Image-Guided Surgery in Rhinology

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Image-guided system (IGS) is the navigator system which helps a surgeon to confirm the anatomy during the operative procedure. The objectives of IGS are to minimize the complication rate and decrease the unnecessary injuries to the neighboring structures of the target area. For almost 20 years, the surgery of nose and paranasal sinuses has gradually changed from the external approach such as the Caldwell-Luc operation or external ethmoidectomy procedures to the procedure so called "Functional Endoscopic Sinus Surgery : FESS" or "Endoscopic Sinus Surgery : ESS".

The improvement of radiologic technology and the breakthrough concept of an ostiomeatal unit (OMU) for drainage of the paranasal sinus lead to the increased use of computerized tomography (CT) scan for the surgical road map in the rhinologic procedures. The rhinologic procedures inside the nose with the important structures nearby such as orbit, skull base and internal carotid artery may be jeopardized especially in certain conditions. IGS helps to reduce that risk.

For more than 10 years, the IGS system has been utilized for the rhinologic procedures in America. It has also been used in the Department of Otorhinolaryngology (ENT), Faculty of Medicine Siriraj Hospital for more than three years. This article will summarize the evolution of imaging utilized in rhinologic surgery, reviews the various IGS systems, shows the preliminary result of Siriraj experience of using IGS in the ENT Department, and provide the guidelines for selection of the proper cases for IGS.

Imaging of the nose and paranasal sinuses

Plain films

Plain films can give a fair quality for some conditions such as the mucosal thickening, retention cyst, etc. For the concept of ESS of drainage at the OMU area with preservation of cilia function, plain films give limited information and become less reques-ted for the preoperative planning of rhinologic surgery.

Polytomography

Comparing to the plain films, a polytomogram gives a better display of bone morphology and anatomical details. However, it has some disadvantages, such as higher radiation dose, increased examination time, and moderately blur display without soft tissue resolution.[1]

CT scan

CT scan is the modality of choice for the rhinologic surgery of an inflammatory lesion, so called ESS. It gives the better visualization of anatomic details especially the OMU, ethmoidal area and skull base.

Certain anatomical landmarks which need to be preoperatively evaluated are:

- The roof of the ethmoid (fovea ethmoidalis) compared with the height of the skull base (cribriform plate)
- The relationship between the orbital floor and the shape of the uncinate process
- Pneumatization of the sphenoid sinus and its relationship to the surrounding vital structures (optic nerve, internal carotid artery and cavernous sinus)
- The anatomical variation which may affect the accessibility of ESS, for instance: the infraorbital cell (Haller's cell), the sphenoethmoidal cell (Onodi cell), and the Agger nasi cell, etcetera.

From the data of Thais' anatomical variation of paranasal sinus[2], some useful information can be used as reference values for ESS in the Asian population. (Table 1)

CT scan also enables the evaluation of the extension of disease and staging of rhinosinusitis and its severity. The most widely accepted CT scan classification system in chronic rhinosinusitis was the Lund-Mackay System which was proposed in 1993[3]. They proposed that each sinus group and the OMU should be graded with a score from 0 (no abnormality), 1 (partial opacification) to 2 (total or complete opacification). The left and right sides are scored separately with the maximum possible score of 24. It should be noted that the OMU score can only be 0 or 2 only, without 1. (Table 2)

TABLE 1. Prevalence of anatomical variations in Thais[2] (n = 264).

Anatomical variations	Prevalence (%)
Skull base : Keros' type II (different from fovea level 4-7 mm)	51.1
Protrusion of optic nerve	14.8
Infraorbital cell (Haller's cell)	12.5
Sphenoethmoidal cell (Onodi cell)	8.3
Protrusion of internal carotid artery	3.0
Pneumatization of the middle turbinate (Concha bullosa)	2.3

TABLE 2. Lund-Mackay CT scoring system for rhinosinusitis.[3]

	Right	Left
Frontal	(0,1,2)	(0,1,2)
Anterior ethmoid	(0,1,2)	(0,1,2)
Posterior ethmoid	(0,1,2)	(0,1,2)
Maxillary	(0,1,2)	(0,1,2)
Sphenoid	(0,1,2)	(0,1,2)
Ostiometal unit (OMU)	(0,2)	(0,2)
Total		

Magnetic resonance imaging (MRI)

Although CT scan may give a better quality of the bony structure of the intranasal anatomy as a surgical roadmap, MRI provides the additional information of soft tissue lesion or the inflammatory lesion which extends beyond the nose and paranasal sinus to the brain or orbit.

MRI also helps to distinguish between neoplasms and inflammatory lesions.

IGS

The component of IGS

The IGS development star-ted in the 1970s in the field of neurosurgery by using the stereotactic property combined with the CT scan data[4]. A group of surgeons in Germany performed the initial experiments with IGS in the field of rhinology in the late 1980s.[5]

The principle of IGS is the converting of the radiographic image, CT scan or MRI, to the surgical field. The computer will integrate the data with the movement of the surgical instrument which is tracked by the system. The surgeon will see the tip of the surgical instrument or probing instrument displayed on the monitor.

The IGS system consists of three components:

1) Computer hardware and software
2) Localization system
3) Probing/tracking instrument

● Computer hardware and software

Most of the hardware are UNIX-based and some of them are Window-based. The hardware consists of the workstation and the display monitor. The data of radiographic pictures will be displayed in a three-planar view as coronal, axial and saggital planes on the screen. The last quadrant on the screen is used for the intra-operative endoscopic picture.

The software is the important component of IGS. The patients will be scanned by CT or MRI, pre-operatively. Then, the data will be transferred from the Radiology Department to the IGS work station in the operating room. The format of data uses the Diagnostic Imaging and Communication in Medicine (DICOM) format by Ethernet link or CD-rom.

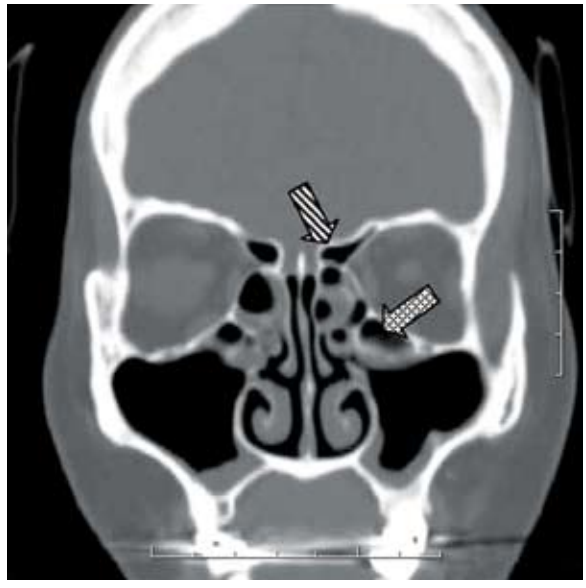

Fig 1. Coronal CT scan shows some anatomical variations. The upper arrow indicates the roof of the ethmoid, and the lower arrow indicates the infraorbital ethmoid cell.

The matching between the data from the computer and the anatomy of the patient on the operating table is called "registration".[6] The accuracy of IGS depends on this process.

Various registrations have been utilized by using the reference point or so called "marker". The examples of registration markers are:[4,7]

- o Anatomic fiducial registration: such as tragus, lateral canthus, nasion and rhinion.
- o Bone-anchored registration: by pin or screw the marker into the facial bone. This technique is very accurate, but too invasive.
- o Autoregistration : by using the head-frame marker at the time of CT scan and wearing the head-frame again intra-operatively.
- o Surface mapping registration: such as using the Vector Vision system for gathering 50-400 data points from the facial contour just before the surgery. The computer will match the data of facial contour with the pre-operative image of the CT scan.

Fig 2. Image-guided system: workstation computer and camera.

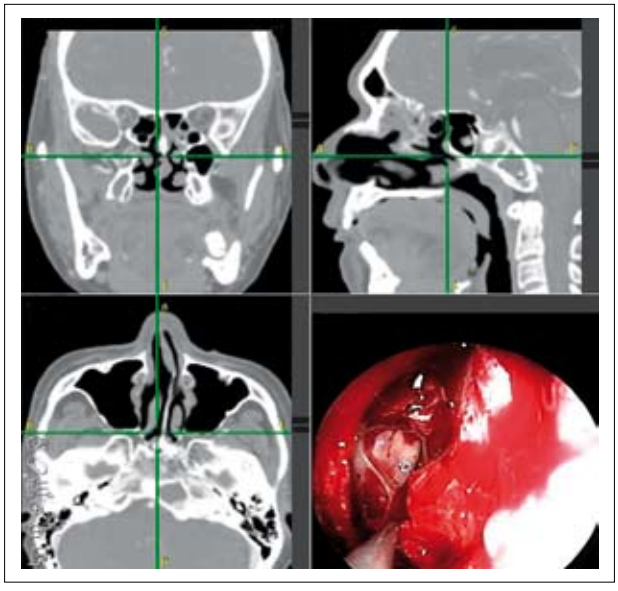

Fig 3. Displayed picture of IGS in three planes with the endoscopic view on the lower quadrant.

The study by Hardy SM et al., in 2006 compared the various registration methods for ESS.[8] The registration time of the anatomic fiducial methods and surface are 5 minutes and 1 minute, respectively. The accuracies between the fiducial method and the surface method are statistically similar.

- Localization system

There are two major systems for localization, optical-based or electromagnetic-based. The electromagnetic-based system is by GE medical company (IntraTrak®) and does not require a line-of-sight between the probing instrument (the transmitter) and the computer workstation (the receiver). This electromagnetic system can be interfered with by metallic objects in the operating field.

The optical-based system uses the infrared light as the vector between the probing instrument and the camera. It requires the line-of-sight during the ESS operation.

Fig 4. Registration process of IGS.

Fig 5. Tracking instrument of IGS.

The camera is connected to the computer (Fig 2). The probing instruments are attached with the optical sensors. The sensors can be 1) Active optical, or 2) Passive optical. The active optical requires a cable connection whereas the passive optical is a cordless system.

Various optical-based systems are

- o LandmarX® from Medtronic company
- o Vector vision® from BrainLab company
- o Stryker Navigation® from Stryker company

- Probing and tracking instruments

The probing and tracking instruments will be used by the surgeon intra-operatively to localize the area of interest. The various types of instruments can be a simple probe, a suction (angled or straight), a forceps or an attached part with a microdebrider or powered instrument.

The necessity of IGS

The accepted accuracy of IGS nowadays is excellent. Less than 2 mm error or anatomic drift has been reported.[5,9,10] The IGS comes with the cost. Even though it is a useful instrument for confirming the anatomy and teaching residents, the implementation of this equipment in every ESS case will add to the unnecessary expense to the patients and insurance reimbursement. The American Academy of Otolaryngology - Head and Neck Surgery gave the examples of indications for IGS in endoscopic sinus procedure as follows:

- Revision sinus surgery
- Distorted intranasal anatomy
- Large or massive nasal polyp
- Lesions in the posterior ethmoid, sphenoid or frontal sinus
- Lesions along the vital structures such as skull base, orbit or optic nerve
- Skull base defect or cerebrospinal fluid leakage
- Sino-nasal neoplasms[11-14]

Siriraj experiences of using IGS in rhinologic procedures

The Department of Otorhinolaryngology has utilized IGS with the rhinologic procedures since 2007. For the first four cases, we used the additional attached instrument with special software with the workstation machine from the Division of neurosurgery, Department of Surgery (Fig 2). The last six cases, we used the optical-

based system from Medtronic and BrainLab companies. Seven cases were chronic recurrent rhinosinusitis which required revision endoscopic sinus surgeries. One case was large frontoethmoidal mucocele which eroded the anterior skull base. One case was cerebrospinal fluid leak at the cribriform plate. The last case was a clival lesion. The outcomes of all cases were good without any complication. The mean registration time was 19 minutes (15 to 30 minutes). Our time is longer compared with the mean registration time of the American Academy of Otorhinolaryngology which is less than 5 minutes.[8] It can be explained by the learning curve process. The accuracy of our results is comparable to the others which reported the anatomic drift less than 2 mm.[8,9,11,12]

CONCLUSION

IGS has gradually grown as an additional armamentarium especially in the difficult rhinologic cases such as revision cases or those cases which have lesions closed to vital structures. There are several systems in the market which the rhinologic surgeon should know the pros and cons of each model. It should be remarked that IGS is a useful instrument for confirming the anatomy, but not a seeking device.

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