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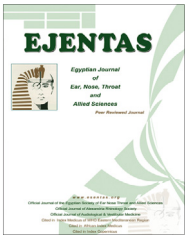

REVIEW

The use of image guided navigational tracking systems for endoscopic sinus surgery and skull base surgery: A review

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Abstract The use of tracking technology and navigation system has revolutionised the field of endoscopic sinus and skull base surgery. The role of the navigation system is to enhance surgeon's knowledge of anatomy and experience and not to replace it. Most common navigation system use is optical or electromagnetic tracking technology. Both tracking technologies have been found to be suitable for the demands of intraoperative navigation. It has improved the precision and accuracy of performing surgery and reduced complication rates. The navigation's accuracy depends on factors such as image modality, tracking technology, and registration technique. It allows the surgeon to have information on bony anatomy, position and size of any lesion, as well as location of critical structures such as the carotid artery and optic nerve. We reviewed the use of optical and electromagnetic tracking systems and their differences in endoscopic sinus and skull base surgery.

Contents

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1. Introduction

The emergence of endoscopic sinus surgery (ESS) in the late 1980s and early 1990s has brought about a revolutionary advancement from the open sinus surgery to the now minimally invasive approach to surgery for sinusitis.[1] The goal of ESS is to re-establish physiologically normal sinus drainage pathways by removing or correcting diseased pieces of tissue in key areas of sinus obstruction. With the advent of more high definition endoscopes and the use of fibre-optics, the ability to see within the nasal cavity and the sinus cavity has much improved. Evolution of the pre-operative procedures such as computer tomography to high resolution computer tomography with thinner slices also aid in the selectiveness of the dissection during endoscopic surgery, whereby the healthy tissue is identified and preserved. Open sinus surgery often requires facial incisions with resulting facial scars and a lot of nasal bleed and packing. Recovery is usually faster in ESS with less post-operative pain and bleed.

Although we have come a long way in addressing sinus disease, surgeons are still faced with challenges such as intra operative bleed, trauma to the surrounding structures such as the eye and central nervous system and even complications leading up to death. This is due to the complex anatomy of nasal cavity and the paranasal sinus, anatomical variations in individuals, narrow surgical field, obscured surgical field due to bleeding that limit the exact placement of the instrument especially in unskilled hands (beginners).[1–5]

ESS as well as surgery to various parts of the anterior skull base is challenging due to the variety of vascular and neural structures in a very confined space and with previous surgical procedures, scaring and the destructive nature of some diseases affecting the skull base, surgical landmarks are distorted thus increasing the immediate intraoperative complications and long term post-operative defects.[2] This is where the image guided systems or navigation systems are fast becoming an important tool. Image guided systems or navigation systems are essentially like GPS (global positioning satellite) systems for the anatomy of the head. These navigational systems are used to aid the surgeon in confirming the location of critical structures. The usage of the navigation systems has tremendously improved the outcome of ESS and has decreased the complication rate of the surgery. With the road map to the anatomy of the head, surgical precision is improved, instrumentation is more accurate up to 2 mm or better and there is less collateral damage to the surrounding tissues.[3] However, image guided surgical navigation is not a substitute for sound surgical judgement and operative experience.

To use the navigation system, a computer tomography (CT) scan of the sinuses or the skull base of the patient is performed using a specific navigation protocol (in some cases the CT scan is saved into a DICOM format). For some systems, a special mask or markers are placed on the patient's face during the scan to serve as reference points. The CT scan is then transferred into a disc or USB, which is then uploaded into the image guidance system. During surgery, a detection array or mask or in some cases a headband is placed on the patient's head. The CT scan images loaded into the navigation system are then calibrated to the patient's anatomy using the pre-set reference points, which may be the mask or markers specific anatomic points on the face such at the lateral canthus, the glabella and the columnella.[4–6] The position of the sinus surgery instruments can then be tracked by the navigation system by integrating the information detected from the patient's preset reference points and comparing it to the information on the CT scan "map". MRI images may also be used with the new navigational systems and the technique is similar to the setting up of the CT scan images into the navigation system.

2. Differences between the optical and electromagnetic tracking systems

There are two main types of navigation systems available in the market today. They are the infrared (optical) systems and the electromagnetic systems. Both systems perform the same functions. However, the technology used to provide the information to the surgeon is very different. In all cases, there will be a device attached to the patient known as the head mask or head frame.[7]

The optical system or the infrared system, as its name suggests, uses infrared sensors in combination with light-emitting structures or light reflectors that are fixed to the patient's head (via a headband strap or sticker) and fixed to a handheld probe (Fig. 1). Both the headband and instrument must be detected or "seen" by the system's camera, or computer in order to track where the surgeon's instrument is within the sinuses.[8]

As for the electromagnetic systems, these systems use electromagnetic fields that use reference points on a device attached to the patient's head (a plastic mask with metallic beads or headband) and a wired instrument that the surgeon uses within the nose and sinuses (Fig. 2).

Unlike the optical systems, the electromagnetic systems do not have to be "seen" by the computer meaning that it does not matter if other devices or equipment in the operation theatre are placed in between the computer and the patient. However, too much metal within the electromagnetic field can cause inaccuracies. The comparison between both navigational systems is listed in Table 1.

Figure 1 Optical image guided navigational tracking system.

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