Computer-Assisted Navigation System in Pediatric Intranasal Surgery

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Objectives: To introduce a computer-assisted navigation system and to evaluate its application in pediatric sinusonasal surgery.

Methods: A commercially available wireless passive marker system that allows the calibration and tracking of virtually any instrument was adapted to children and used during pediatric endoscopic sinusonasal surgery.

Results: The headset localizer that was initially used in computed tomographic scanning was not well accepted by children. Correlation of the preoperative computed tomographic scan to the actual patient was made possible by a laser device. Setup time was able to be decreased from an initial 20 minutes to 3 minutes. The average recording accuracy was 1.1 mm. The advantages of the system became apparent as experience increased in cases involving sinus polypsis, choanal atresia, nasopharyngeal fibroma removal, tumor biopsy, and minimally invasive maxillary, frontal, and sphenoidal surgery.

Conclusions: The computer-assisted navigation system was used first as a control system and then, as experience increased, as a true surgical guide. Indications for its use also increased. Pediatric intranasal surgery was performed using 2 complementary guides: an endoscopic view and a computed tomographic view of the instrument’s position.

Arch Otolaryngol Head Neck Surg. 2002;128:797-800

INUSONASAL SURGERY for children has progressed technologically over recent years, aiding in the application of an endoscopic approach and minimally invasive surgery. Even so, anatomical markers are not adequate for proper perioperative assessment of normal areas and pathological areas. Surgical accuracy could be enhanced by the use of an image guidance system in association with endoscopy.

Computer-assisted navigation systems (CANSs) are based on stereotaxic recording and have long been used by neurosurgeons as a surgical guide for minimal craniotomy or for tumors that are hard to locate. Two main types of image guidance systems have been developed. Optical-based image guidance systems use an infrared camera array to monitor instruments and head position. Unlike electromagnetic-based systems, these devices do not have problems of signal interference from metallic objects near the surgical field. However, a clear line of sight must be maintained between the infrared camera and light-emitting diodes during surgery.

Over the past few years, these systems have been developed in functional endoscopic sinus surgery (FESS) for adults as a surgical control in difficult cases or as a surgical guide for minimal conservative surgery. The objectives of the present report were to adapt an image guidance system for use in children and to evaluate its application in pediatric nasal and sinus surgery.

RESULTS

CANS COMPATIBILITY WITH PEDIATRIC SURGICAL INSTRUMENTATION

During surgery, the CANS could be used to reference all surgical instruments, including a microdebrider and its various blades and suction tubes. The initial extra installation and calibration time of 20 minutes decreased to 3 minutes.

ACCURACY OF PEROPERATIVE RECORDING

The mean reference accuracy for the anatomical marker ranges averaged 1.1 mm using the system with only a perioperative headset. A loss in accuracy was noticed during surgery in the first cases, owing to slight changes in headset position. This was probably due to stretching of the skin by the headset itself.
PATIENTS AND METHODS

COMPUTER-ASSISTED NAVIGATION SYSTEMS

The sinus navigation system (VectorVision; BrainLAB, Heimstetten, Germany) used in this study was previously developed for neurosurgery and FESS in adults. It was a non-invasive system that linked a freely hand probe tracked by a passive-marker sensor system to virtual computer image space on the patient’s preoperative computed tomographic (CT) images. It was based on infrared flashes with passive markers that reflected infrared light-emitting diodes positioned around 2 cameras that detected object positions.

Software was used by the surgeon with a sterile remote control. The CANS that was used initially was replaced by a more compact system (VectorVision Compact System; BrainLAB). The compact design, which was developed exclusively for otorhinolaryngology, was optimized for operating rooms with space constraints.

PREOPERATIVE PROCEDURE

Computed tomographic scanning was performed before surgery. Initially, a headset and fiducial markers were required both during preoperative CT scanning and during surgery. A headset that would be well tolerated was positioned with a noninvasive flexible fixation system and firmly fitted onto the nasal dorsum and parietal area and into the outer ear canals (Figure 1). The headset included 6 passive infrared markers, allowing reliable correlation of the preoperative and perioperative phases, so that the headset could be secured in the right position during surgery. The markers were positioned in the nasal and ethmoidal areas to limit irradiation by CT scanning. The headset that was initially necessary during CT scanning was no longer required. The CT images were transferred from the magnetic optical disk to the navigation system. Because the CT scanning was performed on a 1-mm basis, the accuracy of the system could not exceed 1 mm.

PERIOPERATIVE PROCEDURE

Initially, the headset was placed on the patient’s head in the same position as during the preoperative CT scan. The 6 markers had to be accurately correlated to the 6 fiducial markers on the preoperative images. To optimize the accuracy of the navigation system, the exact position of the headset was checked by a pointing instrument positioned on the nasion.

When the headset was no longer required during CT scanning, a preoperative correlation with preoperative image data was achieved semiautomatically. A cordless laser device sent 2 different laser beams that communicated with the passive camera system during scanning. While the surface points were being acquired, an algorithm matched the position of the acquired laser points to the preoperatively scanned data sets. The navigation system allowed simultaneous display of the coronal, sagittal, and axial views, as well as 3-dimensional reconstruction of the endoscopic image, simultaneously on the same screen.

A passive infrared sensor was set on the intranasal surgical instrument. The instrument could be calibrated in diameter and length, so that its tip could be located with accuracy. Several instruments could be referenced and used simultaneously during navigation.

STUDY POPULATION

The CANS was used in 34 pediatric cases (14 boys and 20 girls; age range, 4 days to 15 years). Surgical procedures were performed in cases involving polyposis (n=10), choanal atresia (n=5), nasopharyngeal fibroma (n=3), and tumor biopsy (n=1); there were also 8 cases in which minimally invasive sinus surgery was performed.

REVISION SURGERY FOR POLYPOSIS

A CANS was first used in revision surgery for polyposis in cystic fibrosis (Figure 2) to help complete ethmoidectomy and polyp resection. It was used as a surgical guide in the 5 difficult cases reported herein, in which the anatomical markers defined by endoscopy were modified by previous surgery. Ethmoidectomy could be completed with respect to the integrity of the orbit wall and ethmoidal roof.

SURGERY FOR POLYPOSIS IN CYSTIC FIBROSIS

A CANS was then used in the first surgical procedures (Figure 3) in cases involving polyposis in cystic fibrosis (n=8). The system was again helpful during ethmoidectomy, and the operation was able to proceed under inflammatory conditions involving blood and purulent secretions. It was particularly useful in cases of cystic fibrosis, allowing quicker surgery: the duration decreased to an average of 20 minutes per side, compared with 45 to 60 minutes per side without CANS.

The CANS enabled the ethmoidal roof to be distinguished from the floor of ethmoidal cells, despite their similarity during FESS. Completion of ethmoidectomy at the end of procedure was ensured by tracking the tip of the referenced pointer along the orbit wall and ethmoidal roof.

CHOANAL ATRESIA

The CANS allowed the position of the instruments to be visualized in relation to bone atresia (n=7). In cases of recurrent stenosis, it was used to complete vomer and pterygoid bone resection (Figure 4). It was found that bone resection was insufficient during the first procedure, being one possible factor of recurrent stenosis. The CANS could also be used as a surgical guide when endoscopic control was made difficult by the presence of blood.

NASOPHARYNGEAL FIBROMA

Recurrent nasopharyngeal fibroma was managed by endoscopic resection in 3 cases. Two recurrences were removed from the sphenoidal sinus. Direct guidance allowed exact location and conservative resection. The other
case was on the external part of the choana. The CANS helped ensure complete removal.

TUMOR BIOPSY

A child with midface osteosarcoma was treated by surgery and chemotherapy. A CT scan showed possible residual tumor invading the sphenoidal sinus. The endoscopic view was insufficient to allow secure biopsy, avoiding internal carotid artery and optic nerve. During the procedure, the CANS was used to guide instruments to the area. In 2 other cases, the CANS guided the biopsy instruments directly to the tumor in the sphenoidal area.

MINIMAL CONSERVATIVE SURGERY

The use of CANS in these pediatric cases enabled surgery to be limited to the pathological area. The system was also helpful for removing polyps in the frontal (Figure 5) or maxillary sinus (n = 5) and for guiding instruments into the sphenoidal sinus using a more conservative approach (Figure 6), without excision of the posterior portion of middle turbinate (n = 3). To carry out this conservative approach, the surgeon had to rely on an endoscopic view and direct guidance from the position of the instruments on the CT images.

COMMENT

The most difficult task in adapting the passive infrared CANS to pediatric intranasal surgery was the development of a noninvasive pediatric headset that would fit accurately both during preoperative CT scanning and during surgery. Still, having to wear a headset during preoperative CT scanning was uncomfortable and often painful for children; therefore, the CT scans were often inadequate. Then, an attempt was made to eliminate the headset during preoperative CT imaging. A laser device allowed perioperative semiautomatic matching between surface points and CT scan data.

Unlike electromagnetic systems, the CANS did not require modification of the instruments. Using a remote control, the surgeon was able to operate the whole system alone during surgery. The indications for CANS use increased, initially from revision surgery for polypsis to the first pro-
CANS was used in pediatric intranasal surgery and appeared to be a helpful surgical guide and not just a control tool. Indications for the use of CANS have extended to various types of surgery for which it was not initially thought to be helpful. Surgery previously relied on endoscopic and preoperative CT scan views of the instruments. However, CANS is not a substitute for perfect endoscopic anatomical knowledge, and it cannot yet be asserted that CANS reduces meningeal and orbital risk.

Accepted for publication December 5, 2001.

This study was presented in part at the 15th Annual Meeting of the American Society of Pediatric Otolaryngology, Orlando, Fla, May 17, 2000.

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CONCLUSIONS

CANS should be a legal requirement in difficult cases of pediatric FESS. Indeed, CANS might encourage the surgeon to take more risks, with the temptation to perform a more complete procedure than would otherwise be attempted.

It is probable that in the near future there will be more demand for CANS in pediatric sinusonasal surgery. The main problem is that at the present time CANS is too expensive for its profitability to be ensured in a pediatric otolaryngology department; however, its cost is likely to decrease in the future.

REFERENCES


Figure 5. Surgery is performed directly in the limited pathological area of the frontal sinus.

Figure 6. The computer-assisted navigation system was used to guide instruments directly into the sphenoidal ostium without removing any part of the middle turbinate.