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Radiology in Focus

A systematic approach to the interpretation of computed tomography scans prior to endoscopic sinus surgery

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Abstract
Computed tomography (CT) provides an excellent map for the sinus surgeon as well as providing information about the extent of disease and the presence of bony destruction. Surgeons need to be aware of the anatomical configuration of the sinuses and the presence of any structural changes such as a dehiscent lamina papyracea, asymmetric skull base, low level of posterior skull base or an Onodi cell, which place the patient at increased risk. Described here is a six-step guide to help the sinus surgeon avoid missing any of the radiologically important features.

Key words: Radiology; Endoscopy; Nasal Cavity; Sinusitis

Introduction

CT imaging of the paranasal sinuses is most commonly used by otorhinolaryngologists for planning endoscopic sinus surgery, but they are also used to assess tumours, inflammatory swellings and trauma of the facial skeleton, paranasal sinuses, orbit and skull base. 'Low dose' imaging protocols are important to reduce the radiation dose to the cornea (Royal College of Radiologists' Working Party, 1995). The distance between cuts can be varied: 2 mm cuts for detail such as in the assessment of CSF leaks, whilst in the assessment of other nasal conditions and prior to sinus surgery 4 mm cuts usually suffice.

Stammberger and Kennedy (1995) have described in detail the anatomical terminology and nomenclature which provide the present accepted terminology for surgeons and anatomists.

Coronal sections are preferred when planning for endoscopic sinus surgery, but in cases of malignancy, sphenoidal pathology or disease involving the orbit, axial sections are needed. The window setting for the scan is selected to demonstrate the contrast between bone and soft tissue (Zinreich *et al.*, 1987; Kopp and Stammberger, 1991).

The value to the surgeon of the CT images prior to sinus surgery is that it demonstrates any anatomical variations, and highlights the structures which may be at risk, such as the orbit, optic nerve and the skull base. There are several important features which should be considered, and unless the observer has a system it is easy to overlook a potentially important sign. Kopp and Stammberger (1991) have listed a useful series of questions for the surgeon to consider 'immediately prior to surgery' (Table I). Described here is a six-step guide to avoid missing any of the radiologically important features.

Step 1: Orientate the scan sequence from anterior to posterior

Identify the frontal sinus (anterior cut) and the nasopharynx (posterior cut), and ensure that the sides are marked and placed as though you are looking at the patient i.e. their right side is on your left, as this is how you will approach the patient. Follow the cuts anterior to posterior, ensuring you can orientate the nasal cavity, orbits, maxillary sinuses, the ethmoid labyrinth, and the anterior cranial fossa. Follow the septum, note any deviation that will block access to the lateral wall of the nasal cavity, and at what level the septum deviates. A septal deviation which affects the upper half of the septum can severely limit access to the frontal recess. The ethmoidal bulla lies medial to the maxillary sinus and is one of the most consistent landmarks, although its size varies from 18 mm long (range 9–28), 5.4 mm high (range 2–13 mm) (Lang 1989) and approximately 3.6 mm wide (Jones *et al.*, 1997) (Figure 1).

Step 2: Examine the lamina papyracea, uncinate process and middle turbinate

When considering the lateral wall of the nasal cavity, first look at the lamina papyracea and see whether it is dehiscent through surgery or disease (Figure 2). It is important to see on the scan what tissue needs to be removed to perform an uncinectomy or a middle meatal antrostomy safely. Delineate the uncinate process as it curls up from the superior surface of the inferior turbinate (Figure 3). A paradoxical uncinate process is uncommon (Jones *et al.*, 1997) (Figure 4). Determine the proximity of the uncinate process to the orbit and the degree of aeration of the agger nasi cells. In moderate or marked polyposis the uncinate process is often eroded and may not be

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TABLE I

PRE-OPERATIVE CONSIDERATIONS (KOPP AND STAMMBERGER, 1991)

What is the condition of the ethmoid infundibulum?
- Is it almost atelectatic?
- Is the uncinate immediately adjacent to the lamina papyracea or is the infundibulum wide?
- At what angle does the uncinate process stand to the lamina papyracea?
- Will I be able to resect the uncinate process directly at its anterior attachment, or is there a real risk of injuring the orbit by carrying the knife too far laterally because of the narrowness of the infundibulum?
- Would it be safer in the given case to resect the uncinate process 'in strips' from its free posterior margin anteriorly?

What are the relationships of the uncinate process superiorly, particularly to the frontal recess?
- Is there a recessus terminalis?
- Can I see whether the frontal recess opens medially or laterally into the uncinate process?
- What is the position of the frontal sinus?
- Is it symmetrical?

Is the ethmoid bulla small or large?
- Is it pneumatized?
- Is there a lateral sinus?
- What is the relationship of the medial wall of the orbit to the middle turbinate?
- Can it be distinguished, does it bulge unusually strongly against the ethmoid?
- Are there bony defects from the previous operation?

Are there abnormalities in the course of the roof of the ethmoid?
- Can the body margins be identified precisely?
- To what extent does the roof of the ethmoid project over the cribriform plate?
- Is the olfactory fossa shallow or deep?
- Do the ethmoid cells extend supraorbitally?
- Are the right and left sides symmetrical?

What is the relationship of the posterior ethmoidal air cells to the sphenoid sinus?
- Are there Onodi cells?
- Is the optic nerve involved within them?

To what extent is the sphenoid pneumatized?
- Are the internal carotid artery and the optic nerve prominent and is there a suspicion that their bony cover may be dehiscent?
- Is the clinoid process well pneumatized i.e., should I expect a deep recess between the carotid artery and the optic nerve?
- Are there bony attachments over the carotid and the optic nerve?

If the patient had previous surgery:
- What was removed?
- Can I identify the middle turbinate or its remnants?
- Is there evidence of a bony defect or scar formation in the lamina papyracea, the periorbita and/or the roof of the ethmoid, the dura and cribriform plate?

discernible. Ensure that the maxillary antrum is not hypoplastic (Figure 5), as under these circumstances it is easy to enter the orbit. Look for a Haller cell (Figure 3), an air cell attached to the floor of the orbit, which may be entered when doing a middle meatal antrostomy and be mistaken as the antrum. Define the middle turbinate and its anterior attachment to the cribriform plate. The middle turbinate is usually convex medially but in about 10 per cent it is paradoxical and concave medially (Jones *et al.*, 1997). Check to see if it is expanded by an air cell, a concha bullosa, which occurs in a third of patients (Figure 6). Look again at the middle turbinate – is it present? Patients without a middle turbinate are more prone to iatrogenic damage because of the lack of this important landmark which is the lateral boundary of the cribriform plate (Lawson, 1994).

TABLE II

SUMMARY OF STEPS EMPLOYED IN READING THE CT SCAN

Step 1	*Orientate* coronal cuts anterior to posterior, check sides correct, identify the ethmoidal bulla.
Step 2	*Lamina papyracea* – is it eroded? Middle turbinate present, concha bullosa or paradoxical middle turbinate.
Step 3	*Frontal recess* – site and size of agger nasi cells, insertion of uncinate process.
Step 4	*Height of the skull base* – asymmetry of skull base, and cribriform plate. Height of posterior skull base – from roof of maxilla to posterior skull base.
Step 5	*Sphenoid* – degree of asymmetry of sphenoid intersinus septum, Onodi cell, carotid dehiscent, optic nerve.
Step 6	*Staging* of pathology, plan procedure, features of atypical infection or neoplasia.

Step 3: Examine the area of the frontal recess

The frontal recess lies anterior and superior to the ethmoid infundibulum (Figure 7). The infundibulum expands superiorly to form the frontal recess, but the way in which it does so varies. Anterior ethmoid cells can interrupt this path. Low ones obstruct anterior access to

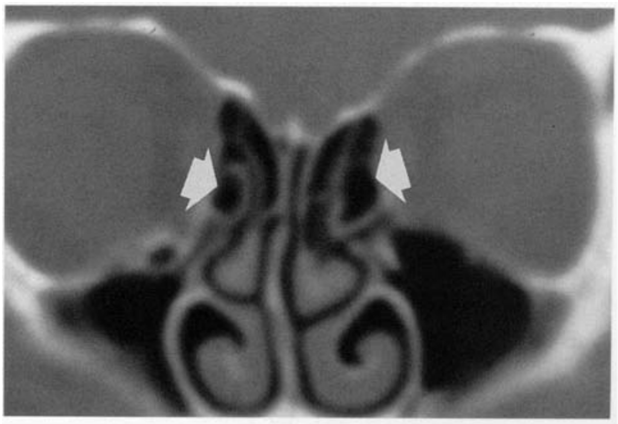

FIG. 1

The ethmoid bulla is a consistent landmark (solid arrow).

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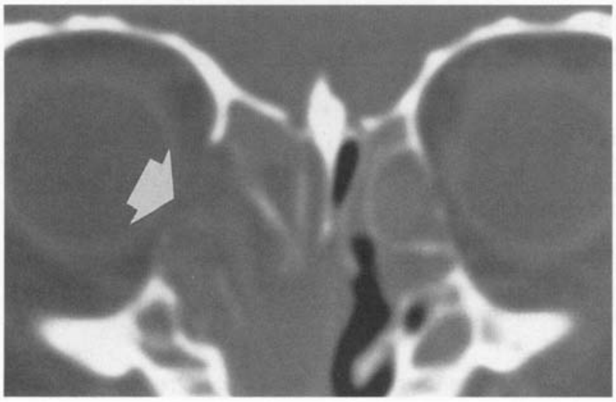

FIG. 2
A dehiscent lamina papyracea (solid arrow).

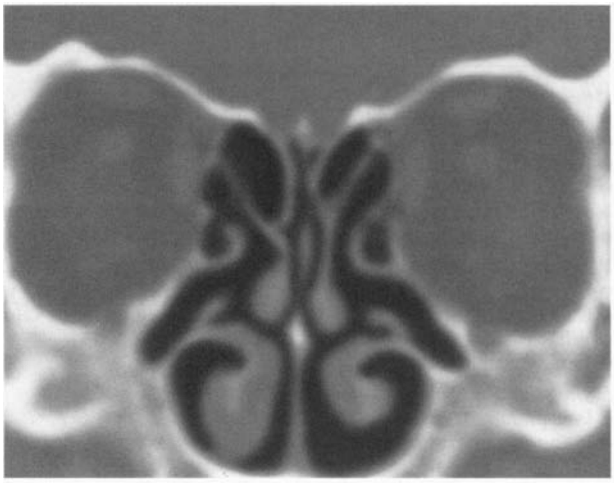

FIG. 5
Hypoplastic maxillary antra.

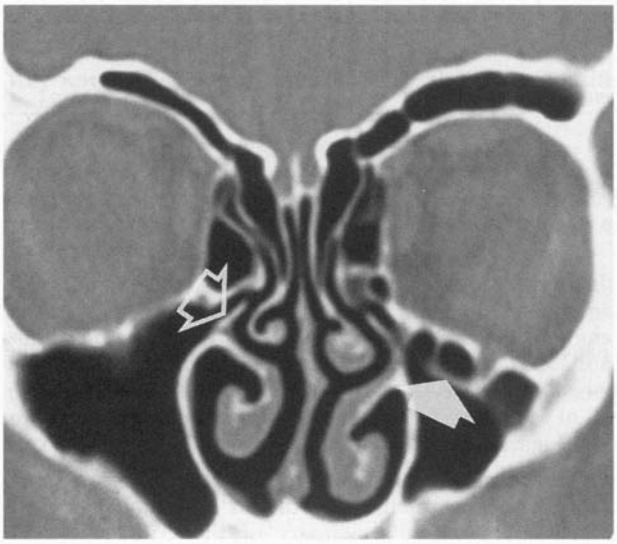

FIG. 3
The uncinate process (outlined arrow) and a Haller cell (solid arrow).

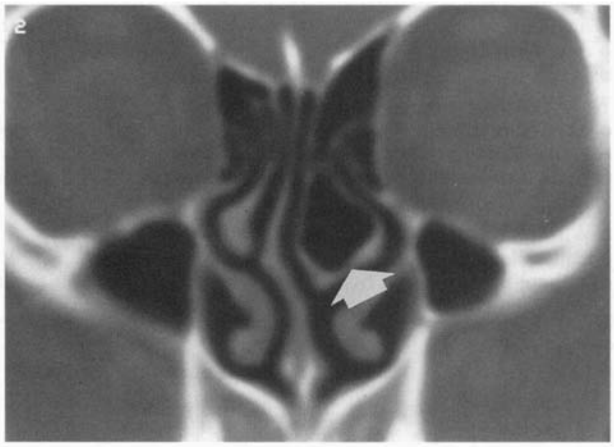

FIG. 6
A concha bullosa (solid arrow).

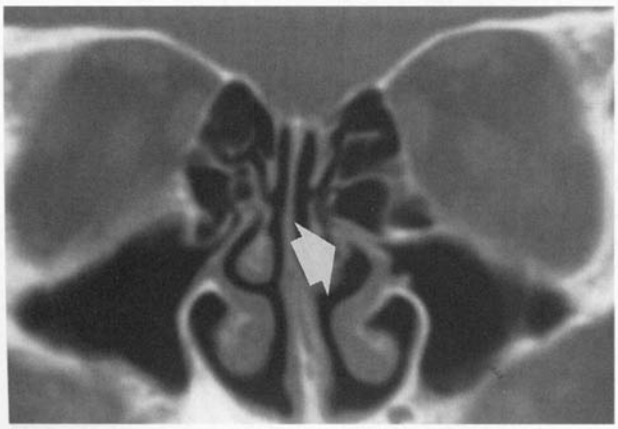

FIG. 4
A paradoxical uncinate process (solid arrow).

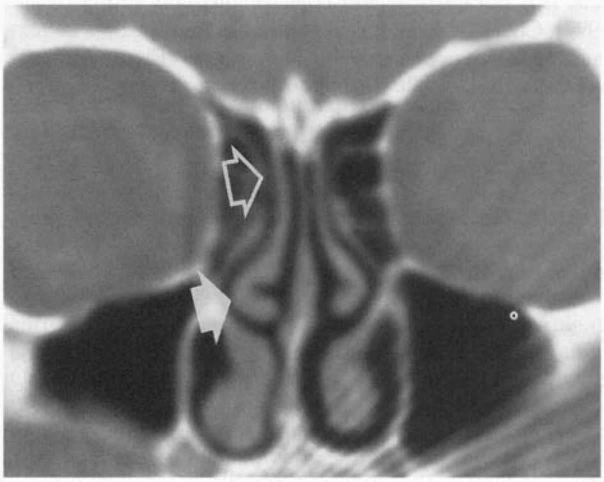

FIG. 7
The frontal recess (outlined arrow) and a paradoxical middle turbinate (solid arrow).

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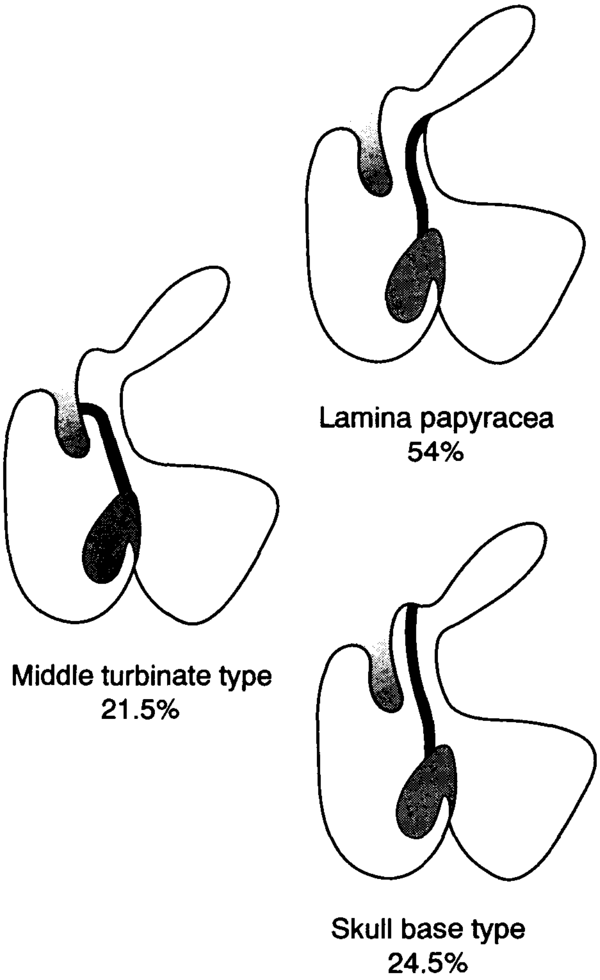

FIG. 8

Variations of the insertion of the uncinate process (after Min *et al.*, 1995)

the recess and higher ones may make the unwary operator think he has entered the superior extent of the frontal recess when he has simply removed the bottom of a higher agger nasi cell as the agger nasi cells may occupy part of the frontal recess (Bent *et al.*, 1994). It is helpful to define how and where the uncinate process is attached. In approximately 50 per cent of patients the uncinate process attaches to the lateral nasal wall, and under these circumstances the frontal recess can be found by following the posterior edge of the uncinate process. In 25 per cent the uncinate attaches to the middle turbinate and the 'web' which it creates at the apex of the anterior end of the top of the middle meatus has to be removed before the frontal recess can be visualized (Min *et al.*, 1995). In the remaining 25 per cent the unicinate process is attached to the skull base and the appearance falls between the latter two descriptions (Figure 8). When it does attach to the middle turbinate, more anterior sections often show it to be attached to the lamina papyracea so it is important to inspect serial sections in order to define its configuration.

FIG. 9

The relationship between the cribriform plate and the fovea ethmoidalis is variable, compare with Figures 1–5.

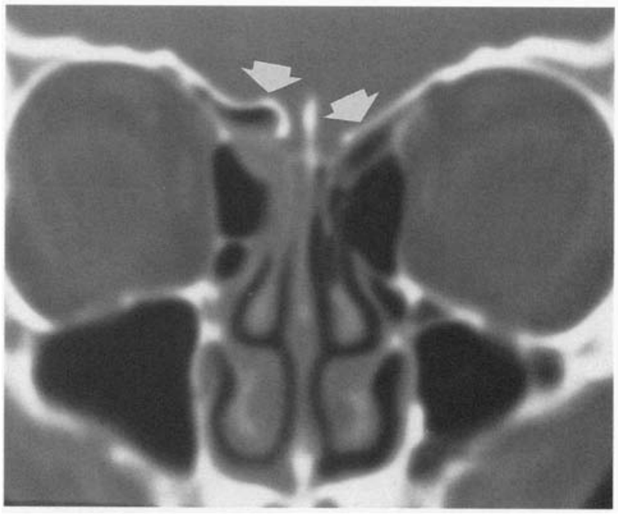

FIG. 10

Asymmetric fovea ethmoidalis (solid arrows).

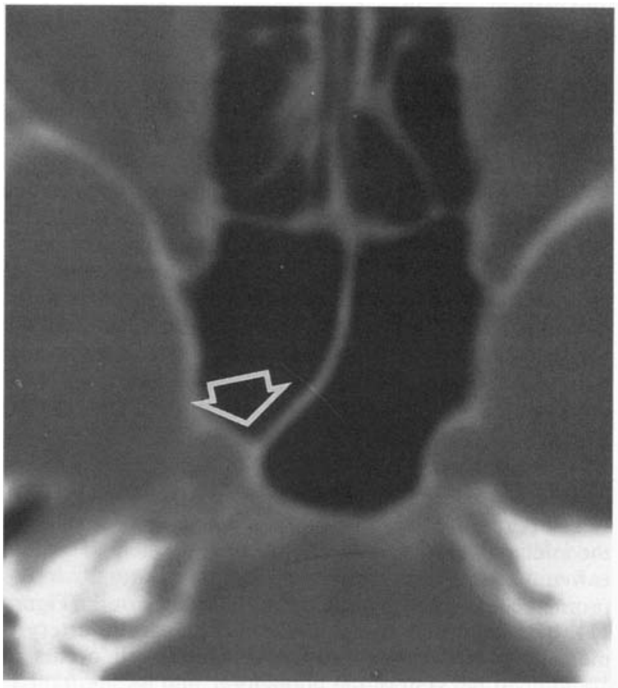

FIG. 11

The sphenoid septum is asymmetric in over 75 per cent and may attach over the carotid (outlined arrow).

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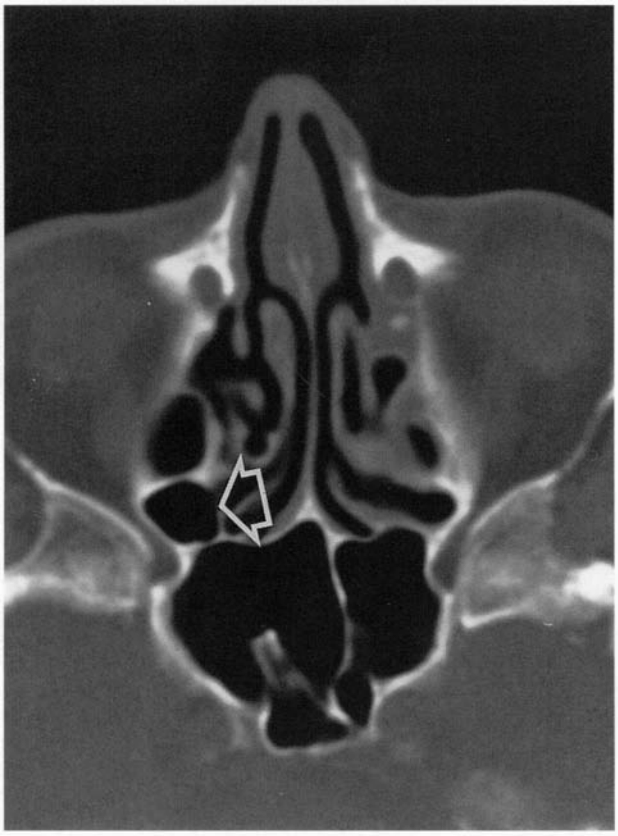

FIG. 12
An Onodi cell (outlined arrow).

Step 4: Determine the height of the skull base

Identify the relationship between the height of the cribriform plate and the fovea ethmoidalis (the roof of the ethmoid sinuses), as this can vary (Figure 9). The medial aspect of the ethmoid roof joins the cribriform plate via a thin vertical strut, the lateral lamella. The lateral lamella is very thin bone and can easily be damaged, particularly near the site of the anterior ethmoidal artery. The fovea ethmoidalis is asymmetrical in approximately seven per cent of individuals (Jones *et al.*, 1997) and it is important for the surgeon to note this in order to tailor the level at which he operates to account for these variations (Figure 10). The height of the posterior ethmoidal cells varies between individuals and is best determined by looking at the distance between the roof of the maxillary sinus posteriorly and the skull base. It must be remembered that the skull base becomes lower as the sections proceed posteriorly and the surgeon should also bear this in mind. Look at the sphenoid sinus and see that once this is opened its roof provides a guide to the superior level of the skull base allowing safe dissection of the superior ethmoidal cells from posterior to anterior.

Step 5: Examine the sphenoid sinus

The perpendicular plate of the vomer always attaches in the midline and is a useful landmark. The sphenoid septum is frequently asymmetrical and may attach laterally to the prominence created by the internal carotid artery (Figure 11). It is important to note whether the carotid artery is medially placed or dehiscent. An Onodi cell occurs in about eight per cent of the population, and is important as the optic nerve is more at risk when it is present. It is a posterior ethmoidal cell placed laterally and, sometimes superiorly, to the lateral wall of the sphenoid sinus through which the optic nerve may run or be in close proximity (Figure 12). The optic canals indent the lateral wall of sphenoid in 40 per cent (Van Alyea, 1941) and the vidian nerve may also encroach in this area. A coronal view gives a better idea about the presence of Onodi cells, as on an axial view the top of the maxillary sinus can feign the appearance of an Onodi cell. Axial views are often not done routinely in many departments because of the extra irradiation and time that it takes but in cases of malignancy, sphenoidal pathology or disease involving the orbit, axial sections are desirable.

Step 6: Stage the pathology and decide on the procedure

At the end of reading the scan, stage the extent of the radiological changes (Lund and Mackay, 1993). Surgery can then be planned more accurately and tailored to the extent of the disease. Surgical lists can be planned accordingly. Erosion of the fovea ethmoidalis or absence of the middle turbinate may influence the informed consent. The presence of unilateral nasal polyposis raises the question of atypical infection such as aspergillosis, inverted papilloma or malignancy.

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