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The feasibility of using magnetic resonance imaging scans for endoscopic sinus surgery*

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Abstract

Background: We have previously shown that an adjusted magnetic resonance imaging (MRI) protocol could be used as an alternative for assessing most bony paranasal and vital structures. Here, we aimed to determine the feasibility of using this protocol during endoscopic sinus surgery (ESS) in patients with chronic rhinosinusitis (CRS).

Methods: Three experienced rhinologists used an adjusted MRI scan to plan and perform ESS. They were blinded to the CT images and observed them only postoperatively. They also completed a detailed questionnaire about their experience.

Results: Forty-three patients with CRS (60.5% with polyps and 39.5% without polyps) were included in the study. MRI navigation was used in 58.3% and 33.3% of surgeries performed by surgeon #1 and #2, respectively. The median Lund-Mackay score was 12 (interquartile range 2-24). None of the surgeons switched entirely to using CT scans during the procedure; No intra or postoperative complications were observed. Two surgeons reported that it was convenient to work with the MRI scans to visualize all nasal sinuses, but the third surgeon found MRI scans convenient for visualizing the frontal sinus. MRI convenience was considered superior to CT in 7 cases (16.3%), the same as CT in 29 cases (67.4%), and inferior to CT in 7 cases (16.3%). All three surgeons agreed that using MRI scans intraoperatively for ESS is safe and comparable to using CT scans.

Conclusion: MRI is a well-suited modality for planning and performing ESS. Rhinologists would be able to rely on it in specific and highly selected indications.

Key words: computed tomography, endoscopic sinus surgery, intraoperative navigation, magnetic resonance imaging

Introduction

Sinus computed tomography (CT) scans help sinus surgeons to assess the extent of disease and is the imaging modality of choice for evaluating chronic rhinosinusitis (CRS) and for planning and performing endoscopic sinus surgery (ESS) [(1-3)]. CT scans provide clear images of the bony septae, which can help increase the precision of surgery and its safety during the procedure. Although CT technology has dramatically changed over the years and now exposes patients to lower doses of ionizing radiation [(4)], most patients are usually still worried about radiation-emitting devices [(5)]. Furthermore, repeated exposure to ionizing radiation can lead to cataracts or neoplastic diseases, especially among younger individuals [(6-10)]. Compared to CT, magnetic resonance imaging (MRI) provides better soft tissue demonstration and does not emit ionizing radiation. However, it is not commonly used for ESS due to its suboptimal bone demonstration. To overcome these obstacles, we assembled an experienced team who developed an adjusted MRI protocol to enable a usable demonstration of the bony structures of the paranasal sinuses. The MRI protocol was previously found as an

Table 1. The distribution of diagnoses in the study population.

Diagnosis*	Total N=43 n (%)	Surgeon #1 N=17 n (%)	Surgeon #2 N=12 n (%)	Surgeon #3 N=14 n (%)	P value
Chronic sinusitis	17 (39.5)	10 (58.8)	1 (8.3)	6 (42.9)	0.022
Chronic sinusitis with nasal polyposis	26 (60.5)	7 (41.2)	11 (91.7)	8 (57.1)	0.022
Hypertrophy of inferior turbinates	34 (79.1)	15 (88.2)	12 (100.0)	7 (50.0)	0.004
Deviated nasal septum	41 (95.3)	17 (100)	12 (100.0)	12 (85.7)	0.114

Surgeon #1, R.L.; Surgeon #2, A.M.; Surgeon #3, A.Y. *Patients could have had more than one diagnosis.

appropriate alternative to CT for assessing paranasal anatomy in most bony elements and vital structures such as the carotid and ethmoidal arteries, the lamina papyracea, orbital content and the brain [11]. This study investigated whether images obtained using the adjusted MRI protocol can be used instead of CT images during ESS for patients with CRS.

Materials and methods

This prospective study was reviewed and approved by the local institutional ethics committee. The study was performed during Jan 1, 2020, Dec 31, 2022. Patients with CRS - with or without polyposis - who were candidates for primary ESS were included in the study. The patients were referred for a CT scan of the paranasal sinuses as part of the routine management. Following the CT scan, the patients signed an informed consent and underwent an MRI scan of the paranasal sinuses. Only primary cases were included in the study.

The patients were scanned in a Magnetom Aera 1.5 Tesla machine (Siemens Healthineers) using the following parameters: volumetric sequences, unenhanced, T1 and T2 sagittal turbo spin echo (TSE), 0.9-mm sections with three-dimensional (3D) reconstruction, for axial and coronal planes, and direct coronal 0.9-1-mm sections T1 and T2 3D TSE images(12). The duration of each scan was approximately 30 minutes.

Three experienced sinus surgeons used the adjusted MRI protocol to plan and perform ESS. They had read the CT reports before indicating surgery but were blinded to the images while planning and performing ESS. The CT images were available as a backup only. The surgeons could use MRI navigation during surgery. Post-operatively they viewed the CT images and completed a detailed questionnaire. The comfort of using MRI images during the study was ranked on a scale of 1 to 3 (1 - very comfortable, 2- comfortable, 3-uncomfortable).

Statistical analysis

Categorical variables are reported as numbers and percentages, and continuous variables are reported medians and interquartile ranges (IQR). Categorical variables were compared using Chi-squared test and continuous variables were compared by Kruskal-Wallis test. A two-tailed p value <0.05 was considered statistically significant. Analyses were performed with SPSS version 28 (IBM Corporation, Armonk, NY, USA).

Results

Forty-three patients (14 females and 29 males) with CRS were included in the study. Twenty-six patients (60.5%) had surgery for CRS with polyps, and 17 (39.5%) had surgery for CRS without polyps. Additionally, 41 patients (95.3%) had surgery to repair a deviated septum, and 34 (79.1%) underwent conchotomy (Table 1). The involved sides, sinuses, and Lund-Mackay scores are summarized in Table 2. The median Lund-Mackay score was 12 (IQR, 2 to 24).

Seventeen surgeries (39.5%) were performed by R.L. (Surgeon #1), 12 (27.9%) by A.M. (Surgeon #2) and 14 (32.6%) by A.Y. (Surgeon #3). MRI navigation was used in 14 of 43 surgeries (32.6%): in 10/17 (58.3%) of surgeries performed by surgeon #1, and 4/12 (33.3%) of surgeries performed by surgeon #2 and in 0 by surgeon #3. During the procedure none of the surgeons switched to using only CT images. CT images were intermittently viewed in one operation (2.3%). No intra or postoperative complications occurred in any of the patients.

Two surgeons (#1 and #3) reported that they found the MRI scans convenient for visualizing all nasal sinuses. Surgeon #2 reported that MRI scans were less convenient for visualizing the frontal sinus (range, 2.3-3, p<0.001 compared to the other surgeons; Table 3). According to the surgeons' immediate postoperative comparison, MRI was superior to CT in 7 cases (16.3%), particularly in its ability to distinguish the anterior ethmoidal artery and the delicate border between the contents of the orbit and the paranasal sinuses. MRI was found to be the same as CT in 29 cases (67.4%). CT was reported as superior to MRI in 7 cases (16.3%) – all of them were related to the frontal recess and sinus cells, and most of them (6/7) were operated on by surgeon’s #2.

All three surgeons agreed that intraoperative MRI is safe and that they would not operate any differently after seeing the CT images. They will now consider working with MRI scans instead of CT scans in selected cases. Representative examples are shown in Figure 1.

Table 2. Involved sides, sinuses, and Lund-Mackay scores.

Variables	Total N=43	Surgeon #1 N=17	Surgeon #2 N=12	Surgeon #3 N=14	P value
Frontal sinus, n/N (%)	**23/43 (53.5)**	**8/17 (47.1)**	**8/12 (66.7)**	**7/14 (50.0)**	**0.552**
Unilateral, n/N (%)	5/23 (21.7)	2/8 (25.0)	1/8 (12.5)	2/7 (28.6)	0.725
Bilateral, n/N (%)	18/23 (78.3)	6/8 (75.0)	7/8 (87.5)	5/7 (71.4)	
Right Lund-Mackay score, median (IQR)	1.0 (0.0-2.0)	1.0 (1.0-2.0)	2.0 (1.0-2.0)	0.0 (0.0-2.0)	0.097
Left Lund-Mackay score, median (IQR)	1.0 (0.0-2.0)	1.0 (1.0-2.0)	1.5 (1.0-2.0)	0.0 (0.0-1.3)	0.030
Maxillary sinus, n/N (%)	**39/43 (90.7)**	**14/17 (82.4)**	**12/12 (100.0)**	**13/14 (97.9)**	**0.258**
Unilateral, n/N (%)	9/39 (23.1)	4/14 (28.6)	0/12 (0.0)	5/13 (38.5)	0.062
Bilateral, n/N (%)	30/39 (76.9)	10/14 (71.4)	12/12 (100.0)	8/13 (61.5)	
Right Lund-Mackay score, median (IQR)	1.0 (1.0-2.0)	2.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (1.0-1.3)	0.036
Left Lund-Mackay score, median)(IQR)	1.0 (1.0-2.0)	2.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (0.0-1.0)	<0.001
Anterior ethmoidal sinus, n/N (%)	**35/43 (81.4)**	**14/17 (82.4)**	**12/12 (100.0)**	**9/14 (64.3)**	**0.065**
Unilateral, n/N (%)	6/35 (17.1)	2/14 (14.3)	0/12 (0.0)	4/9 (44.4)	0.026
Bilateral, n/N (%)	29/35 (82.9)	12/14 (85.7)	12/12 (100.0)	5/9 (55.6)	
Right Lund-Mackay score, median (IQR)	2.0 (1.0-2.0)	2.0 (2.0-2.0)	1.5 (1.0-2.0)	1.0 (0.0-2.0)	0.021
Left Lund-Mackay score, median (IQR)	2.0 (1.0-2.0)	2.0 (1.5-2.0)	1.5 (1.0-2.0)	0.0 (0.0-2.0)	0.004
Posterior ethmoidal sinus, n/N (%)	**31/43 (72.1)**	**13/17 (76.5)**	**12/12 (100.0)**	**6/14 (42.9)**	**0.005**
Unilateral, n/N (%)	2/31 (6.5)	1/13 (7.7)	0/12 (0.0)	1/6 (16.7)	0.387
Bilateral, n/N (%)	29/31 (93.5)	12/13 (92.3)	12/12 (100.0)	5/6 (83.3)	
Right Lund-Mackay score, median (IQR)	1.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (1.0-2.0)	0.5 (0.0-1.3)	0.03
Left Lund-Mackay score, median (IQR)	1.0 (1.0-2.0)	2.0 (1.0-2.0)	1.0 (1.0-2.0)	0.5 (0.0-1.3)	0.012
Sphenoid sinus, n/N (%)	**14/43 (32.6)**	**6/17 (35.3)**	**4/12 (33.3)**	**4/14 (28.6)**	**0.922**
Unilateral, n/N (%)	3/14 (21.4)	2/6 (33.3)	0/4 (0.0)	1/4 (25.0)	0.443
Bilateral, n/N (%)	11/14 (78.6)	4/6 (66.7)	4/4 (100.0)	3/4 (75.0)	
Right Lund-Mackay score, median (IQR)	0.0 (0.0-1.0)	1.0 (0.0-1.0)	1.5 (0.0-2.0)	0.0 (0.0-1.3)	0.344
Left Lund-Mackay score, median (IQR)	0.0 (0.0-1.0)	1.0 (0.0-1.0)	1.5 (0.0-2.0)	0.0 (0.0-1.0)	0.175
Inferior turbinates, n/N (%)	**34/43 (79.1)**	**15/17 (88.2)**	**12/12 (100.0)**	**7/14 (50.0)**	**0.004**
Nasal septum, n/N (%)	41/43 (95.3)	17/17 (100.0)	12/12 (100.0)	12/14 (85.7)	**0.114**
Right OMC Lund-Mackay score median (IQR)	2.0 (2.0-2.0)				**0.491**
Left OMC Lund-Mackay score median (IQR)	2.0 (2.0-2.0)				**0.109**
Total Lund-Mackay score, median (IQR)	12.0 (1.0-24.0)				**0.130**

Surgeon #1, R.L.; Surgeon #2, A.M.; Surgeon #3, A.Y. ; IQR, interquartile range; NA, not applicable; OMC, osteomeatal complex.

Table 3. Comfort of working with MRI scans during ESS.

Regions that were ranked	Total N=43	Surgeon #1 N=17	Surgeon #2 N=12	Surgeon #3 N=14	P value
		Mean score (range)			
Frontal sinus	1.5 (1.0-2.8)	1.5 (1.0-2.0)	3.0 (2.3-3.0)	1.0 (1.0-1.0)	<0.001
Maxillary sinus	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	0.108
Ethmoidal sinus	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	>0.999
Sphenoid sinus	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.5 (1.0-3.0)	1.0 (1.0-1.0)	0.007
Inferior turbinates	1.0 (1.0-1.5)	1.0 (1.0-1.0)	2.0 (1.0-2.0)	1.0 (1.0-1.0)	0.035
Nasal septum	1.0 (1.0-1.3)	1.0 (1.0-1.0)	1.5 (1.0-2.3)	1.0 (1.0-2.0)	0.051

Surgeon #1, R.L.; Surgeon #2, A.M.; Surgeon #3, A.Y. ; Scale scores: 1- very comfortable, 2- comfortable, 3-uncomfortable

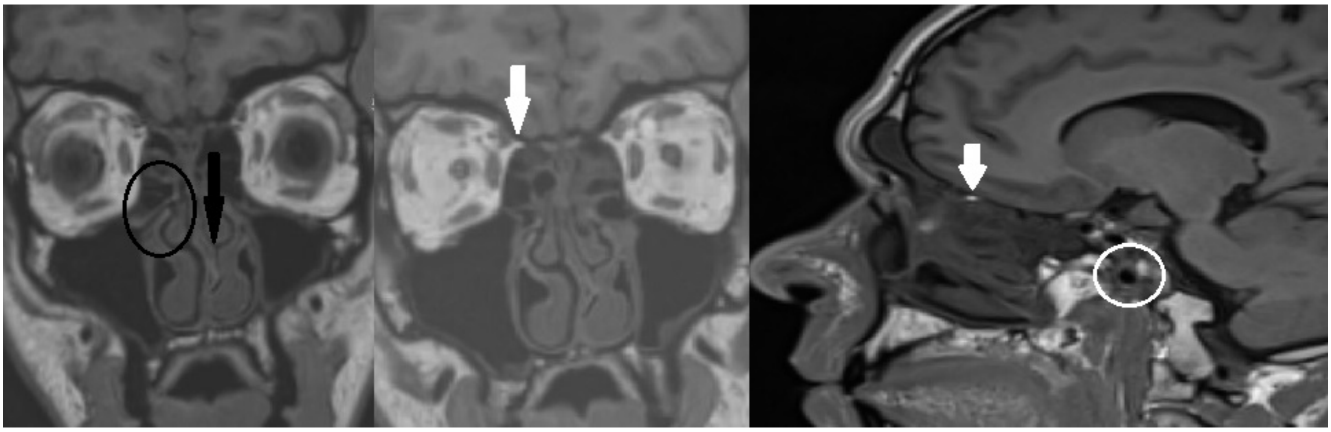

Figure 1. Representative images. Infundibulum (black circle), septal deviation and inferior turbinate hypertrophy (black arrow), anterior ethmoidal artery (white arrow) and carotid artery (white circle).

Discussion

CT scans provide excellent details on bones and are essential for planning and performing ESS [1-3]. There is sparse literature on using MRI during ESS. Fried et al. [12] described 12 cases that underwent a pre-operative CT scan followed by an interactive, intraoperative MRI-guided ESS within a vertically open magnetic resonance system. Thus, if changes in the anatomy occurred during surgery, the images were updated to incorporate them. MRI provided adequate visualization of the disease and the related anatomy and allowed the surgeon to navigate during the surgery [12]. As far as we know, our study is the first to investigate the feasibility of using MRI scans as a substitute for CT scans for planning and performing ESS. The utilization of highly experienced surgeons, thorough endoscopical examinations, meticulous analysis of the CT reports, and subsequent confirmation through MRI images were pivotal in establishing a secure method for selecting appropriate candidates for surgery. Following exposure to the CT scans, surgeons reported that in the majority of cases (67.4%), both MRI and CT were equally effective for surgical planning and execution. Additionally, in 16.3% of cases, MRI was preferred mainly due to its capability to differentiate between the anterior ethmoidal artery and the lamina papyracea. Surgeon #2 preferred CT in 50% of cases. This may be explained by his reluctance to use the navigation system or because he is the least experienced of the three. Difficulties to achieve a clear view occurred in surgeries involving frontal sinus cells. However, these challenges did not affect surgery performance or safety. The main disadvantage of CT is the exposure of the patient to ionizing radiation and the limited soft-tissue demonstration [13-16]. The use of MRI eliminates these shortcomings. For example, a CT image might show ethmoidal mucosal disease, but MRI can reveal that the problem is fat herniating from the orbit [11]. Therefore, the use of MRI scans can contribute significantly to the safety of the surgery and prevent any grave consequences.

MRI navigation has revolutionized the field of neurosurgery, enabling neurosurgeons to perform various procedures with great precision and accuracy. Today, neurosurgeons are often content with using only MRI scans, even when operating on the bony structures of the skull base. Enchev et al. found no statistically significant differences in the accuracy and reliability of neuronavigation using MRI compared to CT [17]. Rhinologists and neurosurgeons share common anatomical structures and complex variants (e.g., sella turcica, optic nerve, cribriform plate, sphenoid septa). Nazri et al. [18] investigated the prevalence of incidental sinus abnormalities on CT and MRI and concluded that MRI is more sensitive than CT in detecting sinus mucosal abnormalities. MRI was also found to be better than CT in its ability to distinguish fluid from tissue. Rhinologists may therefore choose to use CT or MRI based on the patient's characteristics, the level of anatomical complexity and the disease's nature.

The study is not without limitations. Although MRI images can be easily adjusted to highlight the patient's anatomy, their concept and implementation are not intuitive and require proper training and education. The use of MRI also involves high cost, lower accessibility and longer examination time [19,20]. The experience of only three endoscopic surgeons is unlikely to provide an accurate consensus measurement, but this sample size was found to be statistically sufficient for this study. Although CT scans remain the primary tool used for imaging in ESS, the adjusted MRI protocol has many benefits and has been proven as adequate. We have shown that it can provide images with enough resolution to demonstrate the bony paranasal and vital structures. Our initial experience suggests that using MRI during ESS to treat CRS is a safe and feasible option. Sinus surgeons should be aware of the health risks associated with ionizing radiation exposure, especially among radiosensitive populations such as children, pregnant women, and patients with repeated radiation exposure. In such cases, it is advisable to consider selecting an MRI scan as an alternative to a CT scan. Additionally, patients who have undergone an MRI for any reason and have revealed pathology, such as an antrochoanal polyp in the maxillary sinus, which is well demonstrated by MRI [11], should also consider this option.

Conclusions

The results of this study demonstrate that MRI is a well-suited modality for planning and performing ESS. Rhinologists could rely on it for achieving an effective and safe outcome in specific and selected indications, while reducing patients' exposure to radiation.

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Authorship contribution

RL, JL (equal contribution) SS: Study design, data collection, data evaluation and manuscript writing. AY, MMasal, AM, MMasar: Data collection and evaluation.

Ethics approval and consent to participate

The study was approved by the Helsinki committee of the Hospital. All the patients signed a consent form.

Availability of data and materials

The data sets used and/or analyzed during the present study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors have no conflicts of interest to disclose.

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