Neuroradiology (1989) 31: 151-155

Neuro-radiology

Multiplanar reconstructions in the study of ethmoid anatomy

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Summary. Multiplanar and surface reconstructions are useful tools in anatomical studies. Details of ethmoid architecture which are hard to image in axial and coronal scans are well displayed by means of oblique sections. This paper addresses reformatted images of a) the nasal lateral wall; b) the middle meatus lateral wall; c) the lamina basilaris of the middle turbinate and d) the frontonasal duct.

Key words: Ethmoid - Nasal fossa - Frontonasal duct - Middle turbinate - Multiplanar reconstruction - Multiplanar reformatting - CT

"Multiplanar reconstruction" designates computer reprocessing of image data obtained in one plane in order to display the same anatomy as if the images had been obtained in other orthogonal or oblique planes. For this procedure the original data must be gathered as contiguous or partially overlapping 1.5-5.0 mm thick sections through the entire volume of anatomic interest. The thickness of the rebuilt section can be varied. It may be as thin as the base unit, corresponding to the size of the matrix "pixel" on which the images have been calculated, or it may be increased as desired to bring a thicker structure into evidence, cancelling out thinner structures.

Selection of an appropriate plane for computer reconstruction requires the physician to recognize significant anatomic landmarks on the initial series of images. Three points are needed to identify a plane correctly; these may be located in three different axial scans, or two in one section and one in another, even at a distance.

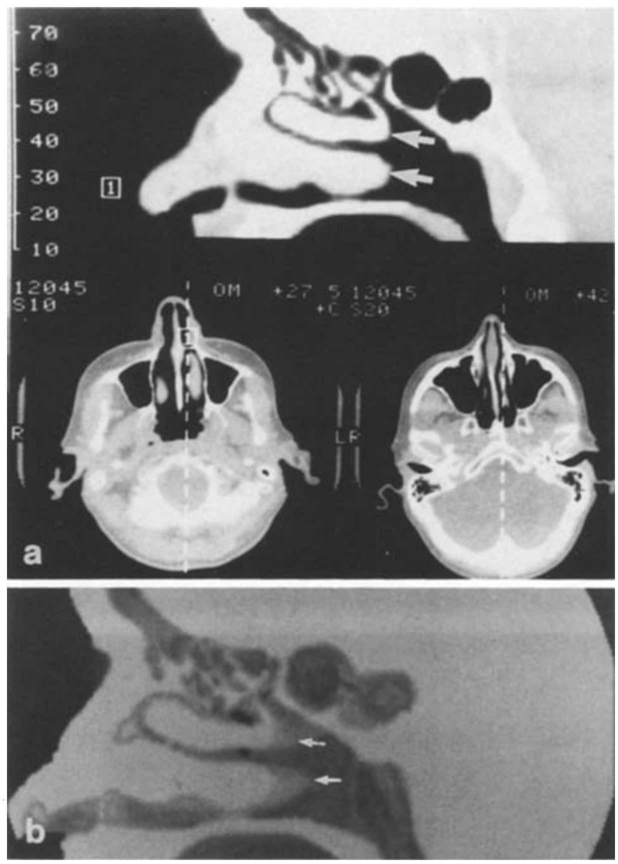

Fig. 1. a, *Bottom:* The dashed lines crossing the axial scans show the plane of the reconstructed section (top), which is a lateral view, slightly slanting in medial-inferior direction, tangent to the contour of the turbinates. **a,** *Top:* Reconstructed section imaging the lower contour of both inferior and middle turbinates. Because the turbinates curve, the posterior margins *(arrows)* shown in this plane do not correspond to the actual posterior tips of the turbinates. **b** Same view as in a in surface reconstruction. The image is rotated a little clockwise to expose the true posterior tips of the turbinates *(arrows)*

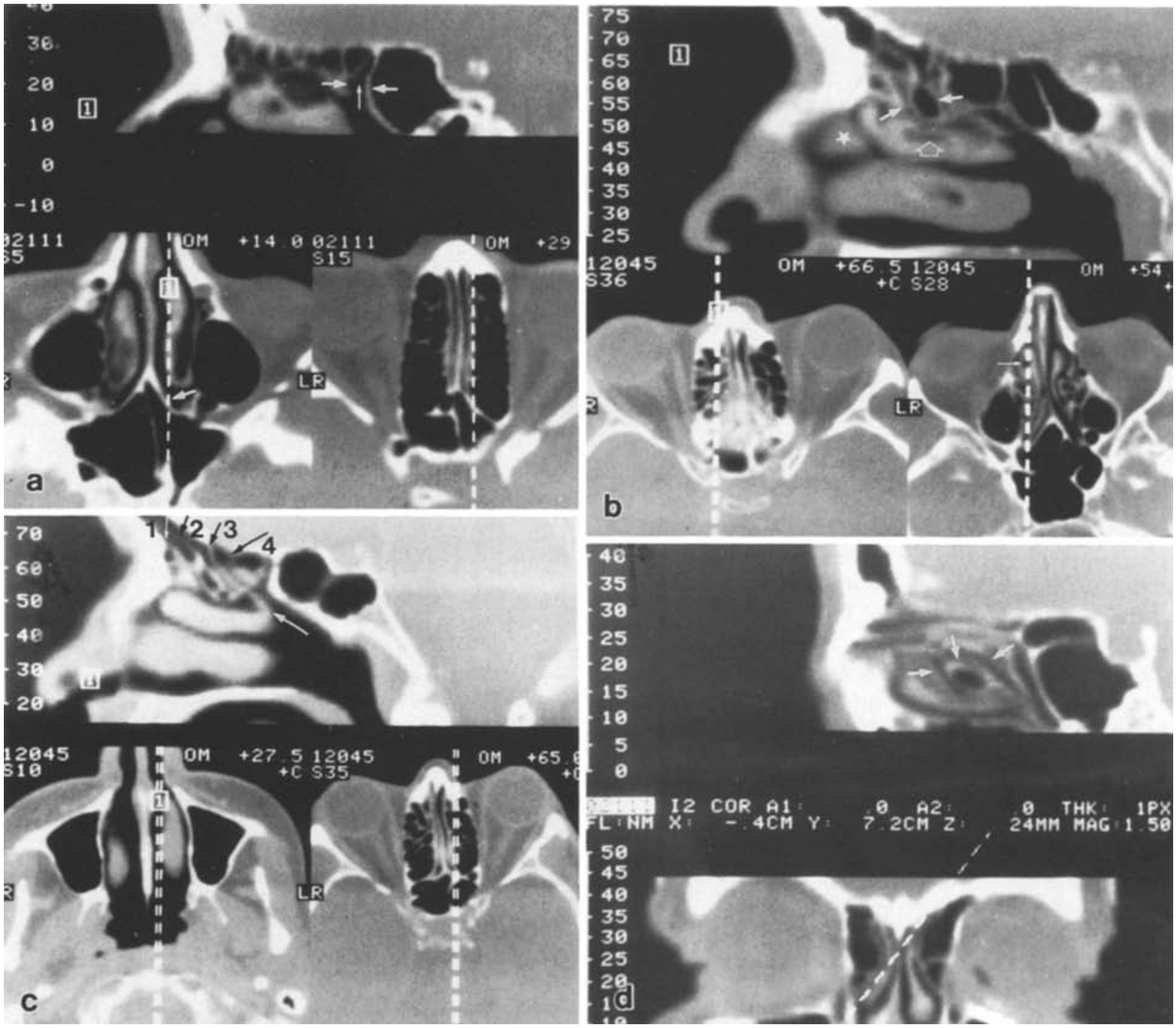

Fig. 2. **a,** *Bottom:* The dashed lines crossing the axial scans show the plane of the reconstructed section, which is a lateral view, slightly slanting in medial-inferior direction, tangent to the lateral nasal wall. In the left scan the cut intersects the sphenoethmoidal recess *(arrow)*. **a,** *Top:* Reconstructed section imaging the sphenoethmoidal recess *(little arrow)* which lies between the posterior tip of the superior turbinate *(left arrow)* and the anterior sphenoid wall *(right arrow)*. **b,** *Bottom:* Same as in a. In the right scan an air cell is viewed within the lamina recurvata of the middle turbinate *(little arrow)*. **b,** *Top:* Reconstructed scan showing the cranial beginning of the uncinate process *(left arrow)* and the bulla *(right arrow)*, partially sectioned. *Asterisk* indicates the prominence of the agger nasi; *large arrow* shows the cell contained within the lamina recurvata of the middle turbinate. **c,** *Bottom:* The dashed line crossing the coronal scan (which has been reconstructed as well) shows the plane of the lateral-oblique section, tangent to the right uncinate process. **c,** *Bottom:* Same as in a and b. **c,** *Top:* Reconstructed lateral-oblique view. *Arrow 1* shows the first lamina (of the uncinate process). *Arrow 2* shows the second lamina, which caudad forks to encompass the bulla. *Arrow 3* shows the lamina basilaris which separates anterior from posterior cells: note that caudad this lamina merges with the free hanging part (lamina recurvata) of the middle turbinate *(arrow)*. *Arrow 4* shows the lamina of the superior turbinate. **d,** *Top:* Reconstructed scan, showing the whole uncinate process *(left arrow)* and the bulla *(middle arrow)*, partially sectioned. Between them, the hiatus semilunaris; behind the bulla, the retrobullar sulcus *(right arrow)*

Careful choice of the 3 points permits the physician to obtain sections that are "anatomically arranged" in spite of individual variability. Such computer generated planes can be reproduced time after time to permit accurate assessment of interval change in a single subject or they can be achieved in different subjects to allow a thorough analysis of anatomical variations.

A second method of computer reconstruction requires the choice of a "threshold" density and, from this, of a limit surface including all major density structures. The reconstructed surface may be viewed from different angles and is shaded so as to give a distance effect to the observer. The result is that of a relief image, appropriately called three dimensional surface reconstruction. This type of a reconstructed

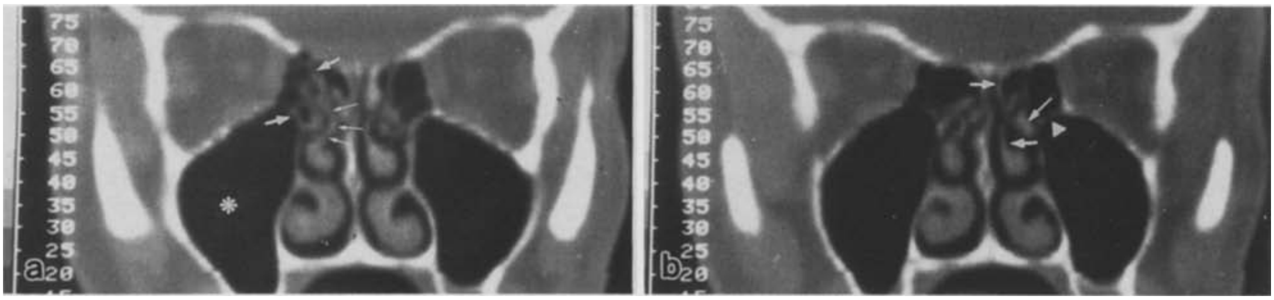

Fig. 3a, b. Reconstructed coronal sections. b is dorsal to a by approximately 3 mm. **a** The section crosses the posterior portion of the bulla *(left arrow)*. *Top arrow* shows a short stretch of the lamina basilaris, merging with the free hanging part (lamina recurvata) of the middle turbinate *(little arrow)*. *Asterisk* marks the maxillary antrum. **b** *Top right arrow* indicates the lamina basilaris, while *lower arrow* shows the lamina recurvata. The lateral end of the lamina basilaris merges with the ethmomaxillary plate (triangle), while the medial end merges with the turbinate plate *(left arrow)*

image is most used for well identifiable surfaces, such as bone or skin. The detail of the rebuilt surface depends on the threshold density chosen, on the thickness of the base scans and their possible partial overlapping. Errors due to inopportune choice of the threshold density overemphasize surface defects or underestimate gaps.

Multiplanar and surface reconstructions both depict ture "anatomy in the living" by a non-destructive technique. This means that it is possible to construct different sections or view progressive erosions without destroying the specimen. In the practice of anatomical research on paranasal sinuses, these reconstruction procedures are particularly useful for identifying and imaging structures with complex spatial arrangements, especially those structures that are not aligned along the perpendicular axial and coronal planes that are usually scanned.

Results

As was stated in a previous paper [1], axial CT examination (1 mm sections with 1–2 mm interscan interval) enables us to see almost all particulars which are important from a clinical and surgical viewpoint; the remaining details are observed on a few coronal scans separated from each other by 1–2 cm [2, 3].

Therefore, reconstructed sections in vertical and oblique planes do not add further significant information. Nevertheless they allow the visualization and expedite the identification of vertical structures, which would otherwise have to be reconstructed mentally by checking up and down the serial axial cuts.

The most important among these structures are:
1) the nasal lateral wall;
2) the middle meatus lateral wall;
3) the lamina basilaris of the middle turbinate;
4) the frontonasal duct.

1) The lateral wall of the nose with the bulges of the turbinates is depicted in lateral and in lateral slightly-oblique sections, tangent to the contour of the turbinates (Fig. 1a). The distances between their inferior margins and the nasal floor can thus measured with a fair precision. Surface reconstructions do not add further significant detail to multiplanar reconstruction (Fig. 1b).

Behind and above the posterior tips of the turbinates it is possible to appreciate the general shape of the sphenoethmoidal recess, as well as its relation with the superior turbinate (Fig. 2a).

2) The lateral wall of the middle meatus is characterized by the pressence of two particular formations, the crescent-shaped uncinate process and the dome-shaped bulla. Although their configuration is fairly constant, they may show considerable variations in size. Lateral views allow their display in a single image, quite similar to the one which is obtained after the middle turbinate removal (Fig. 2b). Of course, the bulla appears to be sectioned in these views, since it generally protrudes in a medial direction more than the uncinate process.

As the axis of the uncinate process is not exactly vertical, but rather slants caudad and laterally, a lateral-oblique section along this plane improves visualization of the hiatus semilunaris and of the infundibulum which overhangs it (Fig. 2c). The importance of this groove, where secretions collect from all paranasal sinuses except posterior ethmoidal cells and sphenoid sinus, is well-known.

3) The architecture of the ethmoid bone was made clear by studies of the past century which have been

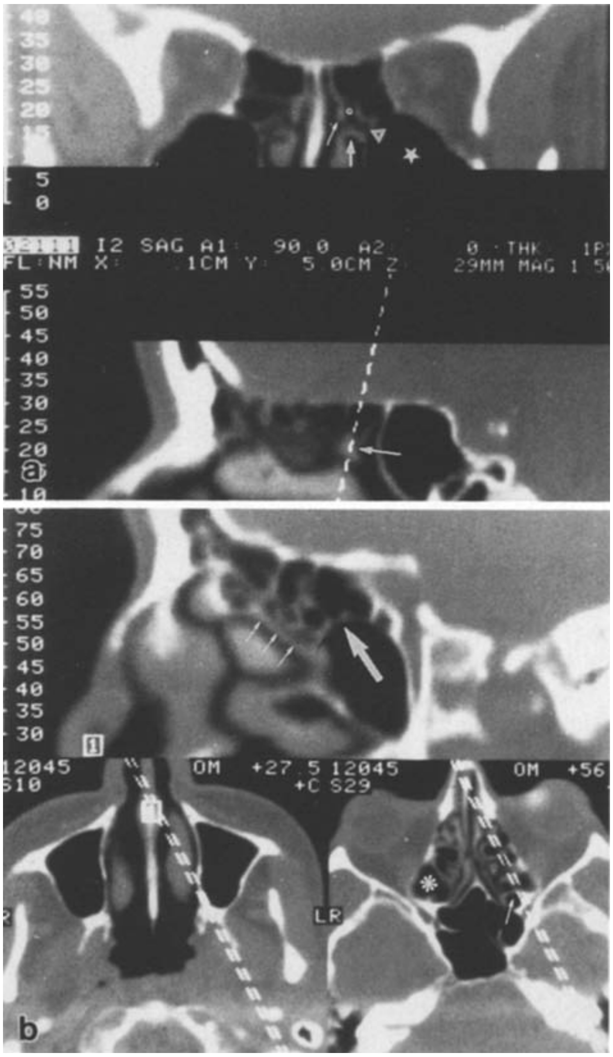

Fig. 4. **a,** *Bottom:* The dashed line crossing the lateral scan (which is a reconstruction as well) indicates the plane of the coronal-oblique section (top). The line intersects the superior turbinate *(arrow).* **a,** *Top:* Reconstructed section. The superior turbinate is indicated by *little arrow:* it surrounds the superior meatus *(circle).* The lamina basilaris of the middle turbinate *(arrow)* merges with the ethmomaxillary plate *(triangle). Asterisk* marks the maxillary antrum. **b,** *Bottom:* The double dashed lines crossing the axial scans show the plane of the lateral-oblique section, carried out along the ethmomaxillary plate *(arrow). Asterisk* indicates the maxillary antrum. **b,** *Top:* Reconstructed scan, showing the whole ethmomaxillary plate *(big arrow),* merging with the lamina basilaris whose ends are marked by *thin arrows.* Note that the lamina basilaris attaches to the ethmoid roof, thus separating anterior from posterior cells

recently confirmed [4]. The ethmoid is partitioned by four, sometimes five, bone laminae (primary laminae) which extend from the medial to the lateral wall. They run in a coronal plane which slopes caudad and backwards. They may vary remarkably in size, but are invariably attached to the same structures from which they draw their names. Thus the first lamina is that of the uncinate process, the second of the bulla, the third of the middle turbinate, the fourth of the superior turbinate and the last of the inconstant supreme turbinate. The ethmoid network is completed by a large number of bony sheets, which are fastened to the primary laminae with an irregular and unpredictable distribution, forming what we call the ethmoid cells.

The primary laminae with their backward slanting courses, roughly parallel between each other, are easily identified in lateral views (Fig. 2d). Among them, the most important is the third lamina, that of the middle turbinate, which consists of two parts, the lamina basilaris, which forms the boundary between anterior and posterior ethmoid cells, and the lamina recurvata corresponding to the free hanging part of the turbinate.

Lamina recurvata and basilaris are nicely imaged in the series of coronal reconstructions which start just behind the bulla, i.e. where both of them converge (Fig. 3). The former is quasi-vertical, and is easily recognized from the bulge of the middle turbinate. At its cranial end it forks into two bony sheets, perpendicular to each other.

The vertical one, which appears to continue the lamina recurvata, is the so called turbinates plate, which forms the lateral wall of the nasal cleft, while the horizontal plate is the lamina basilaris. This merges laterally with the ethmo-maxillary plate, i.e. that portion of the maxillary sinus wall which abuts on the ethmoid cells. Actually, the ethmo-maxillary plate has been indicated in the previous paper [1] as the main landmark to identify the lamina basilaris on axial scans. The coalescence of these two structures is well documented in lateral-oblique sections performed along the plane of the ethmo-maxillary plate (Fig. 4b).

4) The frontonasal duct is another structure which can be imaged on multiplanar reconstructions. Although this procedure is in no way shorter than the usual modus operandi based on looking up and down a sequence of axial cuts, yet it may be useful in visualizing the cells surrounding the duct and in verifying the site of its caudal opening.

For this purpose, oblique scans along both a coronal and a lateral plane are needed, in order to get a full three dimensional representation.

Coronal-oblique sections are obtained by aiming at the starting and ending points of the duct on axial scans. In nearly all cases, two different planes must be examined to image the ducts on either side, as their directions rarely coincide with each other (Fig. 5a, b). From coronal-oblique sections one obtaines the lateral-oblique views (Fig. 5c), which allow identification of the caudal opening of the duct (Fig. 5d).

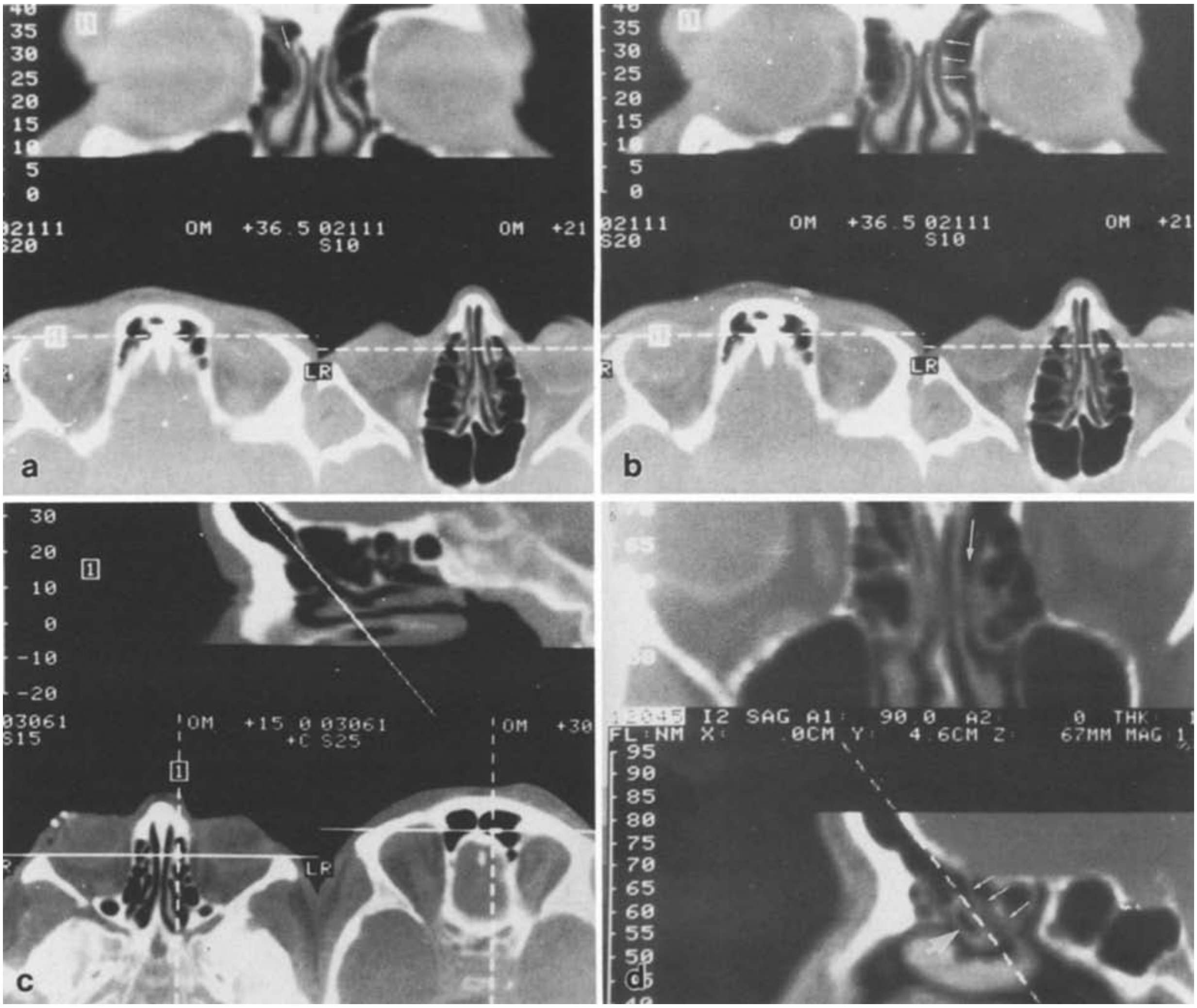

Fig. 5. **a,** *Bottom:* The dashed lines on axial scans cross the cranial *(left)* and caudal *(right)* ends of the right frontonasal duct. **a,** *Top:* The reconstructed coronal-oblique section shows the whole course of the right frontonasal duct, marked by *arrow.* **b,** Same as a, to image the left duct *(arrows).* As the direction of each duct rarely coincides with the other, the procedure must be repeated on either side. **c,** *Bottom:* The targets formed by intersection of dashed and continuous lines indicate the exact position of the caudal *(left)* and cranial *(right)* ends of the duct. **c,** *Top:* Providing the duct be practically rectilinear, a lateral-oblique view can image it completely, as the sawtooth lilne indicates. In this case, the duct opens in the most superior part of the uncibullar sulcus. **d,** *Bottom:* On the lateral-oblique scan, the dashed line shows the course of the duct which opens here in the retrobullar sulcus. *Big arrow:* bulla. *Arrows:* lamina basilaris of the middle turbinate. **d,** *Top:* Reconstructed coronal-oblique section in the plane of the dashed line of bottom figure. The section images the left frontonasal duct *(arrow).* Cells abutting on its lateral side are clearly visible

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Received: 1 August 1988

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