Quality assessment of a new surgical simulator for neuroendoscopic training

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Object. Ideal surgical training models should be entirely reliable, atoxic, easy to handle, and, if possible, low cost. All available models have their advantages and disadvantages. The choice of one or another will depend on the type of surgery to be performed. The authors created an anatomical model called the S.I.M.O.N.T. (Sinus Model Oto-Rhino Neuro Trainer) Neurosurgical Endotrainer, which can provide reliable neuroendoscopic training. The aim in the present study was to assess both the quality of the model and the development of surgical skills by trainees.

Methods. The S.I.M.O.N.T. is built of a synthetic thermoretractable, thermosensible rubber called Neoderma, which, combined with different polymers, produces more than 30 different formulas. Quality assessment of the model was based on qualitative and quantitative data obtained from training sessions with 9 experienced and 13 inexperienced neurosurgeons. The techniques used for evaluation were face validation, retest and interrater reliability, and construct validation.

Results. The experts considered the S.I.M.O.N.T. capable of reproducing surgical situations as if they were real and presenting great similarity with the human brain. Surgical results of serial training showed that the model could be considered precise. Finally, development and improvement in surgical skills by the trainees were observed and considered relevant to further training. It was also observed that the probability of any single error was dramatically decreased after each training session, with a mean reduction of 41.65% (range 38.7%–45.6%).

Conclusions. Neuroendoscopic training has some specific requirements. A unique set of instruments is required, as is a model that can resemble real-life situations. The S.I.M.O.N.T. is a new alternative model specially designed for this purpose. Validation techniques followed by precision assessments attested to the model’s feasibility. (DOI: 10.3171/2011.2.FOCUS10321)

Key Words • neuroendoscopy • surgical training • simulation • validation

Neurosurgical skill formation is a long, consuming process. During the first years of resident training, initial support is provided by anatomical lectures and direct or indirect (video sessions) observation of surgeries. However, improvement in surgical techniques and manual skills must still be accomplished through laboratory training followed by supervised surgeries.

Several models are used in surgical training: cadaveric or animal models as well as surgical simulators. Unfortunately, financial, technical, and operational obstacles more often limit their application. Thus, anatomical models built from a myriad of materials and using computational and artistic techniques have become an interesting option in simulating endoscopic procedures with good accuracy at reasonable costs.

Ideal training models should be entirely reliable, atoxic, easy to handle, and, if possible, low cost. All available models have their advantages and disadvantages. The choice of one or another will depend on the type of surgery to be performed. Cadaveric models are broadly used for microneurosurgical training. However, for neuroendoscopic training, the lack of ventriculomegaly in most cadaveric specimens limits their application. Furthermore, the formol used for preservation is toxic and sometimes makes practicing uncomfortable.

Animal models are also useful in surgical training. They are well accepted and applied by general surgeons. However, ethical issues as well as a poor similarity between animal and human brains make animal models unreliable. One must also consider the high costs involved in maintaining an in vivo experimental laboratory.

Finally, surgical simulators can be divided in 2 types:
virtual reality simulators and real anatomical models. Although very promising, the use of 3D renderings and virtual reality settings are still at the development phase and are quite costly for widespread use. Furthermore, they do not allow the use of real instruments.

Hence, in conjunction with the Pro Delphus company, we created a real anatomical model called the S.I.M.O.N.T. (Sinus Model Oto-Rhino Neuro Trainer) Neurosurgical Endotrainer, which can provide reliable neuroendoscopic training. The aim of this study was to assess both the quality of the model and the development of surgical skills by trainees.

Methods

The S.I.M.O.N.T. is built with a synthetic thermoretractable and thermosensible rubber called Neoderma (Pro Delphus Company), which, combined with different polymers, produces more than 30 different formulas, as described in detail in previous publications. These formulas present textures, consistencies, and mechanical resistance similar to many human tissues. The Endotrainer can be used for neuroendoscopic, rhinological, and endonasal skull base surgical training (Fig. 1).

Silicon and fiberglass molds in the shape of the cerebral ventricles constitute the basic structure of the neuroendoscopic module trainer. An artist completes the setup by setting intraventricular structures, such as the choroid plexus and blood vessels, as well as pathological conditions, such as tumors and cysts. “Basic” models present only ventriculomegaly, whereas “advanced” models present several lesions that can be treated via neuroendoscopic approaches.

Regarding safety, the acrylic and resin used to build the model are odorless and nontoxic and do not deteriorate over time, and thus do not pose any biological or chemical hazards to the surgeons and technicians.

Quality assessment of the model was based on quantitative and qualitative data obtained from training sessions performed by 9 experienced and 13 inexperienced neurosurgeons. Initially, the S.I.M.O.N.T. was presented to 9 neurosurgeons with extensive experience in neuroendoscopic surgery (participation in more than 100 procedures). The technique used for preliminary evaluation was the face validation. That is, resemblance to real-life situations during practice sessions was based on expert opinions.

Subsequently, the model’s precision was assessed in 2 ways: retest reliability (stability of the results between multiple assessments) and interrater reliability (similar results between multiple assessments performed by 2 different surgeons). “Advanced” model simulators with multiple ventricular lesions were prepared and “operated on” several times by the experts. The end points analyzed were the time required to complete the procedure and the surgical technique applied to resect the tumors as relates to the use of instruments and ventricular navigation.

The quality of the model was further assessed using the technique called “construct validity.” During this process, novices and experienced neurosurgeons performed 2 simulated surgeries (third ventriculostomy and resection of a small ventricular tumor located around the head of the caudate nucleus). To be considered valid, the model should have the ability to discriminate between the novices and the experienced surgeons.

Evaluation of the trainees’ learning curves was undertaken in a step-by-step process. After careful theoretical explanations and lab demonstrations, the trainees were invited to perform their own procedures on the simulators. Proper instrument handling, adequate ventricular navigation, and surgical technique were closely observed and objectively assessed in terms of the time required to accomplish each step (limit of 5 minutes to assemble the neuroendoscope, 5 minutes to cannulate and navigate inside the lateral ventricle, and 40 minutes to resect a small ventricular tumor). The trainees performed from 3 to 10 procedures with the assistance of an expert. All mistakes were noted and classified according to Table 1. The Poisson distribution was used for statistical analysis.

Results

The experts considered the S.I.M.O.N.T. capable of reproducing surgical situations as if they were real and of presenting great similarity with the human brain. Furthermore, surgical results achieved from serial training were similar in both assessments (retest reliability and interrater reliability). Resection of the ventricular tumor was completed in between 40 and 50 minutes, while ventricular navigation (pivot and slide) and surgical technique remained almost identical. Thus, the model was considered precise.

Note, however, that 3 novices (23.08%) performed only partial tumor resection on their first attempt. Total resection was performed by 10 novices (76.92%) with a mean time of 78 minutes (range 67–92 minutes). Training performance was mainly characterized by incorrect/uncomfortable surgical positioning, many hesitant movements, mistaken ventricular navigation, and incorrect use of surgical instruments (Fig. 2).

Even so, the development and improvement of surgical skills was observed and considered relevant to further training. No errors were observed after the sixth procedure. Table 2 summarizes these data.

It was also observed that the probability of any single error was dramatically decreased after each training session, with a mean reduction of 41.65% (range 38.7%–45.6%). For instance, the likelihood of incorrect/instrument handling was as high as 90% in the first session and dropped to 20% with further practice (Fig. 3).

Discussion

For centuries, the apprenticeship method has been considered the gold standard for surgical training. The paradigm of “see one, do one, teach one” clearly reveals its educational process. It is a time-honored approach in which a skilled mentor provides practical demonstrations and shares theoretical knowledge with trainees. Therefore, surgery is learned by example and repetition. But this model of training demands a very large number and variety of cases to make a new surgeon.

At the end of the 1800s, William Osler and William Halsted were responsible for spreading and popularizing
They also established a more formal and structured system involving a team of trainees and masters. In fact, the model of residency training currently applied in the majority of medical schools derives mostly from their ideas. Surgical rotations and close relationships between masters and novices guide surgical skill formation, optimizing and amplifying the learning curve. Finally, on completion of the residency program, residents must demonstrate their proficiency through examination boards to be fully certified.

Although the current apprenticeship system of training has been proven, restrictions in resident work hours, financial pressure, patient safety, and heated debates about early specialization, duration of training, and the search for a better quality of life have led some renowned surgeons to propose important alterations to this teaching method. Furthermore, technological advances, such as computer-based simulators, have allowed young surgeons to gain surgical experience in a harmless environment and to quickly improve their skills.

**Neurosurgical Lab Training**

Cadaveric dissection is broadly used for neurosurgical laboratory training. Nonetheless, neuroendoscopic practice presents many specific issues. Ventricular endoscopy is performed mostly through an enlarged, filled cavity, and the use of cadavers is less likely to provide this situation. To date, just a single study has demonstrated postmortem ventricular expansion after water injection. Moreover, only fresh cadavers maintained this property. Authors of another paper proposed a cadaveric model in which a triangular wedge of brain would be removed and the neuroendoscope would be inserted into the ventricular cavities. However, reliability was further compromised given the lack of mechanical resistance (interface tissue/neuroendoscope) and unrealistic wider range of motion (pivot).

With increased subspecializations in the surgical field, residents are required to develop more skills in a relatively shorter period. However, the apprenticeship...
method is tailored on a time basis. The development and use of newly created simulators in residency programs has promoted a shift in surgical education. Through harmless repetition and in an emotion-free environment, the residents can theoretically gain extensive experience in a brief duration of time.\textsuperscript{19}

Recently, Malone et al.\textsuperscript{12} published an interesting paper in which they discuss the current techniques of computer-based simulation in neurosurgery. These authors concluded that there are some limitations impairing the widespread use of these virtual reality models. Realistic simulation requires fidelity (high-resolution images) and strong interactivity between surgeon and machine.\textsuperscript{1} However, tissue reactivity to manipulation and haptic feedback (tactile sensation experienced by the surgeon) remain unreliable to a certain degree.\textsuperscript{12,18}

Nonetheless, based on the clear advantages of teaching surgery through simulation, we created the S.I.M.O.N.T., especially designed for endoscopic training.\textsuperscript{14,24} Similarity between the model and the human brain can be attested to in the pictures (Figs. 4 and 5) and videos. After initial facial validation, the model had its reliability and method of construction strenuously assessed through several practice sessions with many different neurosurgeons. The results proved that an expert would make a very similar decision in both virtual and real-life situations.

Likewise, it was observed that less skilled surgeons seemed to quickly improve their surgical abilities. Hence, we established a simple manner to objectively evaluate the learning curve of the trainees. Through a progressive and modular approach, the major steps of any neuroendoscopic procedure, such as instrument handling, ventricular navigation, and surgical technique, were didactically taught and followed by laboratory training sessions with the Neurosurgical Endotrainer.

After theoretical explanations and lab demonstrations performed by an expert, the novices were instructed to perform several neuroendoscopic procedures in which they could perform ventriculostomies and resect small ventricular tumors. Under careful observation and immediate feedback, all mistakes were noted. As demonstrated before, serial practical exercises showed a remarkable decrease in the number of errors. To our knowledge, this model is not currently available.

\begin{table}[h]
\centering
\caption{Performance assessments}
\begin{tabular}{ll}
\hline
Parameter & Description \\
\hline
instrument handling & recognize the parts & assemble the neuroendoscope \\
& remain in a comfortable & ergonomic position \\
ventricular navigation & maintain the head camera in the upright position \\
& smooth movement for the duration of the procedure \\
surgical technique & proper knowledge of ventricular anatomy \\
& avoidance of iatrogenic injuries during entire procedure \\
& adequate use of surgical instruments \\
\hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{Quantitative assessment of surgical skills: number of mistakes}
\begin{tabular}{lllll}
\hline
Procedure & p Value & Instrument Handling & Ventricular Navigation & Surgical Technique & Total \\
\hline
1st & 26 & 23 & 11 & 60 \\
2nd & 23 & 19 & 11 & 53 \\
3rd & 17 & 11 & 6 & 34 \\
4th & 6 & 4 & 4 & 14 \\
5th & 4 & 2 & 1 & 7 \\
6th & 1 & 0 & 0 & 1 \\
p value & 0.006 & 0.004 & 0.012 & 0.005 \\
\hline
\end{tabular}
\end{table}
to date, the only one considered valid for neuroendoscopic training as well as the only one that provides formative assessment, which demonstrated efficient learning.

Its simplicity, low maintenance, flexibility, and cost-effectiveness allow practicing in small centers where financial constraints are present on a daily basis. Consequently, the S.I.M.O.N.T. can also be considered a feasible tool that is worth using in any neurosurgical residency program. Neurosurgeons interested in training or organizing courses with these models can directly contact the Pro Delphus Company.

Conclusions

Neurosurgical education is a continuous and complex process that involves several particular issues. During the last decade, innumerable factors, such as an increasing demand for subspecialists, have forced some adaptations to the current method of training. In fact, residents have been pushed to develop their surgical skills in a relatively shorter period of time.

Neuroendoscopic training has some specific requirements. A unique set of instruments is required, as is a model that can resemble real-life situations. Neither cadaveric nor animal models possess the properties needed for a “real,” accurate ventricular endoscopic procedure. The lack of ventricular enlargement, among several other aspects, has impaired the widespread use of such models. Such obstacles encouraged us to create and develop a new method of providing efficient neurosurgical training in the endoscopic field. The S.I.M.O.N.T. is a new alternative model specially designed for this purpose. Validation techniques followed by precision assessments attested to the model’s feasibility. Thus, we believe that this simulator can be of great use for all neurosurgeons pursuing initial, advanced, or complementary training in this area.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Vaz Guimarães Filho.
Coelho, Zymberg. Acquisition of data: Vaz Guimarães Filho. Analysis and interpretation of data: Vaz Guimarães Filho, Coelho, Cavalheiro, Zymberg. Drafting the article: all authors. Critically revising the article: all authors. Reviewed final version of the manuscript and approved it for submission: Vaz Guimarães Filho, Cavalheiro, Lyra, Zymberg. Statistical analysis: Vaz Guimarães Filho, Coelho. Administrative/technical/material support: Lyra. Study supervision: Lyra, Zymberg. Neurosurg Focus / Volume 30 / April 2011

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