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Virtual modelling of the surgical anatomy of the petrous bone

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The surgical anatomy of the petrous bone is difficult to learn and to imagine due to the porous structure. Obviously the surgeon's training is based on cadaver dissections as we are still lacking good, versatile models of the temporal bone and its important structures. The clearly visible, rapid development of computer science provides us with new possibilities that should be immediately engaged in modelling and simulating the human anatomy.

The virtual, three-dimensional computer model of the bony pyramid was created based on the tomographic x-ray 1 mm slices and evaluated in accordance to its usefulness in learning and planning the neurosurgical approaches to the petrous region. The model was created in the virtual reality markup language, in order to make it available through the Internet. The basic anatomy of the main surgical approaches used in this region was visualised and evaluated in accordance with the real, intraoperative anatomy.

The model could be easily accessed through the Internet. It was user-friendly and intuitive. The model seemed to be helpful in planning the basic approaches to the petroclival region.

Computer science, with the help of the virtual modelling techniques, gives us a powerful method of learning and training surgical anatomy and approaches, although cadaveric dissection still remains the main point of the surgeon's training.

key words: temporal bone, virtual reality, petrosectomy

INTRODUCTION

The exponentially growing power of the computer systems may now influence strongly our way of thinking and the philosophy of surgical training and anatomy learning. Obviously, the main way to learn is to work with dissections, to study real specimens and to read thoroughly publications and atlases. However, one has to note that cadaver dissections are performed very rarely, to tell the truth. Strictly speaking, the surgeon performs these a couple of times during his training and eventually forgets. His only help in planning and learning new approaches is his own imagination, supported by plain figures and photographs from atlases. Therefore we find there a great role for computer science, capable of creating virtual dinosaurs like real ones.

The surgical, virtual simulators have been working since the late 1990s [1–3]. They always focus on a small part of the body or on one kind of operation.

Nowadays computer science is becoming more and more influenced by the recent rapid widespread use of the World Wide Web. Therefore the power of

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the computer lies not only in its own software, but also in its capability to work as a librarian in the greatest library of the world. That means that all the important ideas and new objects should be easily accessible through the Internet.

We have decided to build and evaluate the model of the petrous bone — the complicated and porous structure of the skull base. The complexity of the petrous bone anatomy greatly complicates the surgical procedures performed in this region by neuro- and otosurgeons. It is very difficult to navigate inside this bone with a drill, even with help of the modern neuronavigation systems spying every move of the surgical tool in real time. Even the decision of choosing the appropriate approach depends greatly on individual preferences and experience.

There are numerous approaches used in the surgery of the petroclival region [4]. When we analyse them, we can realise how complex the decision making in petrous bone surgery is. One can approach the lesion there from nearly all directions. The approaches through the petrous surface forming the middle fossa include the limited middle fossa exposure of the internal acoustic meatus, the anterior petrosectomy (Kawase approach), the extended middle fossa approach and the subtemporal preauricular infratemporal fossa approach. One can make the approach through the mastoid process in front of the sigmoid sinus. It can be minimal mastoidectomy, the retrolabyrinthine approach, partial labyrinthectomy, the translabyrinthine approach and the transcochlear approach. Finally, one can use the postauricular transtemporal approach, giving us access to the mastoid, tympanic cavity, petrous apex and jugular foramen [4].

Usually the role of preoperative anatomical analysis considers four main problems. It should answer the questions: what approach is best for the region we have to operate on, what structures do we have to avoid, what structures can we sacrifice, how much wider an operating space do we gain?

The planning of the surgical approach is usually discussed a day or a couple of days before the operation. The discussion and the process of planning take place in the surgeon's head, imaging the anatomy. It seems easier to work with a model that could be easily available and accessible in the surgeon's office or even at home. Therefore the virtual model for learning and planning the petrosectomy was built in such a way that it could be accessible through the World Wide Web from every place.

One of the popular standards of virtual objects modelling is the standard called the Virtual Reality Markup Language (VRML). Objects represented in this standard can be sent through the net and visualised and manipulated on the user's local computer with the help of the freeware, which means free additional program. We have used the program named Cortona VRML Client (Parallel Graphics, USA). The program is user-friendly and can be loaded free, directly from the Internet (www.parallelgraphics.com). With the help of this software any user can download the virtual objects from the Internet and manipulate them in virtual reality — rotate, shrink, move, make transparent or semitransparent in order to look at what is inside.

We have assumed that the model should meet the following assumptions: it should help in visualising and realising the three-dimensional anatomy, the model should be easy to operate on, the model should be accessible through the Internet and it should simulate as closely as possible the typical anatomy of the petrous bone.

MATERIAL AND METHODS

The 1-mm x-ray tomographic slices of the temporal bone were analysed in search of the chosen anatomical structures (Fig. 1, 2). These structures were delineated. Next the slices with the delineated objects were reconstructed into the three-dimensional model (Fig. 3), which was then translated into the virtual reality markup language (VRML) (Fig. 4). The image processing and 3-D building were performed by the software Artica Software Studio (Szczytna, Poland).

As a result we have built a virtual model of the bony pyramids with those anatomical landmarks assumed important for the surgeon: the internal acoustic meatus, facial canal, labyrinth, middle ear, carotid fissure, jugular bulb, external acoustic meatus and trigeminal impression.

The model was then downloaded in the Internet page and made accessible. We have evaluated the easiness of the model downloading and manipulating through the modem and Ethernet connections. When the model was downloaded into the Cortona program, we manipulated it in order to plan the basic eleven petrous bone approaches: the limited middle fossa exposure of the internal acoustic meatus, the anterior petrosectomy, the extended middle fossa approach, the subtemporal preauricular infratemporal fossa approach, the approach through the mas-

Figure 1. Superficial view of the petrous region.

Figure 2. Tomographic x-ray scan of the petrous bone.

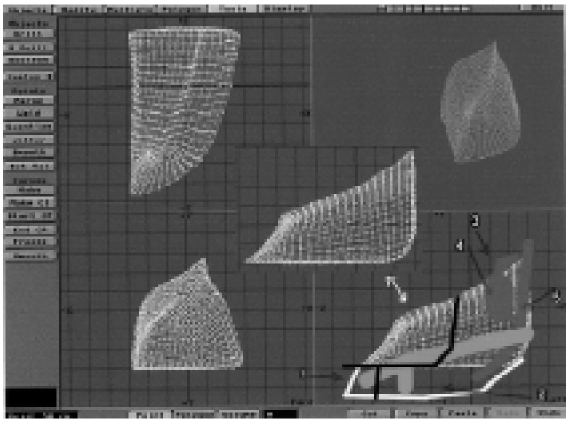

Figure 3. Process of the virtual bone building.

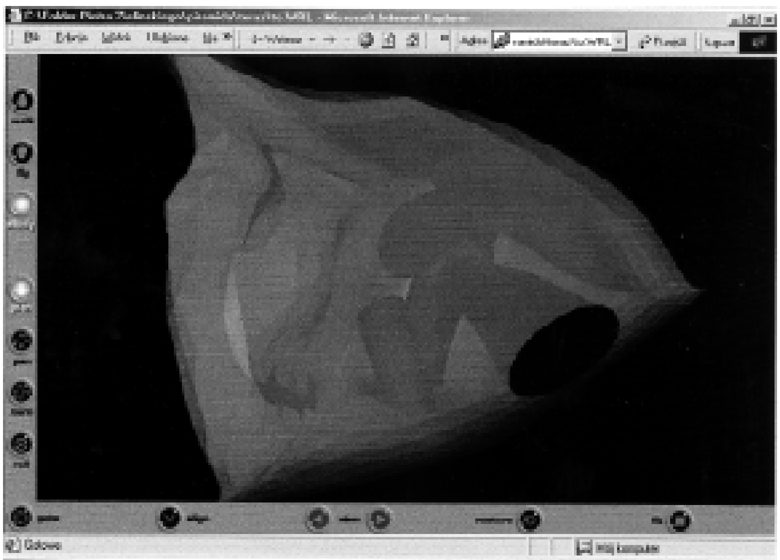

Figure 4. Screenshot of the virtual pyramids, which can be rotated, looked-through, magnified.

toid process in front of the sigmoid sinus, the minimal mastoidectomy, the retrolabyrinthine approach, the partial labyrinthectomy, the translabyrinthine approach, the transcochlear approach and the postauricular transtemporal approach. The basic anatomy of these surgical approaches was visualised and evaluated in accordance with the real, intraoperative anatomy.

RESULTS

The model could be easily accessed through the Internet. The mean download time through the modem line was 10 minutes, and the download time through the local Ethernet was immediate. It was user-friendly and intuitive. The model seemed to be very helpful in learning the anatomy of the basic approaches to the petroclival region.

The limited middle fossa exposure of the internal acoustic meatus could be visualised quite satisfactorily. One could see clearly the layout of the labyrinth, course of the facial canal and the main bony landmarks. The same, clear view was with the anterior petrosectomy, the extended middle fossa approach and the subtemporal preauricular infratemporal fossa approach

The approach through the mastoid process in front of the sigmoid sinus seemed to be poorly simulated due to the lack of the sigmoid sinus visualisation. The same occurred with the minimal mastoidectomy. The retrolabyrinthine approach, the transcochlear approach and the postauricular transtemporal approach, the partial labyrinthectomy and the translabyrinthine approach were also easy to visualise and plan.

CONCLUSION

The model is easy to learn and user-friendly. The model can be used at any time and in any place. The model helps in realising the third dimension in gross surgical anatomy. The standard navigation reconstructions often lack anatomical details. But the reality was still lacking many details and was not tailored to the particular patient's anatomy.

Computer science, with the help of the virtual modelling techniques, gives us a powerful method for learning and training surgical anatomy and approaches, although cadaver dissection still remains the main point of the surgeon's training.

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