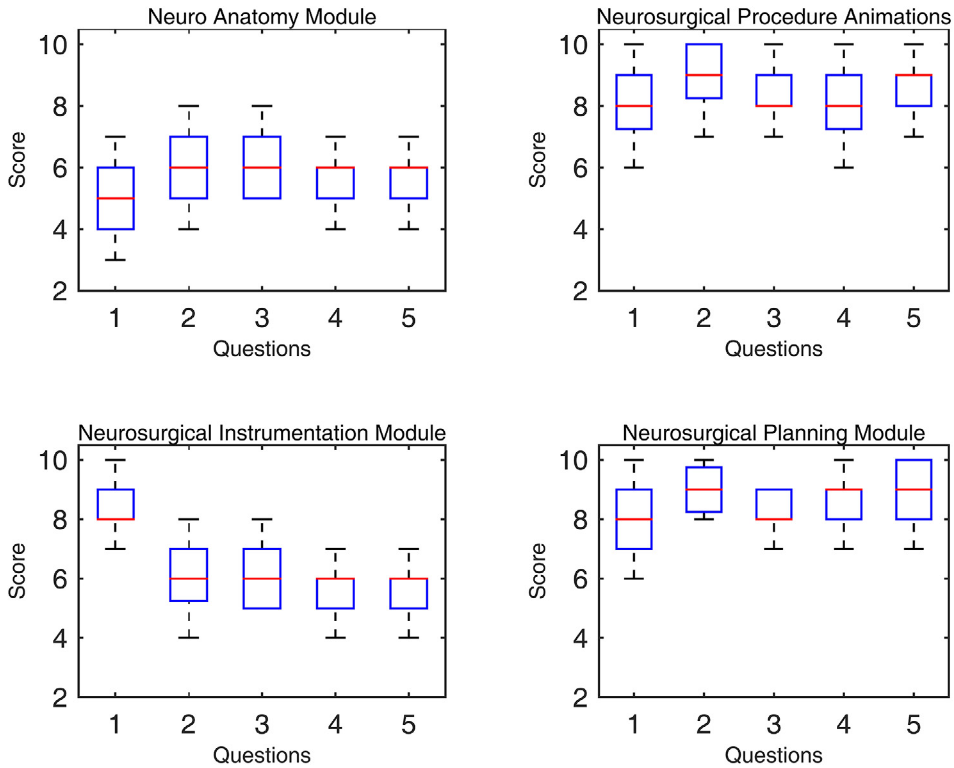

Fig. 5. Distribution of scores of virtual modules based on the feedback of neurosurgeons.

contents [27]. For neuro-anatomy, it is recommended to have learner manipulation (rotate or zoom) of the model over screen control, for better visualization. For neurosurgical planning, it is recommended to continue synchronous mode of learning because it involves discussions and decision-making happening real-time.

Neurosurgeons rated the virtual modules based on evaluation parameters using 10-point Likert scale. The results show that neuro-anatomy modules provided some value to supplement neurosurgical education during the COVID-19 pandemic. Resident neurosurgeons commented that the models of bones were found to have good detailing. But, the models of soft tissues were lacking details and thus cadaver anatomy sessions were recommended to develop in-depth knowledge. For the instrumentation module, the animations of microscopic and neuro-endoscopic instruments were found to have high value in terms of quality. They were found to provide some value for developing familiarity with the neurosurgical instruments. But practical sessions were demanded to get hands-on experience of instrument functionality. The neurosurgical procedure animation and neurosurgical planning modules were found to provide great value for learning approaches and the surgical decision-making process respectively.

Although neurosurgical education using the developed virtual modules was found to be an effective teaching method, preparation of the content for these modules was a laborious and time-consuming process. It required dedicated efforts of neurosurgeons, biomedical engineers, mechanical engineers, and animation specialists. For neuro-anatomy module, the segmentation of anatomical structures from medical images is a manual and laborious process. For instrumentation module, the virtual database of neurosurgical instruments was found useful and convenient. It was used for the development of animations of instrument functionality as well as neurosurgical procedure animation. The development of neurosurgical procedure animations is a multi-stage and time-consuming process, hence one representative animation of ETV procedure was developed. For neurosurgical planning, the 3D models were developed only for the difficult to operate cases, as segmentation of registered images is a lengthy procedure.

5. Conclusion

Maintenance of essential standard neurosurgical education among novice neurosurgeons during the COVID-19 pandemic is of paramount importance. Virtual modules can be used to supplement the existing neurosurgical education methods. In the present study, we developed virtual modules related to neuro-anatomy, instrumentation, neurosurgical procedures and neurosurgical planning. Neuro-anatomy and instrumentation modules were found to provide some value for supplementing neurosurgery education. Neurosurgical procedure animation and planning modules were found to provide great value for neurosurgical education. Such virtual modules can result in better preparedness to allow continuing education of neurosurgeons in such future events involving social distancing and containment. However, the efforts involved in the development of virtual modules needs improvement for scalability and wide acceptance.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jocn.2021.06.039.

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