Chronic Sphenoid Sinusitis Revisited

Comparison of Multidetector Axial Sections, Multiplanar Reconstructions, and Virtual Sinoscopy With Endoscopic Sinus Surgery

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Objectives: To assess the role of multidetector computed tomography (CT) and CT virtual sinoscopy in the evaluation of chronic sphenoid sinusitis and to compare the imaging findings with functional endoscopic sinus surgery.

Design: Prospective study.

Setting: Tertiary care teaching hospital.

Patients: Thirty patients with chronic sphenoid sinusitis referred for preoperative CT.

Interventions: Thin-section helical axial CT was performed using a multidetector CT scanner with multiplanar reformation (MPR) and volume-rendered or virtual sinoscopy images. Sixty sinuses were divided into quadrants for analysis. Extrasinus extension was labeled as the “fifth quadrant.”

Main Outcome Measures: Imaging findings were compared with those of functional endoscopic sinus surgery, and accuracy of the imaging modality was determined.

Results: Multidetector CT (axial CT and MPR) was found to be 100% sensitive, specific, and accurate in the evaluation of extent of sinusitis, status of the sinus septum, integrity of the optic nerve canal in relation to the sinus, and type of sinus pneumatization. Axial CT and MPR images showed sensitivity of 98% and specificity of 92% compared with functional endoscopic sinus surgery in evaluating the ostia. Regarding carotid canal integrity, axial CT and MPRs were 100% sensitive and 98% specific. Virtual sinoscopy showed sensitivity and specificity of 67% and 92%, respectively, for the 22 ostia that could be visualized and evaluated using this modality.

Conclusions: Axial multidetector CT with secondary MPRs provide the necessary preoperative information regarding extent of disease and sphenoid sinus anatomy. Virtual sinoscopy is a navigational aid, an adjunct to endoscopy, and an educational tool for surgeons-in-training.

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chronic sphenoid sinusitis occurs more often in patients with pansinusitis, and fewer than 3% of inflammatory lesions of the sinuses primarily involve the sphenoid sinus.1 Diseases of the sphenoid sinus often display long-standing, subtle symptoms with elusive physical findings. Typically, patients with sphenoid sinus disease report a long clinical history and often present with retro-orbital headache.2 Chronic sphenoid sinusitis requires early diagnosis and should be appropriately treated because its regional complications can be devastating and potentially life-threatening. Proetz3 described 13 structures adjacent to the sphenoid sinus that may be affected by inflammatory spread of the sphenoid abnormality or may be injured during endoscopic surgery, the most important of them being the optic nerve and the internal carotid artery.

During the past decade, functional endoscopic sinus surgery (FESS) has become a standard and effective surgical technique for the treatment of patients with chronic and recurrent sinusitis. For the planning and safety of FESS, considerable attention has been directed toward preoperative analysis of the paranasal sinus anatomy through radiologic imaging.

The earliest imaging modality used for visualizing the sphenoid sinus was the plain radiograph. However, the standard radiographic views were suboptimal because of problems with ideal positioning and overlap of the bony landmarks. This modality is usually helpful in acute sinusitis for the detection of fluid levels but is inadequate in evaluating chronic sinusitis. Computed tomography (CT), because of its superior bone detail and de-
piction of fine anatomical variations, remains the best technique for evaluating the presence and extent of chronic sinonasal disease and planning for FESS. It exquisitely delineates anatomical relationships and variations before surgery, especially the intrasinus septation of the sphenoid sinus and its relationship to the internal carotid artery, the presence of Onodi cells, a dehiscent optic nerve, and carotid canals.

The advent of multidetector CT (MDCT) and newer software techniques, such as volume rendering and virtual endoscopy (VE), has made virtual sinoscopy (VS) possible. There are only limited studies evaluating the diagnostic role of VS, and, to our knowledge, there has been no study evaluating chronic sphenoid sinusitis using VS. This study was conducted to evaluate the role of MDCT with multiplanar reformations (MPRs) and VS in preoperative imaging of chronic sphenoid sinusitis and to compare them with FESS.

METHODS

This prospective study, which was approved by the Ethics and Thesis Committee of the Postgraduate Institute of Medical Education and Research, included 30 patients (16 males and 14 females; mean age, 35.3 years; age range, 10-65 years) with a clinical suggestion of chronic sphenoid sinusitis. The clinical diagnosis of sphenoid sinusitis was based on the presence of recurrent episodes of deep-seated headache behind the eye (retro-orbital pain due to spasm of the extracocular muscles), a history of blurring of vision or ophthalmoplegia in chronic sinusitis, or a history suggestive of cavernous sinus thrombosis in chronic sinusitis. Patients diagnosed as having abnormalities other than chronic sinusitis, such as papillomas, fibrous dysplasias, or malignancies of the sphenoid sinuses, and who had a history of surgery or endoscopic sinus surgery on the sphenoid sinus were excluded from the study. Written informed consent was obtained from all patients. Any medical treatment in patients, and intravenous contrast was not used.

All the patients underwent a single thin-section axial CT study using a 4-slice MDCT scanner. A helical MDCT scanner (Light Speed Qxi; GE Medical Systems, Milwaukee, Wisconsin) was used for data acquisition in the axial plane. The CT raw data were obtained using collimation of 1.25 mm and a pitch value of 3, with a reconstruction interval of 0.63 mm at 120 kV (peak) and 150 to 200 mA in the axial plane from the superior aspect of the frontal sinuses through the maxillary alveolar ridge, inferiorly. The gantry rotation speed used was 0.8 revolutions per second. Primary coronal imaging was not performed in any of the 30 patients, and intravenous contrast was not used.

The axial raw data acquired from these studies was transferred to the Advantage Windows 4.1 Workstation (GE Medical Systems), where MPR software was used to reconstruct coronal and sagittal reformations. The extent of the disease, the status of the sphenoid sinus septum and sphenoid sinus ostium, the integrity of the bony optic nerve canal and the carotid artery canal, and the type of sinus pneumatization were evaluated from the axial raw data and from the reconstructed images.

From the axial raw data, volume-rendering software for VE was applied to reconstruct the sphenoid sinus. A negative threshold of less than −50 was applied to visualize the 22 partially aerated sinuses. The status of the sphenoid sinus septum and ostium and the dehiscence of the optic nerve and carotid canals were evaluated from endoscopic views created by scrolling the cursors placed on the simultaneously displayed MPR images, and the resultant VE images were stored for permanent records. The location of the endoscopic view was correlated from the position of the cursor in all 3 planes. Negative threshold could not be applied in the 38 completely nonaerated sinuses. In such cases, visualization of the sinus ostium was made possible by applying a positive threshold (approximately +30 to +350).

To aid assessment and for statistical analysis each half of the sphenoid sinus on coronal reformations divided by the septum was further subdivided into a superior and inferior quadrant. Thus, in 30 patients we recorded CT observations for 60 sphenoid sinuses, 60 sinus ostia, and 120 quadrants. Extent of disease was described by the number of quadrants involved. Any extension beyond the sinus, such as into the ethmoid sinus or paraellar region, was labeled as the “fifth quadrant.” The scans were read by a resident (B.W.) and a trained head and neck radiologist (J.R.B. or N.K.). The following observations were documented after review of the axial sections and MPRs (coronal and sagittal): (1) extent of disease, (2) status and position of the sinus septum, (3) patency of the sphenoid sinus ostium, (4) optic nerve canal relation and the presence of a dehiscent wall, (5) carotid canal relation and the presence of a dehiscent wall, and (6) type of sinus pneumatization. The type of pneumatization of the sphenoid sinus was categorized based on the classification of Black and co-authors as frontal, presellar, or sellar depending on the extent of pneumatization. This classification was chosen because it is relevant to the endoscopic sinus surgery. The reconstructed VE images were also reviewed. The status of the septum, sinus ostium, optic nerve canal dehiscence, and carotid artery bulge or dehiscence was commented on.

RESULTS

Axial CT and MPR showed sensitivity, specificity, and accuracy of 100% for the presence and extent of sinusitis compared with FESS. Axial CT and MPR showed 4-quadrant (or fifth-quadrant) disease, that is, complete involvement of the sphenoid sinus or extension beyond the sinus, in 17 patients (57%) and less than 4-quadrant disease in the remaining 13 (43%) (Table 1 and Figure 1). The use of VS in evaluating the extent of sphenoid sinusitis was limited because the software could not be effectively applied in the nonaerated involved sinuses.
Axial CT and coronal MPR could accurately show the position and integrity of the sinus septum, which was normal and intact in 26 patients (87%) and eroded in 4 (13%), with sensitivity, specificity, and accuracy of 100% compared with FESS (Table 1 and Figure 1). Virtual sinoscopy could not evaluate the septum in the 38 opacified sphenoid sinuses (63%), and the 4 eroded septae were present in the opacified sinuses. In the 22 partially aerated sinuses, using a negative threshold VS could show the intact sinus septum.

Axial CT and sagittal MPR showed that 48 of 60 sinus ostia were obstructed (80%) and that the remaining 12 were patent (20%), with 100% sensitivity, specificity, and accuracy compared with FESS (Table 1 and Figure 2A and B). On the other hand, using a negative (<−50) threshold, VS showed obstructed ostia in 7 (32%) and patent ostia in 15 (68%) of the 22 partially aerated sphenoid sinuses (37%) (Table 2 and Figure 2C). Compared with FESS, VS showed sensitivity of 67%, specificity of 92%, and accuracy of 77% for the 22 aerated sinuses in evaluation of the ostium. In the 38 opacified sinuses (63%), due to its inherent limitations VS software could not be applied to see the ostium, but it could demonstrate the ostium using a positive threshold (+30 to +350) (Figure 3).

Regarding optic nerve canal integrity, axial CT and coronal MPR showed an intact bony canal in 53 of 60 sinuses (88%) and a dehiscent canal in the remaining 7 (12%), with sensitivity, specificity, and accuracy of 100% compared with FESS (Table 1 and Figure 4). Axial CT and coronal MPR demonstrated the carotid canals to be intact in 52 sinuses (87%) and dehiscent in 8 (13%) (Table 1). In 1 patient there was a dehiscent carotid canal on 1 side, but it was not confirmed at FESS (Figure 5). Hence, axial CT and coronal MPR showed sensitivity of 100%, specificity of 98%, and accuracy of 98% compared with FESS for evaluating the carotid canal.

Axial CT and coronal and sagittal MPRs showed 100% sensitivity, specificity, and accuracy compared with FESS in the evaluation of the type of pneumatization. Most patients (19 of 30 [63%]) in this study had the sellar type of pneumatization, and the remaining 11 (37%) had the presellar type (Table 1). The conchal type of pneumatization, the rarest form, was not seen in any patients. The depiction of the type of pneumatization was best on sagittal MPR.

The introduction of MDCT has widened the range of applications of helical CT in clinical imaging, especially in the field of virtual imaging. With the help of MDCT it is possible to rapidly obtain thin sections with improved z-axis resolution, high-quality MPRs, and volume-rendered images. Volume acquisition makes it possible to retrospectively reconstruct overlapping images, thus producing high-quality 3-dimensional reconstructions.

In this prospective study, 30 patients were evaluated using CT (axial and MPR), which was 100% sensitive, specific, and accurate in showing the extent of disease compared with FESS. The presence of sphenoid sinus septation, its relation to the carotid canal, and the presence of dehiscent bone over it are important preoperative details for the endoscopic surgeon. Axial CT and MPR (coronal and sagittal) accurately demonstrated the status of the sinus septum, with 100% sensitivity and specificity compared with FESS. Similarly, the optic nerve canal and the carotid canal are other important landmarks that the surgeon should be aware of when exploring the sphenoid sinus endoscopically because the optic nerve and the carotid artery can be injured during endoscopic procedures.

The sphenoid sinus ostia were best evaluated on axial CT and sagittal MPR. We observed that there is excellent correlation between axial CT and sagittal MPR with each other and with FESS in assessing the status of the ostia. Axial CT and sagittal MPR showed sensitivity of 98%, specificity of 92%, and accuracy of 97% in evaluating the ostia.

The close association of the optic nerve and the internal carotid artery to the lateral wall of the sphenoid sinus and the posterior ethmoidal air sinus make them vulnerable to direct injury during FESS, especially if the...
overlying bone is thin or dehiscent or there is extensive pneumatization of the sphenoid sinus. Complications such as postoperative blindness, cerebrospinal fluid leak and its sequelae, carotica-cavernous fistula, and even death have been reported. Therefore, it is vital to demonstrate these structures on preoperative imaging studies.

In the present study, 7 optic nerve canals (12%) and 8 carotid canals (13%) were dehiscent in axial CT and MPR images. Axial CT with coronal MPR is highly accurate in assessing the optic nerve canal and the carotid canal. Axial CT and coronal MPR were 100% sensitive, specific, and accurate in showing the relation of the optic nerve canal to the sphenoid sinus and the intactness of the overlying bony plate.

Table 2. VS vs FESS in the Evaluation of 22 Ostia Visualized Using Negative Threshold

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>FESS patent</th>
<th>FESS blocked</th>
<th>Total, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VS patent</td>
<td>11</td>
<td>4</td>
<td>15 (68)</td>
</tr>
<tr>
<td>VS blocked</td>
<td>1</td>
<td>6</td>
<td>7 (32)</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>10</td>
<td>22</td>
</tr>
</tbody>
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Abbreviations: FESS, functional endoscopic sinus surgery; VS, virtual sinoscopy.
Figure 3. A 55-year-old man with chronic sphenoid sinusitis with obstructed ostia of the sphenoid sinus. A, Axial computed tomographic (CT) section showing obstructed ostia (arrows) of the sphenoid sinus. B, Sagittal reformation showing the same finding (arrow). C, Virtual sinoscopy of the same patient revealing a patent right-sided ostium (arrow) due to the use of a positive threshold. D, Virtual sinoscopy also showing a patent left ostium (arrow) due to the use of a positive threshold. L indicates lateral; SA, superior and anterior; and X, Navg, and A83, the navigator tool configuration generated by the CT software.
Regarding the carotid canal, axial CT and coronal MPR showed a 2-mm dehiscence in the left carotid canal in 1 patient in whom FESS showed it to be intact, resulting in sensitivity of 100%, specificity of 98%, and accuracy of 98%. This observation could be because of volume averaging so that a small defect was apparent when actually there was none.

Routine paranasal imaging includes axial and coronal scanning by taking 3- to 5-mm sections. Sonkens et al10 used only coronal contiguous scanning as the “screening sinus CT” protocol in evaluating patients for possible endoscopic sinus surgery and found that screening sinus CT with only coronal scanning has emerged as the single best radiologic evaluation in such patients by accurately identifying the pattern of sinonasal involvement. The surgical approach was planned according to the CT findings.

In this study, only 1.25-mm axial sections were taken from the superior aspect of the frontal sinus to the maxillary alveolar ridge inferiorly. Axial positioning is more comfortable for the patient and results in fewer motion artifacts. It is possible to plan sections avoiding the dental amalgam, which could degrade the images. It also provides easy assessment of the optic nerve canal. The relationship of the optic nerve canal and the intracavernous carotid canal to the sphenoid sinus and the posterior ethmoidal air sinuses are better seen in axial sections. Bernhardt et al9 evaluated paranasal sinuses using thin-section axial helical CT and reported stair-step artifacts in the coronal MPRs, degrading the image quality. In the present study, which used MDCT and overlapping thin sections, good-quality coronal and sagittal MPRs were possible without an additional radiation exposure from separate coronal scanning.

To our knowledge there is no literature on the role of VE in the preoperative evaluation of sphenoid sinus with chronic sinusitis. In 2000, Han et al10 used dual-detector CT to compare VE of the nasal cavities with fiberoptic endoscopy in 9 patients. They compared VE and functional endoscopy in visualizing the normal anatomical structures in the lateral wall of the nasal cavities and the nasal septum as well as the pathologic changes. They observed that VE missed 2 polyps 3 mm and smaller that were seen on functional endoscopy. In addition, “pseudo-foramina” artifacts were present in VE images in 3 patients. These artifacts were seen at points where the curve of the nasal contour changed sharply. We encountered a similar situation in the present study, especially in the nonaerated sphenoid sinus. Virtual endoscopy showed a distinct advantage over functional endoscopy by its ability to enter the narrow middle meatus using the fly-through technique. However, application of this technique was limited in opacified sinuses.

In the present study we tried to evaluate the sinus ostia using VS, which seemed to be a promising imaging modality. Sensitivity and specificity were 67% and 92%, respectively, with accuracy of 77% for evaluating the 22 ostia in the partially aerated sphenoid sinuses. Virtual sinuscopy convincingly demonstrated patency in these 22 ostia, with a negative threshold of −50 to −966. However, in the 38 opacified sinuses the location and patency of the ostia could not be evaluated. By increasing the threshold level to a positive range we visualized them in a range of +38 to +350, showing an “artifactually” patent ostium. Thus, VS requires modifications in technique to demonstrate ostia in opaque sphenoid sinuses. Therefore, the pitfall in VS is that there are no fixed threshold guidelines that can be used for ostium evaluation. The same negative thresholding also hampered evaluation of septae, carotid artery, and optic nerve bulge into the opacified sphenoid sinus. To show a dehiscent bony optic nerve canal convincingly at a negative threshold on VS we need an aerated sphenoid sinus and air outside the sinus, that is, within the optic nerve canal itself, which is not possible. Virtual sinuscopy could not demonstrate the integrity of the canal wall in the aerated and opacified sinuses in the endoscopic images at a negative threshold.

Roth et al13 used intraoperative 3-dimensional CT during FESS to avoid the possible perioperative intraorbital and intracranial complications. Thin-section (3-mm) axial CT was performed using registration markers on the patient's skin, followed by reconstruction of a 3-dimensional image of the patient's skull, skin, and surface markers. The 3-dimensional data were used in the operating room, where with the help of a computer and a viewing
wand system any point on the patient’s sinuses could be accurately represented on a triplanar display consisting of axial CT and the coronal/sagittal reformatted image, thus averting damage to the vital structures during FESS. This technique was particularly useful in patients with distorted anatomy due to previous surgery. With the advent of VS, we hope that this technique can prove to be an important aid and that a similar utility can be made available for intraoperative localization of sphenoid sinus ostia and a dehiscent optic nerve canal and carotid canal during endoscopic surgery. As the technology of MDCT evolves in the future, with efforts to improve the z-plane resolution, we hope that VS will be seamlessly integrated with either axial or direct coronal imaging. Virtual sinoscopy can then be integrated as simulation software for demonstrating the sinus anatomy. It has the advantage of offline applications and can be used in environments other than the operating room. Surgeons in training can benefit from this technique by learning to navigate the anatomy on a workstation, which can closely simulate an actual sinus setting. Software can be simulated using a variety of retrospective cases with variations in the position of the nasal septum and sphenoid sinus anatomy with and without soft tissue opacification. As with the currently available simulation platforms, VS may have substantial advantages, such as increased exposure to difficult scenarios, reduced learning curves, and reduced costs.12

In this prospective study the thin-section axial data of the sphenoid sinus and the MPRs accurately provided the necessary information to the operating surgeon. Avoiding coronal imaging saved time and an additional radiation dose to the patient. Virtual sinoscopy could be applied satisfactorily on a normal and a well-aerated sphenoid; however, it required minor modifications in technique for visualization of sphenoid ostia in opacified sinuses. Virtual sinoscopy was limited by the presence of soft tissue material in the sinus to image a dehiscent bony optic nerve canal convincingly at a negative threshold. However, with further advances in MDCT it can be a potentially useful aid to train surgeons in endoscopic sinus surgery.

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