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ENT Navigation System

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ABSTRACT

The use of navigation systems and tracking technology has revolutionized the field of ENT (Otorhinolaryngology), endoscopic sinus, and skull-base surgeries. The main goal of the navigation system is to remediate the surgeon's knowledge of anatomy and experience. The most common navigation system uses either optical or electromagnetic tracking technology. Both tracking technologies have been found to be suitable for the demands of intraoperative navigation. It has the precision and accuracy of performing surgery and reduced the complication rates. The accuracy of a navigation system depends on the factors such as image modality, tracking technology, and registration technique. It allows the surgeon to have information on bony anatomy, access to the paranasal sinus, position and size of any lesion, as well as location of critical structures such as the carotid artery and optic nerve.

Introduction

1.1. ENT Navigation system

ENT known as Otorhinolaryngology is a surgical subspeciality in medical sciences that deals with surgical and medical management of conditions of the head and neck which includes vital structures in the ear, nose, and throat (middle and inner ear, olfactory sense system, vocal cards, carotid artery, etc). These commonly include functional diseases that affect the senses and activities of eating, drinking, speaking, breathing, swallowing, and hearing.

Fig 1: ENT navigation system

The ENT navigation system will offer the product for sale to hospitals, clinics, and offices performing endoscopic sinus surgery and skull base surgery. This will show the location of the tip of surgical instruments relative to surrounding anatomy, as seen in a pre-surgical CT scan, to guide surgical intervention. It enables surgeons to confidently make more informed decisions during trans nasal surgery, such as when treating sinusitis or skull base tumors.

Technical advances have significantly changed the way we live. From computers to smartphones, from single-purpose to multi-purpose devices, technology has become an intrinsic part of our daily routine. Navigation in surgery is an important example of today's technological capabilities being applied to medicine. It has emerged as one of the most reliable representatives of technology as it continues to transform surgical interventions into safer and less invasive procedures. In surgery, navigation has spurred technical progress, enabled more daring procedures, and unlocked new synergies. What was once a simple localization tool has evolved into a centerpiece of technology in the surgical theatre. ENT navigation system is a computer-based system for use in surgical navigation. It is built on decades of scientific, clinical, and engineering research. ENT navigation system offers electromagnetic technology that expands what was previously possible with image-guided surgery so the surgeon can see more, and do more.

This study helps to learn about a real-time updated 3D ultrasound navigation system capable of the high-speed transfer of image data and that will help the doctors to perform an accurate surgery fast and secure with meliorate outcome.

1.2. Working of Navigation System

We are describing the components and working of the Fiagon Electromagnetic Navigation system. This navigation system consists of a navigation screen, navigation module, and tracking pointer. There are four windows on the navigation screen; three of which display raw CT and Magnetic Resonance Imaging (MRI) data of orthogonal cross-sectional images of the axial, coronal, and sagittal planes of the patient and the fourth window displays the video image of the surgical field as visualized by the endoscope that is represented in Fig 2. The navigation module is equipped with a DVD or CD drive, USB port, plug points for navigation sensor, patient localizer, and pointer system. The pointer system is equipped with a connecting plug, sensor cable, and a pointer.

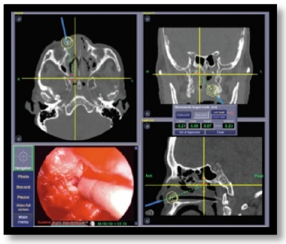

Fig 2: Navigation screen

1.3. Using Electromagnetic Navigation System

A detailed pre-operative clinical evaluation and imaging studies precede the use of a navigation system in the operating room.

1.4. Testing of Accuracy

The accuracy with which the navigation system works is then verified by testing known landmarks on the patient's face and correlating their position with the CT images. The data obtained from this process is saved and utilized to monitor the accuracy of the device during the surgery. The role of the navigation system is vital in localizing a difficult frontal sinus, locating small sphenoid sinus, delineating skull base contour during a revision procedure, and distinguishing smooth-walled peripheral cells from surrounding landmarks.

Technology

1.5. Electromechanical systems

Electromechanical systems were the first to be used, being easy to construct. A jib supports an arm comprising several segments articulated to provide 5 or 6 degrees of freedom Fig 11. The articulations usually include a precision potentiometer encoding the angle between each segment. Accuracy was to within a few micrometers, but they required the patient to be totally immobile. Other reasons for their being abandoned were bulk and poor ergonomy.

Fig 11: An electromechanical localizer

1.6. Ultrasound-beam system

Ultrasound-beam systems comprise a piezoelectric ultrasonic transmitter fixed on the instrument, generating a signal picked up by a set of at least three microphones remote from the operative field. If sound propagation time in the air is known, the relative position of the instrument can be calculated by quadratic triangulation. Unfortunately, sound propagation time is highly dependent on temperature and local hygrometry, leading to cumulative error of as much as several centimeters, even after meticulous calibration. Moreover, the interposition of the surgeon's hands and instruments and any sudden displacement of air induce errors that are hard to detect. These systems have therefore remained at the prototype stage.

1.7. Opto-electronic systems

Opto-electronic systems were developed a little later. They are based on a set of two or three high-resolution charge-coupled cameras remote from the operative field. They analyze the spatial projection disparity of an identifiable object such as a set of near-infrared LEDs fixed on the instrument (active system), or micro prism-covered spheres reflecting infrared emission from a projector in the camera bay (passive system) so that no cable is needed to feed the LEDs Fig 12. Accuracy is satisfactory, at around half a millimeter for electroluminescent diode systems, and slightly poorer for passive systems.

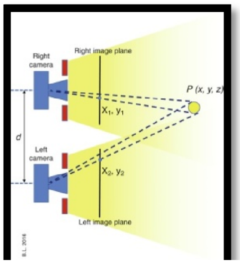

Fig 12: optical tracker

1.8. Electromagnetic systems

Electromagnetic systems are a more recent development. They are based on generating an alternating magnetic field on three perpendicular axes. A sensor, comprising coils that are also perpendicular to one another, detects its position and orientation relative to the transmitter according to the voltages induced in each coil Fig 13. As magnetic field strength decreases with the cube of the distance from the source, sensitivity and resolution are excellent, to within a 10^{th} of a millimeter. The technology is very robust and can be miniaturized to the point where the surgeon can just forget about its presence. Another advantage is that they function without restriction, whatever the position of the surgeon, instruments, and aids, as they do not depend upon a line of sight.

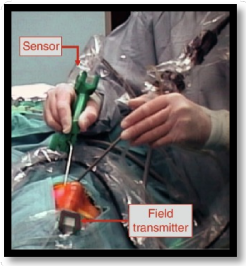

Fig 13: Sensor and field transmitter

1.9. Other tracking technologies

Gyroscopic inertial sensors combined with accelerometers or spectrum-modulating fiberoptic sensors (in which transmission varies with fiber curvature radius) have been described, but are not widespread due to specific drawbacks. On the other hand, direct intraoperative cone-beam X-ray or intraoperative MRI imaging is feasible, enabling direct image analysis without necessarily needing a spatial localizer. Although costly and not easy to implement, these techniques provide real-time updated imaging, enabling tissue margin assessment during resection.

1.10. Image dataset registration Principle

The position and orientation of the patient's head on imaging depends on how he/she was installed on the radiology table with respect to the radiogenic tube. There is obviously no reason why, once positioned lying on the operating table, the patient's position should remain identical with respect to the localizer. Registration, therefore, seeks to determine transfer equations to convert the coordinates of any point on the localizer to match exactly the corresponding point in the image coordinate system. These transfer equations from one coordinate system to another generally take the form of a rotation matrix around three axes (x, y, z), combined with a translation vector along each axis.

1.11. Paired points registration

The simplest registration technique is to provide the machine with the coordinates of a certain number of points acquired on the patient's face and skull and select the corresponding points on the images Fig 14. Natural anatomic landmarks, such as the nasion, frontozygomatic suture, tragus, or nasolabial junction, can be used, or else radio-opaque markers fixed on the skin or screwed onto the external skull.

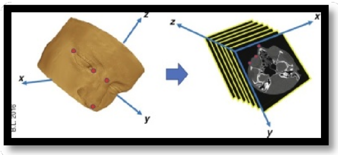

Fig 14: Paired points registration

1.12. Surface registration

The principle of surface registration is to create a 3D surface model, with a predefined resolution, from a set of images, then acquire hundreds of random points on the patient's face via a probe governed by the localizer, and perform iterative rotation and translation until optimal superimposition on the surface model is obtained by monotonous convergence. Algorithms prevent the convergence from being trapped in a local minimum rather than the global minimum of the function. Adjustment requires only a few secondsof calculation, performed automatically by the computer Fig 15.

Fig 15: Surface registration measuring

1.13. Photo- and video-based registration

Photogrammetric methods have been proposed in order to make the image-to-patient registration process even simpler. Photogrammetry, which is widely used in geodesic science, for instance, to create maps from high-resolution satellite pictures, relies generally on 2D Fourier image decomposition to extract spectral content and hence the most significant signals. If the camera is 3D-tracked, it is possible to a certain extent to compute the relative translation and rotation of broadly similar pictures. For surgical purposes, it is possible to use this image processing technology to find the pose of a surgical view relative to the 3D reconstruction performed from the patient’s CT dataset. Despite their appealing potential, these techniques are very difficult to apply to surgical registration, due to their lack of robustness. With the same purpose, some authors have proposed using endoscope image streams to dynamically register the patient relative to the image dataset. While some interesting results have been demonstrated in lab conditions on immobile dry plastic skulls, such methods are hard to apply under real surgical conditions where blood, tumor, and, moreover, the progressive modification of the surgical field by the surgical procedure itself, seriously vitiate success.

Working principle

ENT navigation system provides enhanced visualization to surgeons and also offers new software and hardware innovations including Virtual Endoscopy, which provides a simulated view of sinus cavities previously inaccessible with a traditional endoscope. Virtual Endoscopy can be loaded with the patient's preoperative data to allow the surgeon to practice an individual's surgery before he or she enters the surgical suite. To support operating room efficiency, the ENT Navigation system includes an emitter that can be placed under the patient's head—allowing more space for personnel around the table - and a 27-inch, high-resolution touchscreen with an intuitive user interface that can be tailored by the surgeon as shown in Fig 16.

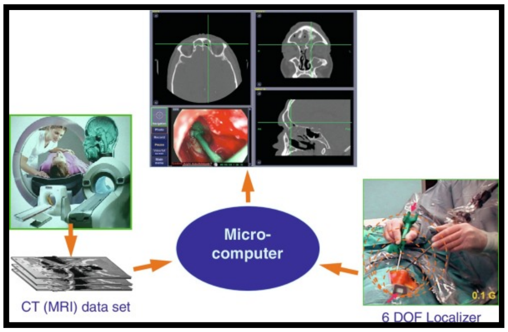

Fig 16: Working principle of ENT navigation system

CT images that delineate bony structures benefit otolaryngologists better and MRI guidance helps neurosurgeons better by providing enhanced visualization of intracranial soft tissues. Integrating CT and MRI as one image guidance system could benefit both otolaryngologists and neurosurgeons to integrate their work. Further development in the field of bioengineering could make the process of registration and usage of navigators less time-consuming and more user-friendly for beginners. Techniques that use fluorescent dyes to differentiate tumor cells from normal areas can be used along with an intra-operative navigation system to make tumor identification and removal more effective. The navigation screen size can be reduced and made more compact.

Robotic surgery can be integrated with the navigation system to develop an advanced surgical technique. Robot-assisted surgery uses a surgical robot that has four articulated arm ports. One arm port carries a dual-channel endoscope coupled with a camera for 3-D visualization of the surgical field, the other two arm ports carry right and left surgical arms that permit surgical manipulations, and the fourth arm port is used as a spare arm that could be used for the retraction or for inserting another instrument. Robotic surgery provides the opportunity to perform a two-handed tremor-free procedure and eliminates the need for manual stabilization. Combining robotic surgery with navigation techniques could help in further progression of the endoscopic approach to the skull base and offer the scope to perform surgeries with greater accuracy and precision.

Advantagesand Applications

Advantages

- Easy accessibility and Wide field of view (For deeper structures).
- Cosmetically better accepted (Minimal / no skin incision).
- Less time-consuming procedures and a short period of hospitalization.
- Minimal blood loss and minimal tissue damage.

Application

- Tumor navigation
- CMF Surgery (Craniomaxillofacial)
- Ear surgery

2. Future scope

ENT navigation system can be used as a drug delivery system to the deeper structure. For example, trance tympanic drug delivery system into the inner ear.

CONCLUSION:

Introducing electromagnetic navigation systems to anterior skull base surgeries and ESS, particularly to endoscopic endonasal surgeries has revolutionized and moved the field forward. It provides an opportunity to localize the surgical trajectory and monitor it on a continuous basis. The navigation system has enhanced the precision by which a surgeon can operate as it provides accuracy up to 2 mm or better. Approaching difficult and non-accessible regions of the skull base has been made safer and easier through the use of a navigation system as it provides better delineation of anatomical landmarks. Using a navigation system requires a good amount of training and expertise on the part of the surgeon. The navigation system is adjunctive to the surgical skills of a surgeon while performing surgery but not a substitute. The surgeon still needs to have good knowledge about the anatomy of the surgical field. There is scope for further development in the field of Otorhinolaryngology and head and neck surgery by integrating newer techniques like robotic-assisted sinus and skull base surgery with navigation systems.

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