ORIGINAL ARTICLE

Endoscopic Sinus Surgery Under Navigation System—Analysis Report of 79 Cases

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Background: Functional endoscopic sinus surgery (FESS) is the most popular method for treating medicine-refractory sinonasal disease. However, there are some pitfalls with this technique that can result in serious complications. Under the assistance of a navigation system, surgeons can overcome such problems. This study aimed to evaluate the efficacy of FESS aided by a navigation system.

Methods: There were 79 patients who underwent FESS under the assistance of a navigation system in our department between September 2004 and September 2005. Data on preoperative setup time, accuracy of the navigation system, operative time, and amount of blood loss during the operation were collected and analyzed.

Results: Mean preoperative setup time and mean operative time were 10.6 minutes and 112.3 minutes, respectively. The mean number of paranasal sinuses operated on was 5.8. The mean accuracy of the navigator system was 1.08 mm. Mean blood loss was 102.5 mL. Compared with data collected 2 years ago, preoperative setup time and operative time had both shortened. In addition, the number of operated paranasal sinuses had increased. This indicates that operative skill had improved. Moreover, operative time, amount of blood loss during the operation, and number of operated paranasal sinuses presented positive associations and significant differences ($p < 0.05$). No major complications such as blindness or cerebral spinal fluid leakage were noted.

Conclusion: The characteristics of FESS aided by a navigation system include: (1) being able to pilot the relative positions of the operative instruments correctly in 3 dimensions; (2) being able to remove lesions more thoroughly; and (3) its inability to disclose the positions of vessels. As the number of patients we operated on increased, operative time was reduced. On the other hand, blood loss increased when the operations became more aggressive. However, performing FESS with the assistance of a navigation system is a safe way to treat patients with chronic paranasal sinusitis. [*J Chin Med Assoc* 2006; 69(11):529–533]

Key Words: endoscopy, functional endoscopic sinus surgery, navigation system, paranasal sinus disease, stereotaxic techniques

Introduction

Rhinosinusitis is an extremely prevalent disorder that affects individuals and places a large economic burden in the United States as a whole. It is estimated that approximately 33 million Americans per year get sinusitis, with 26.7 million office visits attributed to sinus and related airway disorders.[1,2] In most conditions, endoscopic sinus surgery (ESS) is the first choice of surgery to treat medicine-refractory sinonasal disease. It was estimated that over 250,000 procedures were being performed annually in the United States.[3] However, when a single lens system is used to perform ESS, the 2-dimensional imaging results in a loss of depth of field. Also, the small visual field limits the learning curve of surgeons. Surgeons may find themselves lost, especially when faced with distorted anatomy, significant disease, significant bleeding, or scarring from previous surgery. This can lead to serious injury to patients, including intracranial penetration and loss of vision. Complications resulting from ESS continue to be one of the greatest sources of litigation facing otolaryngologists today.[4] There is an inherent risk of major complications occurring

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in 0.5–1% of such procedures.[5,6] Despite the low occurrence of serious complications, a significant number of severe complications occur every year, given the large number of endoscopic sinus procedures performed.

In an attempt to lessen complications and operate with greater precision, frameless stereotaxic integration of computed tomography (CT) has been used by surgeons during functional endoscopic sinus surgery (FESS) for intraoperative localization. With the use of 3 reference points and the principles of triangulation, any point in space can be localized. The surgeon can precisely identify the position of the surgical instrument without losing his way.

Currently, in our hospital, we employ an optical tracking device for image guidance. The device is the newest generation of navigation system, and is also the first system to be used in the field of otorhinolaryngology in Taiwan. The system is frameless, wireless, and easy to use. The patient undergoes CT imaging using a set protocol that allows the acquired data to be transferred to a computer workstation. At the time of surgery, the CT data that have been processed by the workstation is used for registration of the operative field. The accuracy, within 2 mm, is acceptable for the operation, and the instruments for navigation are calibrated. Axial, coronal, and sagittal views of the location of the monitored instrument's tip are then displayed on the computer screen (Figure 1). The optical systems use infrared light-emitting diodes to localize the patient's head and then track the movement of the tip of an instrument within the field. The workstation can localize, monitor, and project the coordinates of the location of that tip onto a screen in 3 planes. Using a navigation system provides displays in 3 views, and this facilitates the surgeon's ability to think and operate in a 3-dimensional fashion. The placement of the tip of a probe can be used not only to localize structures but also to cross-check the navigational accuracy periodically during surgery by touching known points and documenting that those points are correctly detected on the screen. Throughout the procedure, the location of the monitored probe can be tracked, allowing surgery on the desired areas while avoiding the surrounding vital structures.[7] This study aimed to evaluate the efficacy of FESS aided by a navigation system.

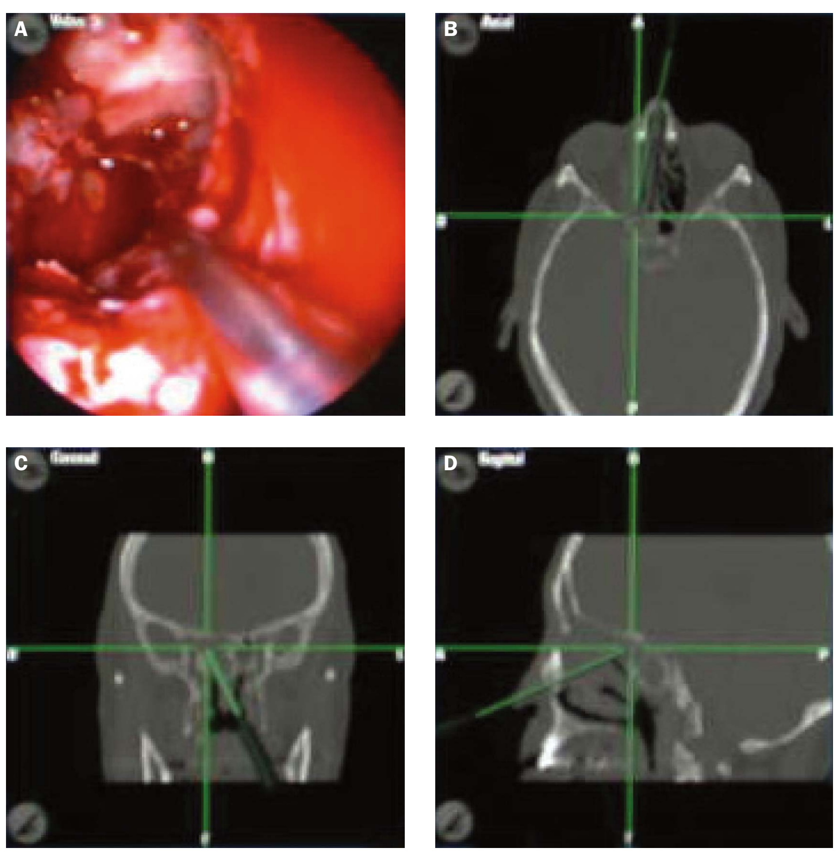

Figure 1. The intraoperation appliance for identifying the sphenoid sinus: (A) camera view of functional endoscopic sinus surgery. Real-time display of instrument location from: (B) axial; (C) coronal; and (D) sagittal views.

Methods

Between September 2004 and September 2005, 79 adult patients who had chronic paranasal sinusitis refractory to medical treatment were enrolled in this study. FESS was performed with stereotactic guidance provided by VectorVision® ENT (BrainLAB AG, Feldkirchen, Germany). The setup time, accuracy of the navigation system, number of diseased sinuses operated on, operation time, intraoperative blood loss and complications were recorded and analyzed.

We separated the diseased sinuses into maxillary, anterior ethmoid, posterior ethmoid, sphenoid and frontal, i.e. a total of 5 sites on each side. FESS was usually performed over the ostium of the maxillary sinus, part of the anterior ethmoid and the posterior ethmoid to minimize the technique's invasiveness. If, on each side of the nose, ≥4 sites were operated on, or there were ≥7 sites in total, then the dissection was considered extensive. Two-sample *t* test was used to determine the relationships between variables. All calculations and analyses were done using SPSS version 12.0 (SPSS Inc., Chicago, IL, USA).

Results

Data for the number of sinuses operated on, setup time, operative time, accuracy of the navigator system, and intraoperative blood loss are listed in Table 1 and illustrated in Figure 2. For comparison, our initial experience with the navigator system is shown in the column "2 years ago" in Table 1.[8] Operative time, intraoperative blood loss and number of paranasal sinuses operated on showed significant positive correlations and differences ($p < 0.05$) (Table 2). There were no major complications such as blindness or cerebrospinal fluid leakage, although there were a few cases of massive and minor bleeding (Table 3).

Table 1. Descriptive data of results

	Mean ± SD	Range	2 years ago[8]
Sinuses operated on (*n*)	5.77 ± 2.98	1–10	5.5
Setup time (min)	10.62 ± 2.03	10–20	19
Operative time (min)	112.32 ± 51.18	20–255	129.7
Accuracy (mm)	1.08 ± 0.22	0.50–1.80	1.10
Blood loss (mL)	102.53 ± 155.72	2–800	101

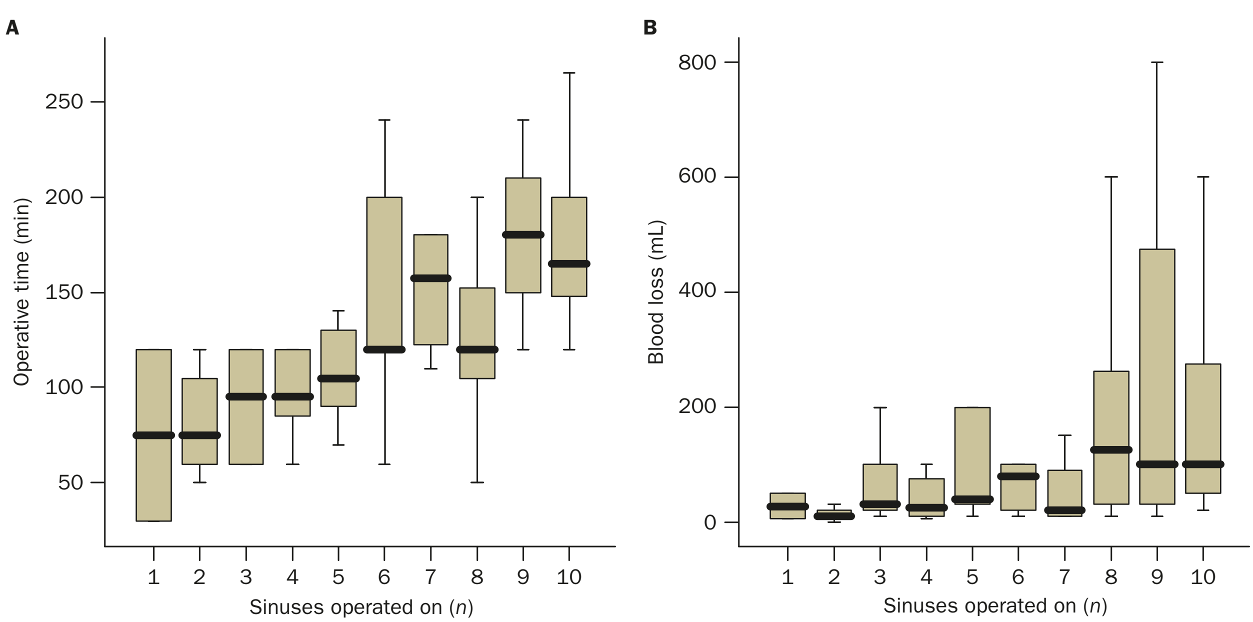

Figure 2. Box-and-whisker plots showing the distribution of: (A) operative time; and (B) intraoperative blood loss with number of sinuses operated on.

Table 2. Relationships between number of sinuses operated on, operative time and intraoperative blood loss

	Total number of sinuses operated on	Mean	*p*
Operative time (min)	≥ 7	157.59	< 0.001
	< 7	98.93	
Blood loss (mL)	≥ 7	168.10	0.008
	< 7	53.77	
	Number of right sinuses operated on	Mean	*p*
Operative time (min)	≥ 4	150.96	0.001
	< 4	106.67	
Blood loss (mL)	≥ 4	182.00	0.010
	< 4	56.33	
	Number of left sinuses operated on	Mean	*p*
Operative time (min)	≥ 4	147.50	< 0.001
	< 4	97.57	
Blood loss (mL)	≥ 4	149.86	0.009
	< 4	52.33	

Table 3. Complications and recurrence

Major complications, *n* (%)	
Major bleeding (blood loss > 400 mL)	4 (5.06)
Cerebrospinal fluid leakage	0
Meningitis	0
Brain damage	0
Brain hematoma	0
Orbit penetration	0
Orbital hematoma	0
Diplopia	0
Proptosis	0
Blindness	0
Death	0
Minor complications, *n* (%)	
Minor bleeding (blood loss > 200 mL)	2 (2.53)
Periorbital ecchymosis	0
Infection	0
Facial pain	0
Stenosis of nasolacrimal duct	0
Smell disturbance	0
Recurrence, *n* (%)	6 (7.59)

Discussion

Early image-guidance systems required fixation of the patient's head in a stereotactic frame during surgery. Subsequently, armless and frameless systems have used either electromagnetic or optical (infrared) signals to localize instruments within the surgical field. This has greatly enhanced the applicability of this technology for FESS, and means less patient discomfort (from headset fixation), and less time and money spent on repeated CT scans.

The value of a navigation system lies in its ability to allow the surgeon to accurately determine the boundaries of the surgical field and the location of surrounding vital structures. This facilitates safer and more thorough eradication of disease, particularly in cases of extensive polyposis, revision surgery, and neoplastic sinonasal disease. The navigation system allows more precise and confident identification of specific anatomic sites during FESS. Accuracy to within 2 mm is generally acceptable during image-guided surgery. This is useful in confirming the identity of large compartments within the sinus cavities (i.e. posterior ethmoid cell *vs.* sphenoid), rather than in distinguishing between millimeter increments.[9] Compared with our initial experience about 2 years ago, preoperative setup time and operative time had both shortened. In addition, the number of paranasal sinuses operated on had increased. Although not statistically significant, these results indicate maturation in our use of the navigator system as we gained more experience.

However, image guidance cannot serve as a substitute for a thorough knowledge of the surgical anatomy. The image shown on the navigation system is the same as a CT scan image. The surgeon cannot tell where the blood vessels are from simply looking at the screen. He would be required to make a judgment according to his experience and knowledge of the surgical anatomy. When performing FESS, there are 3 vessels that can be involved in massive bleeding: the anterior ethmoid artery, posterior ethmoid artery and sphenopalatine artery. The anterior ethmoid artery is located between the frontal sinus and anterior ethmoid sinus. The posterior ethmoid artery and sphenopalatine artery are located posterior to the ground lamina. Approaching the deeper part of paranasal sinuses, larger branches of main vessels will be met. If the disease extends to the frontal sinus or sphenoid sinus, the chance of encountering those vessels will be increased. If the dissection extends more widely, the bleeding risk will increase and the operation time will be prolonged. In our study, extent of disease was significantly ($p < 0.05$) correlated with blood loss and operation time. Although we encountered some bleeding during operations, there were no other complications. If bleeding is excluded from our analyses, as in other studies,[5,6] our complication rate would be 0%.

We found that even with the loss of landmarks or with bleeding, an experienced surgeon can complete FESS under the guidance of the navigation system without any major brain or ocular complications. The real-time localization of surgical instruments resulted in safer and more thorough surgery, and setup and operative times can be shortened as the surgeon's technique matures. The navigator system was deemed helpful in situations where the surgical anatomy was altered by previous surgery and extensive inflammatory disease (polyposis, fungal sinusitis, pansinusitis).[10]

In our experience, the success rates of FESS were 93.5% as demonstrated by improvement in symptoms and 71.9% as shown by improvement in CT findings.[11] In this study, we did not routinely examine patients with CT scan on postoperative follow-up. Patient complaints or physical findings of recurrence were 7.6%. This is compatible with our previous experience.

Cohen and Kennedy are of the opinion that ESS is no longer exclusively for the management of chronic rhinosinusitis and nasal polyposis.[12] Advances in imaging technology and increased experience with endoscopy has broadened the endoscopic ventral skull base exposure from the odontoid process to the foramen ovale to the olfactory bulb. Sinonasal malignancies as well as anterior skull base lesions have become part of the rhinologist's responsibility.[12] We use the navigation system to assist in skull base surgery, and find it to be very useful in identifying specific locations in a 3-dimensional manner and in helping the surgeon to eradicate the disease.

In conclusion, the characteristics of FESS aided by a navigation system include: (1) being able to pilot the relative positions of the operative instruments correctly in 3 dimensions in real time; (2) being able to remove lesions more thoroughly; and (3) its inability to disclose the positions of the vessels. When we first started to perform operations with the navigation system 2 years ago, longer preoperative setup and operative times were required compared to now. As the number of patients we operated on increased, our operative skill matured, and operative time was gradually reduced. On the other hand, blood loss increased when the operations became more aggressive, when the surgical field was enlarged, and when branching vessels were encountered. However, performing FESS with the assistance of a navigation system is a safe way to treat patients with chronic paranasal sinusitis.

Acknowledgments

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