Rhinology, 45, 20-23, 2007

Evaluation of an anatomic model of the paranasal sinuses for endonasal surgical training*

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SUMMARY

Objectives: *To assess the suitability of a new anatomic model of the paranasal sinuses for endonasal surgical training.*

Study design: *Prospective observational pilot study.*

Methods: *A new anatomic model of the paranasal sinuses was developed by the Department of Anatomy at the University of Zurich. The practicability of the model was evaluated by three experienced endoscopic sinus surgeons with a special focus on its possible use in training. Standardized surgical procedures were performed under simulated real-life conditions in the operating theatre.*

Results: *The endoscopic appearance of the nasal airway closely resembled real human tissue and the detailed anatomy of the model allowed the same structured surgical steps to be performed as in real life in the absence of bleeding.*

Conclusion: *This anatomic model is a readily available teaching tool for endoscopic sinus surgeons.*

Key words: anatomic model, paranasal sinuses, surgical training, endoscopic sinus surgery

INTRODUCTION

Recent advances in imaging, endoscopes, video-technology and surgical instruments have helped the rhinologist to surgically treat patients with chronic rhinosinusitis and other pathological conditions of the paranasal sinuses and the anterior skull base. However, the huge variation in anatomy of the paranasal sinuses and their close relationship with the brain and orbit pose a surgical challenge. Intensive training is needed to become familiar with the anatomical variations and the surgical techniques required to manipulate instruments within the sinuses under endoscopic vision [(1)].

Traditionally, part of the training for endoscopic sinus surgery is performed on human anatomic specimens although some hand-eye coordination with the endoscope can be learnt using a sheep model [(2,3)]. However, the paranasal sinus anatomy of sheep differs markedly from humans. The availability of appropriate human specimens is limited. To overcome this limitation, several artificial training models have been developed [(2-9)]. Until now, most of these models have only allowed a limited amount of surgical training, as duplicating the pneumatisation of the sinuses has been problematic. Recent modeling techniques have allowed the digitalized information from CT images to be used to reconstruct a 3-D model [(11,12)]. However, whilst these can produce a very accurate reproduction of the bony anatomy, the polymers used do not have the same texture as normal tissue and are not good for practicing endoscopic surgical techniques. They are more suited to practicing purely bony surgery such as repairing facial fractures. An alternative to practicing on a model is robotic virtual endoscopy [(13)] using computer simulation but at present these provide very limited interactive dissection and manipulation of tissue [(6,8)] and the "force feedback systems" that have been developed do not provide a realistic feel of surgery [(7,9)].

A close relationship between clinicians and the Anatomic Department of the University of Zurich led to the development of an artificial anatomic model of the paranasal sinuses. Over several years trials of various polymers have been used before the current model was arrived at that provide good colour, consistence and allowed detailed duplication and pneumatisation of the paranasal sinuses. In a prospective pilot study, the practicability of this model was evaluated with a special focus on its possible use in training and teaching endoscopic sinus surgery.

*Received for publication: August 8, 2006; accepted: November 9, 2006

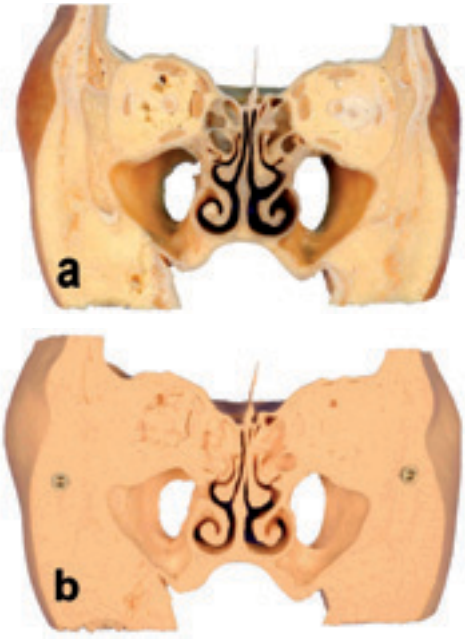

Figure 1. Anatomic model for endonasal surgical training.
a) embalmed cadaver head, slice 4
b) polyurethane cast, slice 4
note the exact copy of the anatomical details

MATERIAL AND METHODS

Anatomic model

A plastic model of the nasal airway and paranasal sinuses was produced based on a cadaver specimen (Figure 1) [10], which was obtained according to the protocol of donors to Institute of Anatomy. The head of a male cadaver (age 72 years) was embalmed with formalin, frozen at -20°C and cut into 1.5 - 2 cm thick slices at the coronal plane. Each slice was then molded with highly fluid soft silicon rubber, which penetrated even thin spaces of the specimen forming a negative cast after it had hardened. In the next step the negative cast was filled with a two-component polyurethane (ReoFlex60, KauPo©) resulting in a flexible plastic slice, which showed all the anatomical details. The different slices were then superimposed to reconstruct the entire head. The moulds mean that many models can be made and these are commercially available (Karl Storz GmbH & Co, Tuttlingen, Germany). At the moment, only one model of the above mentioned cadaver is available, however, the technique described allows to produce other models from other cadavers with different anatomical details if there will be a need for it in the future.

Practical evaluation

A CT-scan of the embalmened cadaver specimen was performed before the block of the paranasal sinuses was sectioned in order to provide radiological information relevant to surgery of the paranasal sinuses. Three experienced surgeons (HRB, DS, NSJ) evaluated the model using a systematic protocol that involved the most frequently used procedures undertaken in sinus surgery. The procedures comprised infundibulotomy; partial anterior ethmoidectomy; maxillary sinusotomy; spheno-ethmoidectomy; sphenoid sinusotomy; fronto-ethmoidectomy and frontal sinusotomy (Figure 2) and were performed under simulated real-life conditions in the operating theatre using the same setup as far as instruments, nursing and video equipment was concerned (Figure 3).

The procedures were recorded by digital imaging and video. A subjective scale (bad – poor – moderate – good – very good – perfect) was used to separately assess the quality of the specimen, the feasibility of the procedure, any technical limitations and the surgeon's overall impression.

RESULTS

The texture of the specimen was considered to be good and reasonably resemble human tissue although there was no bleeding. The surgeons remarked that the elasticity of the tissue was higher than human tissue and this made it more diffi-

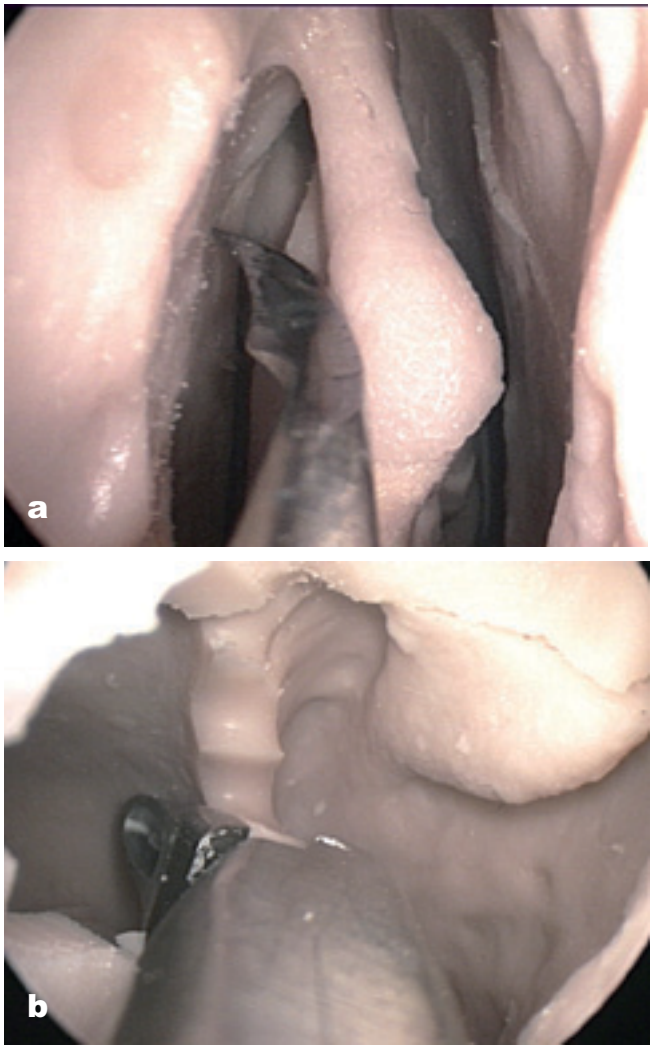

Figure 2. Endoscopic view of a surgical training procedure (right side of the nose).
a) Sickle knife on the uncinate process
b) Sinusotomy of the maxillary sinus

Figure 3. Endoscopic sinus surgery procedure performed on the model.

cult to remove tissue using grasping forceps. When through-cutting instruments were used it gave a realistic sensation akin to human tissue.

The feasibility of practicing endoscopic examination, uncinectomy, maxillary sinusotomy and ethmoid surgery was regarded as good to very good by all three surgeons (see Table 1). Additionally, it was remarked by all three surgeons that surgery in the frontal recess area was more difficult compared to real surgery on a human due to higher elasticity of the tissue. Introducing instruments and working in the middle meatus and ethmoid sinuses was felt to be realistic. Since the model was made of five slices, the cuts between the different slices could sometimes be seen during the procedure. However, the junctions between the slices were minimal and did not hinder surgery. The ethmoid cells were well pneumatized making it easy to explore the posterior ethmoid sinuses and the area of the frontal recess. Due to an increase in rigidity compared with a human specimen, the force used to perform some parts of the surgery was higher than in real life. However, all procedures could be performed without any significant technical limitation.

The overall impression was stated as good to very good by all three surgeons.

Table 1. Evaluation of the paranasal sinuses model for surgical training: Individual rating of the three surgeons.

	Perfect	Very good	Good	Moderate	Poor	Bad
Quality of specimen			3			
Feasibility of procedure		1	2			
Technical limitations			3			
Overall impression		1	2			

DISCUSSION

Endoscopic sinus surgery is an effective method for treating patients with chronic Rhinosinusitis who have not adequately responded to medical management. However, the anatomy of the paranasal sinuses is complex and the narrowness and close relationship with the brain and orbit pose a surgical challenge. Thorough training is needed for the surgeon to become familiar with endoscopic sinus surgical technique. An ideal way for training in this technique is to perform the procedure on a human specimen. Since the availability of suitable human cadavers is limited, an alternative is needed. A variety of devices and models to replace human specimens have been developed, but most of these models are limited to training only certain aspects of the procedure. The ideal replacement of a human specimen would be an artificial model that is identical concerning anatomy and texture of the tissue. Having this in mind, a new anatomic model of the paranasal sinuses was developed to copy the fine details of the complex ethmoid anatomy from a human specimen and the texture of the material was designed to allow surgery on this model with normal instruments. When opening the sinus ostia through cutting instruments give a more lifelike sensation because of the models elasticity. This is good as it encourages the careful removal of specific punched out pieces of tissue. Punches avoid the grabbing and pulling tissue that is less well controlled and result in more torn mucosa and the increase in bleeding that this produces.

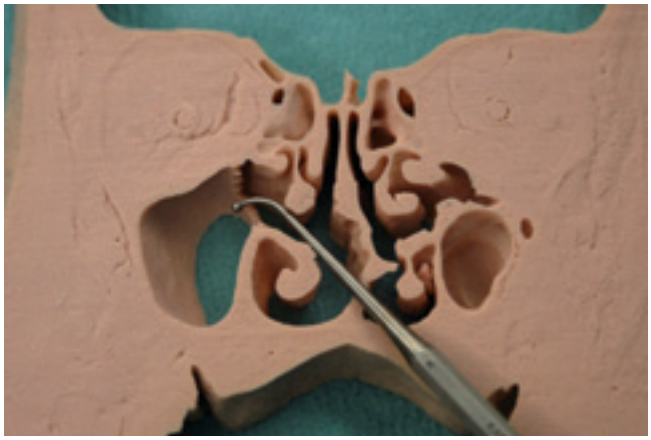

Figure 4. Anterior ethmoid section of the model for evaluation of the performed procedure (sinusotomy of the right maxillary sinus).

The texture and detailed anatomy of the ethmoid system allowed most common procedures to be performed. Two main differences with a human specimen were noted. The first was the higher rigidity of most of the soft tissues compared with a human specimen, which made work in the frontal recess area more difficult than in a human specimen. The other was the elasticity of the material as it made the removal of tissue more difficult when using non-cutting forceps. On the other hand, cutting instruments worked very well. Overall the balance between the rigidity and elasticity of the material that the model obtained was regarded as good.

One big advantage of the model is the fact that it is made of 5 slices. This allows taking the model apart at the end of the procedure and the surgery performed can be evaluated in detail on the slices (Figure 4).

This model is a realistic and readily available teaching tool in education for sinus surgery. Audiovisual examples of the surgical steps that could be done on the specimen could help to get the maximum benefit out of the model.

CONCLUSION

A model has been developed to simulate the human nasal airway and paranasal sinuses. The model was found to reasonably resemble human tissue although there was no bleeding. As the model comprises several sections that can be separated it is especially helpful in teaching the three dimensional anatomy of the paranasal sinuses. The texture of the model and the detailed anatomy of the ethmoidal system allowed the most common procedures to be done without difficulty. This model has the potential to become a realistic and easy available teaching tool for rhinologists to endoscopically examine the nasal airway and learn the techniques of endoscopic sinus surgery.

REFERENCES

1. Kinsella JB, Calhoun KH, Hokanson JA, Bailey BJ. Complications of endoscopic sinus surgery in a residency training program. Laryngoscope 1995; 105: 1029-1032.
2. Kopchok GE, Cavaye DM, Klein SR, Mueller MP, White RA. Endoscopic surgery training: application of an in vitro trainer and in vivo swine model. J Invest Surg 1993; 6: 329-337.
3. Gardiner Q, Oluwole M, Tan L, White PS. An animal model for training in endoscopic nasal and sinus surgery. J Laryngol Otol 1996; 110: 425-428.
4. Edmond CV, Heskamp D, Sluis D, et al. ENT endoscopic surgical training simulator. Stud Health Technol Inform 1997; 39: 518-528.
5. Rudman DT, Stredney D, Sessanna D, et al. Functional endoscopic sinus surgery training simulator. Laryngoscope 1998; 108: 1643-1647.
6. Ecke U, Klimek L, Muller W, Ziegler R, Mann W. Virtual reality: preparation and execution of sinus surgery. Comput Aided Surg 1998; 1: 45-50.
7. Bockholt U, Muller W, Voss G, Ecke U, Klimek L. Real-time simulation of tissue deformation for the nasal endoscopy simulator (NES). Comput Aided Surg 1999; 4: 281-285.
8. Wolfsberger S, Forster MT, Donat M, et al. Virtual endoscopy is a useful device for training and preoperative planning of transsphenoidal endoscopic pituitary surgery. Minim Invasive Neurosurg 2004; 47: 214-220.
9. Yamauchi Y, Yamashita J, Morikawa O, et al. An endoscopic sinus surgery training system for assessment of surgical skill. Stud Health Technol Inform 2004; 98: 416-418.
10. Manestar D, Matanic-Manestar M, Manestar M. Up to date endoscopy of the nose and paranasal sinuses – A model of the nose and paranasal sinuses for FESS training. Medicina 2000; 36: 39-63.
11. Uhl JF, Plaisant O, Ami O, Delmas V. 3D modelling in the field of morphology: methods, investigation and results. Morphologie 2006; 90: 5-50.
12. www.3di.de (web site address)
13. Levy ML, Nguyen A, Aryan H, Meltzer HS, Apuzzo ML. Robotic virtual endoscopy: development of a multidirectional rigid endoscope. Neurosurgery 2006; 59: 134-141.

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