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Research Article

# Comprehensive Dissection and Safety of Endoscopic Sinus Surgery with and without Image Guidance System

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## Abstract

### Purpose

Preoperative CT in conjunction with image guidance system (IGS) is commonly used during endoscopic sinus surgery (ESS). However, comparison for level of completeness and safety with and without IGS during ESS has not been evaluated. In this study, we compare ESS dissections with and without CT IGS, and evaluate the ability of intraoperative CT (ICT) in identifying the dissection completeness.

### Methods

CT scans were performed before ESS. Each side of the cadaver was randomized into two groups. Group 1 (IGS+) was dissected using CT IGS to complete ESS. Group 2 (IGS-) was dissected without IGS. ICT was performed after completion of ESS to document any residual cells for both groups. All post-dissection CT scans were evaluated for incompleteness and disruption outside the sinuses. Comparisons were made between the two groups.

### Results

Ten cadavers with 20 paranasal sinus cavities were used in the study. Complete dissections were performed for maxillary antrostomy, anterior ethmoidectomy and sphenoidotomy in both groups. Residual unopened air cells were identified in posterior ethmoidectomy (PE) and frontal sinusotomy (FS). The percentage of complete dissection was higher in IGS- (100% for PE, 80% for FS) than IGS+ (80% for both), though it did not reach statistical significance (p=0.2, 0.7 respectively). Using the ICT, complete dissection was achieved with the subsequent dissection. There was no orbital or skull base invasion in either group.

### Conclusion

The precision and safety profile of ESS may be similar regardless of IGS. ICT scan can detect unopened air cell and can be useful in assisting comprehensive ESS dissection.

**Keywords:** Complication; Image Guidance; Intraoperative Imaging; Computer Tomography; Endoscopic Sinus Surgery; Complete Dissection; Study

## Introduction

Endoscopic sinus surgery (ESS) can pose inherent challenges at any level of surgical experience. Both the efficacy and incidence of complications may be affected by a surgeon's ability to navigate through normal variations in sinus anatomy. Furthermore, because of the documented risk of significant complications while performing ESS, an inexperienced surgeon may be tempted to stay away from critical structures (e.g., lamina papyracea or skull base) to avoid complications [1]. Endoscopic sinus surgery, however, has become a treatment of choice for operations involving paranasal sinuses [2]. Therefore, the importance of completeness must be emphasized to avoid treatment failure and disease recurrence. In recent years, preoperative CT image guidance has served as an advantageous adjunct to assist surgeons in advanced or revision endoscopic sinus and skull base operations [3]. The use of image guidance has improved the precision and thoroughness of surgeries like ESS by providing a sense of enhanced safety [4]. Additionally, data suggested that procedures performed by residents with image guidance had improved surgical accuracy and less risk of major complications [5]. Image guidance, however, has notable shortcomings. The enhanced confidence can possibly lead to incomplete dissection of sinus cavities. Also performing image-guided surgery (IGS) requires operators to mentally revise real-time changes in anatomy of the surgical field [6]. This lowers the precision of IGS as changes are not reflected when the anatomy is now distorted. Furthermore, since normal sinus anatomies are variable; tissue planes changes and get displaced during surgery, navigating patients' unique anatomical differences may add complexities to already advanced procedures.

The xCAT® ENT (Xoran Technologies, Ann Arbor, MI) has addressed the need for real-time CT imaging. The xCAT® ENT captures 600 frames in 40 seconds to provide concurrent intraoperative computed tomography (ICT) imaging. This technology allows physicians to capture progressive data revealing tissue changes while still within the surgical field [2,6]. Images can then be used to determine the degree of completeness in dissection and to verify that the initial surgical plan has been met. In this study, we aim to: 1) determine whether ESS using IGS can achieve the same degree of precision and safety as ESS without IGS and 2) determine if ICT can assist in completing the ESS without IGS.

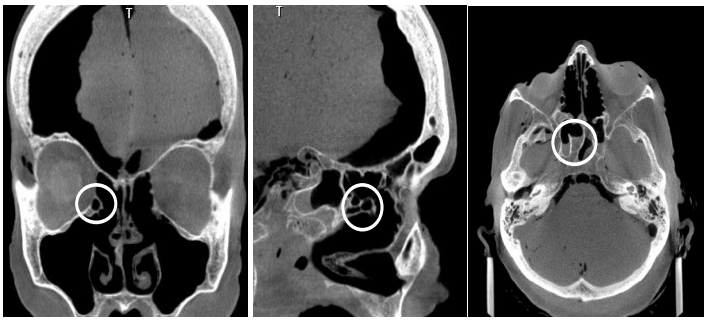
## Methods

A total of 20 endoscopic dissections were performed on 10 cadavers by one physician. Each cadaver was scanned with a Xoran xCAT® ENT portable CT scanner prior to dissection (preCT). CT scans were then used to identify normal anatomical variations, specifically: low-hanging anterior ethmoid artery (AEA), Haller cells, Keros classification, uncinate attachment, frontal cell classification, Onodi cells, supraorbital ethmoid cells, and intrafrontal septal cells.

Each nasal cavity of the 10 cadavers was randomly assigned to one of two groups and each dissection was performed independently. In the first group (Group 1: IGS+), complete dissection was performed [(i.e., maxillary antrostomy (MA), anterior ethmoidectomy (AE), posterior ethmoidectomy (PE), sphenoidotomy (SP) and frontal sinusotomy (FS)] using preCT images in IGS. Post-dissection CT scan or intraoperative CT (ICT) was performed at the end of the dissection to evaluate for any remaining sinonasal cell. Any reattempt to the incomplete dissection after the initial procedure was based off of the most current ICT image. The second group (Group 2: IGS-) attempted the dissection without IGS and subsequently performed ICT scans after the complete dissection to evaluate completeness. A final CT scan was obtained after completion of all dissections. All CT scans were then evaluated by 2 independent physicians for residual unopened air cells and breaches of the lamina papyracea or skull base; comparisons in number of attempts and completeness were then made between both groups using one-tail Fisher exact test to determine statistical significance.

## Results

There were 10 cadaver heads with 20 independently sorted nasal cavities. Each group consisted of 10 paranasal sinuses. There were no differences in the number of residual unopened air cells between groups for MA, AE or SP (Table 1). However, a second attempt to perform a complete PE was required in 4 cases, 2 from each group (Table 2, p=0.7). For both groups, a residual cell remained after an initial attempt and was cleared after a second attempt (Figure 1).



| SUBJECT ID | GROUP | LOW HANGING AEA | HALLER CELL | KEROS TYPE | UNCINATE ATTACHMENT | FRONTAL CELLS | ONODI CELL | SUPRA-ORBITAL ETHMOID CELL | INTER-FRONTAL SINUS SEPTAL CELL | MA ATTEMPT | AE ATTEMPT | PE ATTEMPT | SP ATTEMPT | FS ATTEMPT | ORBITAL INVASION | INTRA-CRANIAL INVASION | SKULL BASE RESIDUAL | LAMINA PAPRYCEA RESIDUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08096 R | IGS- | yes | no | 2 | lamina | type 2 | no | no | yes | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08096 L | IGS+ | yes | yes | 2 | lamina | type 2 | no | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08106 R | IGS+ | no | no | 1 | lamina | no | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08106 L | IGS- | no | no | 1 | lamina | no | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08108 R | IGS+ | no | yes | 1 | skull base | no | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08108 L | IGS- | no | yes | 1 | skull base | no | yes | no | no | 1 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08111 R | IGS+ | no | no | 2 | lamina | no | yes | no | yes | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08111 L | IGS- | no | no | 2 | lamina | no | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08113 R | IGS- | no | no | 1 | lamina | type 1 | yes | no | no | 1 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08113 L | IGS+ | no | no | 1 | MT | type 1 | yes | no | no | 1 | 1 | 2 | 1 | 2 | 0 | 0 | 2 | 0 |
| 08161 R | IGS+ | no | no | 1 | skull base | type 1 | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08161 L | IGS- | no | no | 1 | skull base | type 1 | yes | no | yes | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08163 R | IGS- | yes | no | 1 | skull base | type 1 | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08163 L | IGS+ | yes | no | 1 | skull base | type 1 | yes | no | yes | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08166 R | IGS- | no | no | 1 | skull base | type 1 | yes | no | yes | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08166 L | IGS+ | no | no | 1 | skull base | type 1 | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08167 R | IGS+ | no | no | 2 | lamina | type 1 | yes | no | no | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| 08167 L | IGS- | no | no | 2 | lamina | type 1 | yes | no | no | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08175 R | IGS- | no | no | 2 | skull base | type 1 | yes | no | yes | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 08175 L | IGS+ | no | no | 2 | skull base | type 1 | yes | no | no | 1 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |

| PE only | Complete | Incomplete | Total |
|---|---|---|---|
| **IGS+** | 8 | 2 | 10 |
| **IGS-** | 8 | 2 | 10 |
| Total | 16 | 4 | |
| p=0.7 Fisher exact test, one-tail | | | |

| FS only | Complete | Incomplete | Total |
|---|---|---|---|
| **IGS+** | 8 | 2 | 10 |
| **IGS-** | 10 | 0 | 10 |
| Total | 18 | 2 | |
| p=0.2 Fisher exact test, one-tail | | | |

| All ESS | Complete | Incomplete | Total |
|---|---|---|---|
| **IGS+** | 7 | 3 | 10 |
| **IGS-** | 8 | 2 | 10 |
| Total | 15 | 5 | |
| p=0.5 Fisher exact test, one-tail | | | |

PE= Posterior ethmoidectomy; FS= Frontal sinusotomy; ESS= Endoscopic sinus surgery

For FS, there were differences between the 2 groups (Table 2). Group 1 (IGS+) completed 8 of 10 (80%) FS dissections after one attempt (p=0.2). On one sample two residual cells remained at the skull base after all efforts to remove them. In group 2 (IGS-), 10 of 10 (100%) FS dissections were completed after one attempt and all residual cells at the skull base were dissected. There was no breach of the lamina papyracea or skull base using either method.

In comparing the overall dissection (of all paranasal sinuses) for completeness between the 2 groups (Table 2), group 1 completion rate was 70% compared to 80% in group 2 (p=0.5). No positive trend was observed for differences in completeness regarding low hanging AEA, Haller cells, Keros classification, uncinate attachment, frontal cell classification, Onodi cells, supraorbital ethmoid cells or interfrontal septal cells. Interestingly for one specimen, both sides of nasal cavities required multiple attempts for complete dissection. The PE and FS on the left side both required 2 attempts. All Haller cells were opened with equal success in both groups.

## Discussion

Complete yet safe ethmoid and frontal sinuses dissections are especially difficult to perform due to anatomical variations and their close proximity to vital structures. Whether using IGS or not to perform ESS, similar degree of completeness can be achieved in our study. Although, the results were not statistically significant, IGS did not seem to provide additional benefit. In addition, ICT appeared to be useful in completing PE and FS dissections even without the use of IGS. Variations in anatomy did not significantly affect levels of complete-

ness of MA, AE, PE or SP with regards to IGS. However, the incomplete resection of an uncinate attached to middle turbinate in one specimen resulted in failed PE and FS dissections on first attempt.

IGS has almost become the standard of practice in endoscopic sinus surgery nowadays. Current IGS technology relies on preoperative CT imaging only. This can negatively affect IGS accuracy as ongoing dissection distorts and displaces the surgical anatomy. Intraoperative-CT scans can overcome this by providing real-time localization and guidance. The present study showed that ICT alone without IGS may be sufficient to ensure complete dissection without violating vital structures especially in FS. This provided additional insight to a previous cadaver study conducted by Wise et al, which demonstrated the superior anatomical identification as well as surgeon's confidence with IGS compared to endoscopy alone [7]. In an independent cadaver study, the use of ICT also significantly improved the accuracy of surgery at the skull base [3].

Although anatomical variations presented differently between patients, our experiment showed that the evaluated structures (i.e., AEA, Haller cells, Keros classification, uncinate attachment, frontal cell classification, Onodi cells, supraorbital ethmoid cells, and intrafrontal septal cells,) did not significantly affect a surgeon's ability to achieve complete dissection with the same safety profile with or without IGS.

Limitations to our current study include the nature of a cadaver study and the small number of cadavers available. Ideally, the comparison should be made in living patients with nasal polyposis and bleeding to best represent a true operative environment. However, such clinical studies will unlikely meet IRB criteria for human study approval.

## Conclusion

IGS has shown to be accurate and reliable when performing ESS. However ESS without IGS was as effective as ESS with IGS in our study. Intraoperative CT or post-dissection CT demonstrated unopened sinus air cells and provided information for a complete dissection after the scan was performed. Our study demonstrated the beneficial use of ICT in ensuring a comprehensive sinus dissection as well as determining any intraoperative complication even when IGS is not available.

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