COMPUTER-ASSISTED FUNCTIONAL ENDOSCOPIC SINUS SURGERY (C-A FESS) – A REVIEW

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ABSTRACT : *CT and MR imaging give spatial information of patient's disease and anatomy. They help in preoperative surgical planning and guide the surgeon during operation. In conventional Functional Endoscopic Sinus Surgery (FESS), surgeon mentally correlates the information of CT and MR with the direct sinuscopic view of operative field. In Computer-Assisted Functional Endoscopic Sinus Surgery (C-A FESS), computer provides image guidance for the surgeon. Surgeon can appreciate the immediate surrounding structures outside the direct endoscopic vision of the surface. Thus widely enhancing the field of endoscopic image. The overall accuracy of 1 to 2 mm has been reported. Many systems of tracing are being developed and tested for. Each system has its own advantages and disadvantages. It is now possible to guide surgery with intraoperatively acquired MR images. The real-time imaging shows the tissue changes occurring during the operation. Surgeon can safely operate the lesions of optic nerve, sphenoid sinuses, pituitary gland, and cranial base.*

***Key Words:** Computer-Assisted Surgery, Computer-Aided Surgery, Computer-Augmented Surgery, Image-Guided Surgery, Functional Endoscopic Sinus Surgery, Endoscopic Sinus Surgery.*

INTRODUCTION

Kennedy originally coined the term FESS in 1985 to draw attention for reestablishing the sinus drainage and mucosal recovery. Although formidable complications have been well documented in the literature, in the properly trained hands the technique of FESS is fairly safe.

MR imaging techniques have expanded the indications of ESS (endoscopic sinus surgery) beyond the inflammatory disease to benign tumors of the nose, sinuses, anterior skull base. It helps in precise mapping of tumor size. The scans also help in preoperative surgical planning and guide the surgeon during surgery.

In spite of its numerous advantages, such a 2D head display has some shortcomings. Location of the endoscope relative to the target site presented on CT image can not be quite precisely determined (Klapan, 1997).

Even the expert neurosurgeons face extreme difficulty in operating the tumors of the skull base because of the close proximity of cranial nerves, eye, inner ear, major vessels and the brain itself. Injury to these structures used to lead to formidable complications, and lesions in this area were considered to be inoperable.

Only within the recent past has surgical treatment of lesions in this area become a reasonable alternative for patients with these tumors (Jackson, 1981). Computer-assisted surgery (CAS) was initially developed to provide neurosurgeons with accurate guidance during surgical procedures.

Computer-assisted surgery means a method that allows intraoperative navigation in the surgical field based on digital image data like CT, MRT, MRA, DSA and others. A computer processes the image data in real time and is intraoperatively connected to a measuring system for coordinate determination. CAS has been used in ENT surgery since 1986 (Klimek & Mosges, 1998).

Frameless stereotactic technologies provide image guidance for the surgeon. Preoperative CT images are entered into a computer linked to the operative field by a variety of methods such as an articulated mechanical arm, an infrared optical probe, an electromagnetic probe, or sonic probe. Points on a three-dimensional computer model of the patient reconstructed from the preoperative CT scan are matched with identical points of a patient's position on the operating table. These points are represented by a x-y-z coordinate. The display of the images incorporates a marker and that identifies the surgical location. So the computer system acts as a navigator providing localization. Imaging assists the surgeon in navigating through diseased and/or surgically revised complex anatomy.

Different Approaches to C-A ESS :

Fried et al (1997) has reviewed the literature on the current opinion in the use of intraoperative CT guidance sys-

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tems for ESS.

Electromagnetic Tracking :
A magnetic field is superimposed around the surgical field. The probe determines the position in the surgical field by detecting the gradients in the magnetic field. It can provide six degrees of positional information in three-dimension. The main disadvantage of this approach was the distortion of magnetic field by ferromagnetic substances, aluminium, and electromagnetic radiation. This impairs the accuracy of localization.

Fried et al (1997) used this technology by resolving this problem to localize the intraoperative pointer (InstaTrak, Visualization Technology, Boston, MA). They have provided information on the system's accuracy, stability, and ease of use in their multicenter study (four sites). The freehand armless device provides real-time position tracking of a suction instrument in orthogonal CT images created by reformatting of preoperative axial CT images.

Two sensors connected to the computer by flexible cords provide positional information. One sensor incorporated into patient's headset is worn intraoperatively and during the preoperative scan. Second sensor is incorporated into the handle of the suction device. The headset allows automatic registration. The fiducial registration was performed using six fiducials embedded in the headset. The fiducials were located in the images with on-screen crosshairs and touched with the suction tip to set registration.

Electromechanical Device :
Viewing Wand (ISG, Mississauga, Ontario, Canada) uses a table-mounted position-sensitive mechanical arm constructed with two degrees of freedom at each of three joints. Sensors are located within the joints of the arm. The exact position of the probe is calculated from the data relayed by the sensors to the computer.

Sipos et al (1996) report on an experience with 250 patients involving a wide range of procedures (6% of them were performed by Otolaryngologists). The 250 surgeries were studied for the safety, efficacy, and accuracy of the device. Patient's head was immobilized in a Mayfield head holder because the device is susceptible to the head movement. The probe tip's position was visualized in the three orthogonal planes reformatted from the original CT (or MR imaging) scan. It can superimpose further CT, MR imaging, and positron emission tomography (PET) data and can provide an oblique projection in the plane of the probe to appreciate its trajectory.

Bale et al (1996) developed a holder to keep the patient's head still so as to maintain the registration between the Viewing Wand's mechanical arm and the patient. They reported overall accuracy of 1 to 2 mm throughout the procedure for 15 ESS procedures.

Carrau et al (1996) found the device extremely useful in their 20 patients for skull base surgery. The device provided with reliable mapping of the sinus boundaries and relationship to tumor, and a decreased need for dissection.

Schlondorff et al (1987) developed an arm that had 6 degrees of freedom with digital increment encoders for shaft angle measurement. A dedicated computer calculated any given position of the probe tip which was attached to the arm (Laborde et al, 1992 and Klimek et al, 1991).

Freysinger et al, 1997 and Gunkel et al, 1997 have reported on the successful development of suction tools, angled probes, and a microdebrider for use with the Viewing Wand in place of standard straight solid probes. This multiuse approach to the pointer thus eliminates the necessity for changing to separate instruments for their respective purposes.

Optical device :
This uses IREDS (InfraRed Emitting DiodeS) in an instrument handle to provide data to an array of cameras as to the location and orientation on the probe's tip. If IREDS are placed on the patient, motion of the patient can be detected by the computer. Surgery can then be performed under either local or general anesthesia.

The first optical digitizing system used for otolaryngologic surgery had a triangular camera array attached to an aluminium frame placed above the patient (Krybus et al, 1991). For registration a radio opaque or MR opaque fiducial marker is attached on the patient's face at the time of CT or MR scan. These are then identified intraoperatively and targeted on the same fiducial on the three-dimensional virtual image thus entering the coordination.

Saenz et al (1998) using an infrared system carried out excision of benign or radioresistant lesion of pineal region in 5 cases and did not observe any morbidity and mortality. They were able to accomplish gross total removal of mass in 3 cases and subtotal resection greater than 90% in 1 case.

Hauser et al (1997) described a highly precise CAS system with noninvasive referencing that can be used in ear, nose and throat surgery. It is based on optical digitizing with several custom-made self-localizing surgical instruments. The system was evaluated clinically with 11 patients who received surgery for different pathologies of the paranasal sinuses.

Sonic Device :
These digitizers determine position by measuring the time needed for sound from an emitter to travel to a microphone array of known geometry. It needs constant speed of sound for accurate measurement. So the temperature difference, echoes and air flow interfere with the reliability of the sonic system.

Ideal Criteria for Systems of C-A FESS :
Roth et al (1995) summarized the following criteria for the systems providing image guidance for ESS:

1. Accuracy of 2 to 3 mm should be maintained.
2. The second CT should be eliminated possibly through standardized surface marking.
3. The computer should update for any head movement under general or local anesthesia.
4. Sensors should be applied to suctions and dissecting instruments to allow more flexibility.
5. The surgeon must easily operate the device in order to eliminate the technicians.

Accuracy :
The accuracy of the Surgicom arm, as determined by measurement on a plastic skull and a specially Plexiglas measurement model, is approximately 2.0mm, with 95% of the errors falling between 0 and 3.7 mm (Zinreich et al, 1993). Laboratory measurements based on CT scans from a specially constructed phantom show an accuracy of the third-generation mechanical arm of 0.61+- 0.24 mm (mean error+- SD). The accuracy of the optical system is 0.87 +- 0.31 mm. Clinical accuracy of the arm using fiducial markers is 1.8 +- 1.1 mm. The FlashPoint 5000 system has accuracy in the laboratory setting of 1.3 mm. The OptoTrak system has an accuracy of about 2.0 mm in clinical applications. The InstaTrak system has an accuracy of approximately 2.0mm (Anon et al 1997)).

Advantages and Disadvantages of C-A FESS :
By providing direct interactive link with the patient's preoperative CT or MR images, C-A FESS increases intraoperative patient safety. There is an immediate appreciation for the anatomy surrounding the surgical field outside the direct endoscopic visualization and enables more thorough removal of the tumor. Surgeon's efficiency is increased and the procedure can be finished in shorter time.

Computer assistance can be used in almost any type of endoscopic or microscopic sinonasal procedure. Anon et al (1997) have used these devices in surgery for extensive disease with obliteration of landmarks, tumors of the sinonasal cavities, sphenoid sinus disease, frontal recess/ frontal sinus pathology, orbital surgery for optic nerve or orbital decompression, skull base tumors, drainage of abscesses, and revision cases.

A basic problem common to all systems for computer assisted surgery is patient referencing, or the transfer of preoperative image data to the intraoperative pathology.

Broad clinical application is hindered by high costs, additional time during intervention, problems of intraoperative man and machine interaction, and spatially constrained arrangement of additional equipment within the operating theater.

Other Modalities of C-A FESS :
It is now possible to guide surgery with intraoperatively acquired MR images. Freid et al (1996) stresses the importance of intraoperative image guidance during endoscopic sinus surgery and in another study had clinical trial of laser application under image guidance. Integral to this approach is that feedback is continuous intraoperatively. It is not available as a general clinical tool but significantly, the intraoperative MR images reflect tissue changes incurred during surgery.

Freysinger et al (1997) discusses their initial experience with the ARTMA Virtual Patient (ARTMA Biomedical, Viena, Austria) that allowed endoscopic 3D navigation by using augmented reality techniques and was found very promising.

Tele 3D C-FESS :
In the first week of November, 1998 Klapan performed a Tele-computerized-functional endoscopic sinus surgery with 3D support from one location (clinical center) to another location (20 km distance) in Croatia. It was the first Tele-surgical transmission of FESS in real-time together with Tele-radiology, Tele-education, and Tele-video conferencing. He believes that it is the first of its kind in the world. He also considers the technique quite safe and fast because it took him only 15 minute to complete this Tele 3D C-FESS.

CONCLUSION

E.N.T. Surgeons are getting accustomed to the endoscopic sinus surgery and another dramatic concept of computer–assisted endoscopic sinus surgery has emerged at the world horizon of medicine. Klapan has even started performing Tele three dimensional computer-assisted FESS. Computer-augmented FESS assists the surgeon in removing the disease thoroughly especially in cases of revision surgery with deformed structures. Computer-aided surgery provides a direct interactive link with the patient's preoperative CT or MR images, and marker identifies the surgical location. The improved quality of Imaging techniques will bring many more new technologies like virtual reality and simulation techniques. The days are not far when the surgeon will be able to practice the surgery on the virtual patient before the real operation. But these new techniques are not short cuts. Computers can not replace the doctors but they are just an aid to them. One who has better understanding of complicated and intricate anatomy of head and neck along with good clinical acumen will be benefited the most. CAS in its current state of development is a useful tool however further technical refinement is necessary.

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