mp ORL 86 ANGLAIS 207-275(new) 15/02/05 11:33 Page 23



# Sinus navigation: contribution and limitations

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## ABSTRACT

Computer-assisted systems can be used for image-guided navigation during endoscopic sinonasal surgery. The objective is to diminish the risk of orbital or skull-base injury when abnormal anatomy or previous surgery makes landmarks difficult to identify accurately. Endoscopic visualization combined with real-time localization on a reconstructed 3D model allows for the use of new landmarks that are less likely to show variations. We have been using a computer-assisted navigation system since 2001; thus far, 22 patients have been treated with this system for sinonasal polyposis, mucocele, or chronic sinusitis, usually after earlier procedures for the same reasons. We compared these 22 patients to 22 controls in terms of operating time and of recurrence and adverse event rates after a mean follow-up of 2 years. The rates of early recurrence and severe adverse events (orbital wall damage and cerebrospinal fluid leakage) were similar in the two groups. In contrast, computer-assisted navigation was associated with significantly lower rates of minor adverse events (postoperative infection, bleeding, and headaches). Use of computer-assisted navigation did not increase operating time counted from the time the equipment was set up. Thus, computer-assisted navigation may be useful in patients with recurrent sinonasal polyposis, mucocele, or chronic sinusitis. *(Fr ORL - 2005 ; 86 : 23-28)*

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mp ORL 86 ANGLAIS 207-275(new) 15/02/05 11:33 Page 24



## INTRODUCTION

The development of endoscopy has radically transformed sinus surgery over the last two decades. Endoscopic sinus surgery has obviated the need for a surgical microscope, which is awkward to handle and provides a narrower field of view. Furthermore, the indications of external approaches for sinonasal surgery have changed. Advances in computer-assisted technologies have fueled these new developments. Better methods for image acquisition and computed tomography (CT) image processing provide accurate visualization of sinus abnormalities, benefiting the diagnosis and facilitating the selection of surgical strategies.

The surgeon can use the images to identify structures that will serve as landmarks after the usual endoscopic landmarks are altered by the surgical procedure. To optimize intraoperative identification of sites of interest, a group working at the Aachen Hospital in Germany started using a neurosurgery stereotactic guidance system for sinonasal surgery as early as 1986 [1]. Since then, better guidance systems that use fiducial markers attached to the patient have superseded conventional stereotactic guidance systems.

The objective of this study was to determine whether computer-assisted navigation improved recurrence and adverse event rates after sinonasal surgery without increasing the operating time.

## MATERIAL AND METHODS

We retrospectively reviewed the medical charts of the 22 patients who underwent endoscopic sinus surgery using computer-assisted navigation (CAN) at the Otorhinolaryngology Department of the Gui de Chauliac Teaching Hospital, Montpellier, France, between May 2001 and February 2003.

Mean age was 48 years 10 months (SD=14.29 years) and age range was 15 to 73 years. There were 16 males and 6 females. The mean number of sinonasal procedures prior to the CAN procedure was 1.41 (SD=1.05; range, 1-4).

Reasons for surgery were mucocele, sinonasal polyposis, and chronic sinusitis of unknown cause (Table I). Of the 22 patients, 17 (77.3%) had a single diagnosis and 5 (22.7%) had more than one diagnosis.

**Table I: Diagnoses in the 22 patients who had surgery with a computer-assisted navigation system (5 patients each had two diagnoses: sinonasal poly posis and mucocele).**

| | Sinonasal polyposis | Mucocele | Chronic sinusitis |
|---|---|---|---|
| Sinonasal polyposis | 5 | | |
| Mucocele | 5 | 10 | |
| Chronic sinusitis | - | - | 2 |

The surgical procedure was bilateral in 10 (45.5%) patients, unilateral in 11 (50%) patients, and combined with an external approach in 1 (4.5%) patient (Table II). To eliminate potential bias related to variability across surgeons, all 22 patients included in this case-series were treated by the same surgeon.

**Table II. Surgical procedures in the 22 patients who underwent surgery with a computer-assisted navigation system**

| Procedures | Number of patients | Percentage |
|---|---|---|
| Bilateral ethmoidectomy | 10 | 45 |
| Unilateral ethmoidectomy | 6 | 26 |
| Middle meatotomy with restoration of naso frontal canal patency | 2 | 9 |
| Middle meatotomy | 1 | 5 |
| Restoration of naso frontal canal patency | 1 | 5 |
| Sphenoidectomy | 1 | 5 |
| Conversion to an external approach | 1 | 5 |

Mean follow-up was 24.90 months (SD=7.15; range, 10-35). All patients were evaluated regularly and contacted for information about recurrences. We selected 22 controls who had surgery performed during the same period and by the same surgeon. The control group was similar to the patient group regarding age (p=0.19, Student's t test with 42 df), sex (p=0.34; chi-square test), history of sinus surgery (p=0.25, Student's t test with 42 df), diagnosis (p=0.61, chi-square test), and type of surgery (p=0.97, chi-square test).

mp ORL 86 ANGLAIS 207-275(new) 15/02/05 11:33 Page 25



For each patient and control, we recorded the following data: number of recurrences, preparation time counted from patient arrival in the operating room to the incision, operating time, total time (sum of preparation and operating times), and number of intraoperative and postoperative adverse events.
The LandmarX navigation system (Medtronic-Xomed, Jacksonville, Florida, USA) was used, with Mach 3.0 software until April 2002 and Mach 4.0 software thereafter. This system includes a reference headframe and several optical probes containing infrared-emitting diodes. The infrared light is transmitted to an optical camera. A 3D model of the patient's anatomy is built from CT images obtained with 1-mm slice thickness and no gap. The reference headframe and instruments were sterilized in compliance with current recommendations.

**Statistics**

For data analysis, we used the Student t test and the chi-square test. The variance equality hypothesis was verified for the mean-duration variables (F test). For all tests, the results were considered significant when P was smaller than 0.05.

## RESULTS

**Influence of computer-assisted navigation on the recurrence rate**

The recurrence rate in the CAN group was 22.7% (5/22). In these 5 patients, the number of previous procedures for the same diagnosis ranged from one to three. The diagnosis was mucocele in 2 patients, chronic sinusitis in 2 patients (including 1 patient subsequently diagnosed with Wegener's granulomatosis), and sinonasal polyposis in 1 patient.
Of the 2 patients with mucocele, 1 had a primary unilateral ethmoidofrontal lesion and the other a bilateral frontal lesion secondary to a fracture of the anterior skull base. Each patient had had one previous procedure for the same condition. The patient with recurrent sinonasal polyposis had had three previous procedures. A patient with chronic bilateral ethmoidal and maxillary sinusitis had had one previous procedure.
The recurrence rate in the control group was 27.3% (6/22). Of the 6 patients with recurrences, 3 had unilateral frontal mucocele, 2 had sinonasal polyposis, and one had mucocele of the maxillary sinus. Recurrence rates were similar in the two groups after a mean follow-up of 2 years (p=0.73, Student's t test with 42 df). CAN use did not seem to influence success rates in patients with a history of multiple surgical procedures for mucocele, sinonasal polyposis, or chronic sinusitis.

**Influence of computer-assisted navigation on the postoperative course**

Of the patients treated with CAN, 16 (72.7%) had uneventful postoperative courses. There were no major intraoperative adverse events (orbital wall injury, massive bleeding, or cerebrospinal fluid [CSF] leakage). One patient required combined use of an external approach to the frontal sinus (eyebrow approach) for reaming of the nasofrontal canal. Postoperative adverse events were as follows: mild infection of the operative site requiring outpatient antibiotic therapy in 4 patients, bleeding requiring wick drainage for 4 days in 1 patient, and acute decompensation of latent adrenal gland insufficiency after corticosteroid discontinuation in a patient with polyposis.
The postoperative course was uneventful in 11 (50%) controls. Orbital wall injury with minimal fat extrusion occurred in 1 patient and temporary CSF leakage in another patient. One patient complained of persistent headaches. Seven patients required outpatient antibiotic therapy for mild operative-site infection. Prolonged wick drainage for bleeding was used in 1 patient.
Severe adverse events, namely, orbital wall injury and CSF leakage, occurred with similar rates in the two groups (p=0.24, test exact de Fisher).
Minor adverse events (bleeding, infection, and headaches), in contrast, were significantly less common with CAN (p=0.04, chi-square test).

**Influence of computer-assisted navigation on operating times**

We studied three durations: preparation time, operating time and total time, computed as the sum of the preparation and operating times. With CAN, mean preparation time was 68 min 11 sec (SD=20.56;

mp ORL 86 ANGLAIS 207-275(new) 15/02/05 11:33 Page 26



range, 40-110), mean operating time was 91 min 22 sec (SD=33.06; range 45-130), and mean total time was 159 min 33 sec (SD=37.29; range, 110-255). In the control group, mean preparation time was 54 min 5 sec (SD=17.43, range, 30-100), mean operating time was 81 min 49 sec (SD=37.21, range, 35-130), and mean total time was 135 min 55 sec (SD=45.87, range, 60-230).

**Figure 1: Surgery for mucocele in the right maxillary sinus.** ***The operator makes contact with a bony wall at the roof of the sinuses.***

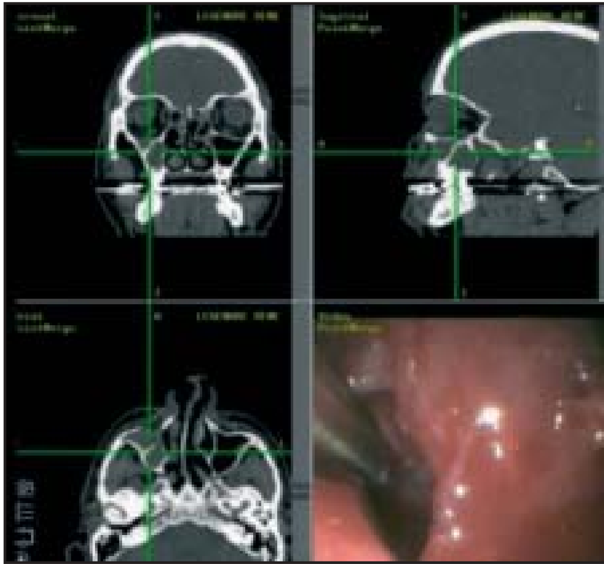
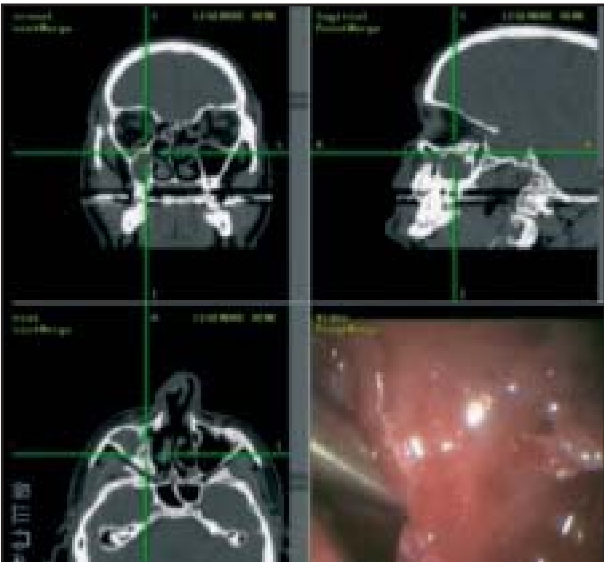


**Figure 2: Use of computer-assisted navigation.** ***The wall is seen as a neoseptum rather than the floor of the orbit and can therefore be collapsed safely.***



Using CAN significantly increased the preparation time (p=0.018, Student's t test with 42 df), on average by 14 min 3 sec. Neither operating time nor total time were significantly different in the two groups (p=0.37 and p=0.07, respectively; Student's t test with 42 df), although trends toward longer times were found in the CAN group. The increase in preparation time in the CAN group reflected the time needed to set up the equipment. However, this increase was not large enough to significantly increase the total time spent by the patient in the operating room.

## DISCUSSION

In our study, using CAN did not influence recurrence rates (22.7% vs. 27.3% in the controls), i.e., the long-term effectiveness of the surgical procedure.
In the only published study reporting long-term recurrence rates after surgery with CAN, the 5-year recurrence rate in 120 patients was 16.5% [2]. Whether recurrences are ascribable to CAN or to the characteristics of the disorders treated with CAN deserves discussion.
Many studies have found a high degree of accuracy in surgical landmark identification by CAN, in the order of 2 mm with last-generation devices [3-6].
Our experience supports these findings. Furthermore, recurrences after endoscopic surgery with or without CAN in our study were associated with a history of multiple surgical procedures, sinonasal polyposis, and frontal location of mucoceles. Tabaee et al. reported similar risk factors [2]. Taken together, these data indicate that recurrences are ascribable to the characteristics of the disorder being treated rather than to inadequate effectiveness of endoscopic surgery.
This has implications for the use of CAN. CAN expands the spectrum of cases that can be treated endoscopically but does not completely eliminate the need for external approaches [7]. In some patients, most notably those with frontal mucoceles, an external approach may be needed in addition to endoscopic surgery in order to increase the likelihood of complete excision, thereby reducing the recurrence rate [8].

mp ORL 86 ANGLAIS 207-275(new) 15/02/05 11:33 Page 27



CAN was associated with a decreased adverse event rate (27% vs. 50%). In keeping with most of the previously published studies, none of the patients in the CAN group experienced serious adverse events (orbital wall injury, massive bleeding, or CSF leakage) [2-3]. The adverse event rate in the control group was higher than in earlier studies [8], but this can be ascribed to selection bias. Indeed, adverse event rates were higher in studies that included only patients with multiple surgical procedures, frontal and sphenoidal disease, or abnormal sinus anatomy [4]. All the patients included in our study were treated by the same surgeon, which eliminated potential bias due to inter-operator variability. Rates of serious adverse events (orbital wall injury and CSF leakage) were not significantly different in our two groups.

Although the ability to position landmarks on a 3D model may add to the information provided by endoscopic visualization (Figures 1 and 2), the absence of a difference in serious complications between the CAN and control groups in our study indicates that the surgeon's experience remains the most important factor. ?

Minor adverse events (bleeding, infections, and headaches) were less common in the CAN group than in the control group (p=0.04), in agreement with earlier studies [2,10]. One possible explanation is that the decreased invasiveness associated with CAN obviates the need for extensive ethmoidal curettage, a procedure that adversely affects function.

Setting up the CAN system significantly increased the preparation time in our study, by 14 min on average. Shorter times have been reported with other navigation systems [4,11-12]. Although setting-up times vary across systems, they are also influenced by the experience of the surgical team. Thus, only 10 min were needed to set up the CAN in each of the last 10 patients in our study. Neither the operating time nor the total time was significantly increased by CAN use in our patients, in keeping with earlier data [13-14]. One explanation is that the procedure is done using the same technique and instruments but that the 3D landmark identification system decreases the time needed to access the lesions. Thus, the time needed to set up the CAN is compensated for during the procedure, so that there is no increase in total time. Another possibility is that our sample size was too small to detect an increase in the total operating time; thus, the p value was close to the significance threshold (0.07). However, this does not explain why we found no difference in operating time (p=0.37).

Independently from the increased preparation time, CAN requires a specific imaging protocol that differs from the diagnostic protocol. This increases the use of resources (additional CT or magnetic resonance imaging, need for additional equipment and consumables).

The cost of CAN is difficult to evaluate given the rapid changes in prices of imaging studies, equipment, and consumables, as well as the variations in frequency of CAN use. However, a number of devices can be modified to serve both for neurosurgery and for skull-base surgery.

In sum, use of a navigation system produces results that compare favorably to conventional surgery and involves only minimal loss of time. However, the results reported here were obtained by a surgeon who had extensive experience with endoscopic surgery. Whether similar results would have been obtained by a less experienced surgeon is unclear. Therefore, although navigation systems may be useful adjuncts to the surgeon's armamentarium, thorough familiarity with facial and skull-base anatomy remains essential for making decisions when the endoscopic data fail to match the 3D reconstruction data.

## CONCLUSION

Navigation systems for treating sinonasal disorders constitute a useful addition to the therapeutic armamentarium. In experienced hands, navigating systems expand the indications for repeat endonasal surgery at the cost of a slight nonsignificant increase in treatment time. However, the results are not better than with conventional endoscopic surgery, most notably in disorders that are often refractory to endoscopic surgery alone (e.g., frontal mucoceles). Thus, use of a navigating system does not completely eliminate the need for combined endoscopic and external approaches.

Although CAN was useful in experienced hands for treating challenging cases, results obtained by young surgeons who are learning to perform endoscopic endonasal surgery remain to be investigated. Another area for further study is first-line treatment of sino-

mp ORL 86 ANGLAIS 207-275(new) 15/02/05 11:33 Page 28



nasal disorders with CAN. Technological advances will probably improve the precision and ergonomic characteristics of navigating systems. Nevertheless, these systems are merely tools, and their use requires in-depth knowledge of endoscopic endonasal surgical techniques.

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