Chapter 2: Radiology of the nose and paranasal sinuses

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Sinuses

Although computerized tomographic scanning is now the best means of imaging the sinuses, cost and rationing of scan time in the UK necessitate a continuing reliance on plain film views. Standard radiographic sinus projections are the commonest imaging examination of the ear, nose and throat, undertaken to confirm or exclude sinusitis in patients with nasal symptoms or to show evidence of neoplasia. Computerized tomography is reserved for problem cases or those where neoplasia is found or suspected.

Plain radiography

Views for the nose

Radiological examination of the nasal bones can best be made by placing a dental film in direct contact with the side of the nose and centring the incident beam horizontally through the nose. This lateral view may be supplemented by a cranio-caudal projection obtained by inserting an occlusal film between the teeth and directing the vertical beam through the nasal bones onto the film. These views are usually requested following facial trauma, to show fractures of the nasal bones as well as lateral shifts and displacements.

Standard sinus views

A specialized skull unit should be used whenever possible to allow accurate positioning and unvarying focus film distances with a moving grid. Pathological processes affecting the paranasal sinuses encroach on the air in the sinuses and are seen on the radiographs as alterations in the translucency of the sinus. Examination in the erect position is desirable to reveal fluid levels which may be present. It is possible to perform erect examinations on modern isocentric skull units, but without the advantages of fixed reference planes (see Volume 1, Chapter 17).

Asymmetry of the paired sinuses will usually result in the smaller sinus appearing more opaque because of its thicker bony walls. This should not be mistaken for a pathological state. It is not uncommon for one frontal sinus to be much smaller than its fellow or even to be absent. Antra differ in size less often, though small differences are not uncommon. Rarely one maxillary antrum fails to develop and in consequence the maxilla looks dense on plain X-ray films. The smaller size of the affected antrum should alert the observer to this possibility.

The following projections allow a good all-round assessment of the paranasal sinuses: the occipitomental, the occipitofrontal, and either or both the lateral and the overshot axial views.
Occipitomental (or Waters') view

The patient sits facing the Bucky support with the chin resting against it, the median sagittal plane aligned to the midline. The mouth is supported wide open with a transradiant perspex 'bite block' and the baseline is adjusted to make an angle of 45° with the film. In older patients it may be necessary to angle the central ray of the tube caudally to compensate for an inability to extend the head sufficiently, but if a skull table is used with the object table angled through 20° (or more) forwards towards the patient, the correct position will be consistently maintained, and will always allow the use of a horizontal X-ray beam. The tube is adjusted so that the central ray passes horizontally to the middle at the level of the inferior orbital margins and to the centre of the film.

Structures demonstrated

The antra are clearly visible, the frontal sinuses are projected obliquely, though their floors are clearly shown. The ethmoid cells are largely obscured, but a few cells may be seen within the nose and medial to the lamina papyracea on the inner wall of the orbit. The sphenoidal sinuses are visible through the open mouth. If, after examining the film, a fluid level is suspected, its presence or absence can be confirmed by repeating the view with the sagittal plane of the head tilted 20-40° to the side in question.

Occipitofrontal (or Caldwell) view

The patient sits or lies prone with the forehead and part of the nose in contact with the Bucky support. The baseline is adjusted perpendicular to the film and the tube is angled 15° caudally. If a skull table is used the object table is angled 15-20° towards the patient, the central ray is directed horizontally to the nasion, and to the centre of the film.

Structures demonstrated

The frontal sinuses are clearly shown. The upper parts of the antra are obscured by the petrous bones but their lower parts are visible. The floor of the sella turcica, the crista galli, the nasal septum and middle and inferior turbinates can be seen. The ethmoidal and sphenoidal sinuses are superimposed.

Overshot axial - submentovertical view

The patient sits facing the tube. The neck is fully extended, so that the vertex rests against the Bucky support. The baseline should be as near parallel to the film as possible. The central ray is directed 2.5 cm anterior to the intermeatal plane to the midline, from beneath the mandible at an angle of between 90 and 100° to the baseline, and to the centre of the film. Slight over-extension is an advantage as both anterior and posterior walls of the frontal sinuses are then seen behind the dental arch.
Structures demonstrated

The ethmoidal and sphenoidal sinuses are shown free of superimposed cells. The posterior walls of the antra, petrous apices and base of the anterior and middle fossae of the skull are clearly seen. In elderly patients, or in those with short thick necks, it is often difficult to obtain sufficient extension of the head to bring the baseline parallel to the film. If a skull table is available this can be easily countered by angling the object table forwards towards the patient. If not, the central ray of the tube must accordingly be angled cephalically, to compensate for lack of head extension.

Lateral

The patient sits facing the Bucky table and the skull is then rotated into the lateral position. The central ray is directed horizontally to a point behind the outer canthus of the eye and to the centre of the film. When particular interest is directed to the nasopharynx, the patient sits sideways on with the head in the lateral position and the chin protruded. In children under 7 years of age the central ray is directed horizontally to a point immediately posterior to the angle of the mandible. In older children or adults the central ray is directed to a point 2.5 cm in front and 3.75 cm below the superimposed external auditory meatus and to the centre of the film. The focal film distance is increased from the standard 90 cm to reduce magnification.

Structures demonstrated

On the lateral projection the paired sinuses are superimposed on one another, but the extent of pneumatization of the frontal and sphenoidal sinuses can be gauged, especially in their vertical and horizontal directions. The thickness of the soft tissues in the nasopharynx, the uvula, and the extent of the nasopharyngeal airway can be assessed. Enlarged adenoids can be clearly shown. This view is essential when opaque foreign bodies are being sought, or when surgery on the sphenoid bone or transnasal implantation of radioactive isotope seeds into the pituitary gland is contemplated.

Other radiographic examinations

Oblique views

These may be useful to show the posterior ethmoid cells and optic foramina. The right and left sides are examined separately. The patient is positioned to face the Bucky table and the baseline is adjusted perpendicular to the film, the head is then rotated through 35-40° so that the rim of the orbit, the nose and cheek on the side to be examined, are 'flattened' against the Bucky support. The central ray of the tube is angled 10-15° caudally (or the baseline raised 10-15°) to prevent the petrous bones obscuring the ethmoids, and directed to pass through the centre of the orbit and the centre of the film.
Structures demonstrated

This view shows the posterior and middle groups of ethmoidal cells with some superimposition of the sphenoidal sinuses on the side to be examined, as well as the optic foramen and floor of the anterior fossa. The frontal sinuses are shown obliquely. Half the sphenoid bone and a few posterior ethmoidal cells of the opposite side are also shown.

Occipitomental views with varying angulation

Overangled or underangled occipitomental views may be used to give tangential views of the roof of the antrum in suspected injuries in that area. The patient is positioned as for a normal occipitomental view and the additional views are taken with the baseline at 60° and 30°, respectively. Increased angulation may be needed in patients in whom the petrous bones overlie the base of the antrum in the standard view.

Panoramic views (orthopantomography)

Panoramic tomography in the plane of the dental arches is used for dental surveys (see Volume 1, Chapter 17), but at the same time the orthopantomograph gives a good display of the lower aspects of the antra which may be used to supplement the plain film demonstration of the sinuses.

Conventional tomography

Hypocycloidal or spiral tomography is preferable as fine bone detail on thin sections can be shown without the streaking produced by the linear mode. Until recently, complex motion tomography was the definitive investigation for most sinus lesions after plain radiographs. It has been replaced almost entirely by high resolution computerized tomography which gives similar sectional imaging, but with the advantage of much better discrimination of soft tissues.

Coronal section tomograms may be useful for elderly patients unable to adopt the chin up or head hanging position needed for coronal computerized tomography. The examination should be performed with the patient prone to restrict the radiation dose to the eyes. Ready comparison of symmetry between the left and right sides can be made. Lateral tomograms in the sagittal plane are also useful because positioning for direct sagittal CT sections is particularly difficult.

Computerized tomography (CT)

The superiority of CT over other methods of imaging the sinuses can be summarized as follows:

(1) the bony walls of the sinuses are demonstrated at least as well by CT in the high resolution mode as by conventional radiography and tomography
(2) an excellent anatomical display of soft tissue densities, including fluid levels and polypoid masses, within the normally air-filled cavities of the sinuses, nasal cavity and postnasal space is provided

(3) most important of all, disease extending beyond the bony perimeters of the sinuses into the adjacent soft tissue of the orbit, brain and infratemporal fossa can be imaged.

These applications of CT have disappointed in only one way. While giving an excellent anatomical display, CT generally fails to predict the histological nature of the pathological process, unless there is characteristic calcification within a tumour such as a meningioma or chondroma.

'Tissue characterization' with or without contrast enhancement is almost always unsuccessful if measurement of attenuation values is used, and this was appreciated in the early days of CT (Forbes et al, 1978). Contrast enhancement is required:

(1) if intracranial extension of disease is suspected on clinical grounds or from the anatomical demonstration, particularly on the coronal CT sections

(2) if a particularly vascular tumour such as a meningioma or juvenile nasopharyngeal angiofibroma is suspected; a contrast infusion to ensure that enhancement occurs in the vascular phase is required in such cases (see Volume 1, Chapter 17)

(3) occasionally if an inflammatory process is suspected.

Most American authorities, however, recommend routine use of contrast enhancement for the investigation of the facial area (Hasso, 1984). The present author does not advocate this approach, as intravenous contrast medium usually enhances all soft tissue structures around the sinuses, and is therefore unhelpful, besides adding to the length of the examination, increasing the not inconsiderable radiation dose to the patient, and adding the risk of a systemic reaction to the contrast agent.

The standard plane for CT scanning of the paranasal sinuses is parallel to the infraorbital meatal baseline. This plane is nearly parallel to the planes of the hard palate, the zygomatic arches and much of the orbital roof. The antra are seen in cross-section, the ethmoid and sphenoid sinuses are well demonstrated, as are the anterior and posterior walls of the frontal sinuses. These axial sections are also the best for demonstrating the orbital contents and the nasopharynx.

The axial scans are then reviewed to decide whether further sections are necessary in the coronal plane. Generally, evaluation of structures parallel to the infraorbital baseline or evidence of intracranial extension of the disease process necessitate coronal sections. For both axial and coronal scans, contiguous sections, 5 mm thick, are usual. Degradation of the images by metal fillings in the teeth, especially in the coronal plane, may require repositioning of the patient's head or the angle of the gantry.

The soft tissue structures of the face need to be assessed on a window setting of 400-800 Hounsfield units, while bone detail is best shown at a setting of 1000-3000 Hounsfield
units. Even at the wide window setting, thin plates of bone, especially the lamina papyracea forming part of the medial wall of the orbit, may appear to be dehiscent because of partial volume averaging. Erosion of a thin plate of bone should not be diagnosed on the CT scan unless an adjacent soft tissue mass can be demonstrated, and then the problem of soft tissue silhouetting is added to that of partial volume averaging (see Volume 1, Chapter 17).

The maxillary antra are small at birth and expand progressively during the first decade of life. Occasionally they may remain infantile, and then it can be difficult, on plain films, to distinguish this cause of opacity from the more usual such as chronic infection or fibrous dysplasia. The antra are rarely asymmetrical but the absence of pathological features and presence of a normal ostium can be confirmed by axial CT. Sometimes a small sinus may be double.

**Magnetic resonance (MR)**

The bony margins of the sinuses appear as a plane of absent signal on magnetic resonance scans and this limits the usefulness of the technique for examination of the sinuses. Moreover, the intense signal from the high fat content of bone marrow, as in the basisphenoid and petrous apices and around the frontal sinuses, can be very confusing for the radiologist interpreting the scans. This is particularly so as retained fluid within the sinuses gives a similar intense signal from the high water content.

It is difficult or impossible on a CT scan to differentiate tumour tissue from retained fluid in sinuses where the drainage of a sinus is blocked by obstruction from the tumour. Differentiation on an MR scan is simple and clear. Extension of sinus neoplasia into the cranial cavity is shown very well by magnetic resonance without the need for contrast enhancement and the ability to image in any plane is a considerable advantage.

**Angiography**

The requirements for angiography of the sinuses have become much reduced since the advent of CT and MR imaging. Occasionally, angiography is needed to demonstrate the blood supply of soft tissue lesions of the face, especially in vascular tumours such as juvenile nasopharyngeal angiofibroma, when therapeutic embolization may be carried out as a preoperative procedure.

The important radiological features of some of the commoner conditions affecting the paranasal sinuses will be considered briefly.

**Specific clinical situations**

**Trauma**

Injuries to the face and sinuses are considered in Chapter 14. Fractures are usually demonstrated by conventional radiographic techniques, but tomography and CT are often necessary to show the fracture lines. Fluid levels in sinuses indicating a cerebrospinal fluid fistula are well shown by CT. The improved soft tissue imaging of CT and MR imaging can also be an advantage in trauma cases, especially for showing the state of the orbital contents.
Inflammatory disease

Mucosal thickening, a common finding on plain sinus views, is shown far more readily on CT scans. Normal mucosa is too thin to be demonstrated on the scan, but minor degrees of thickening in the absence of relevant symptoms may be dismissed as an incidental finding. If the sinus ostium becomes blocked, a completely opaque sinus will result. An air/fluid level may be observed at an intermediate stage before the obstructed sinus becomes totally opacified.

Chronic obstruction of the ostium or a septate portion of the sinus cavity gives rise to mucocoeles. Proptosis is often the presenting symptom. The diagnosis is often suspected on plain skull radiographs, but CT confirms the benign nature of the lesion and gives an accurate display of its extent (Price and Danziger, 1980). Initially it was hoped that a low CT attenuating reading would help to confirm the diagnosis of mucocoele but such readings have proved extremely variable. Nevertheless, the diagnosis can usually be made from the expansile appearance of the lesion.

The characteristic radiological features of benign nasal polyposis are familiar to otolaryngologists. However, in a proportion of patients the changes are much greater and include widening of the ethmoid labyrinth and nasal cavity, bone thinning and expansion, and mucocoele formation (Lund and Lloyd, 1983). The ethmoid widening and opacity can be shown by plain films or CT.

Most acute sinus infections are successfully treated by antibiotics, but sometimes the inflammatory process spreads beyond the confines of the sinus cavities. The close association with the orbit means that the most frequent complication of acute inflammatory sinus disease is orbital cellulitis with pain, oedema and proptosis. A subperiosteal or orbital abscess is a more serious complication which may require surgical exploration and drainage. The decision regarding surgical intervention is greatly helped by the CT demonstration of the site of the abscess. Patients with orbital cellulitis frequently require external drainage. Frontoethmoidectomy may be required if resolution does not occur or chronic infection is present (Harrison, 1980). Pus between bone and orbital periosteum is well shown by coronal CT. If the infection breaches the periosteum the normal muscle and fat planes rapidly become indistinct and vision deteriorates. Orbital ultrasound is said to be helpful in the differentiation of orbital cellulitis and abscess formation (Goodwin, 1985).

Postoperative state of the sinuses

Following surgery on the paranasal sinuses, radiological investigation may be required to determine the presence of recurrent disease. After the Caldwell-Luc operation, the postoperative appearance is opaque on plain sinus views, but CT has shown that this opacification is commonly due to bone thickening (Cable et al, 1981). This would seem to be the result of periosteal stripping followed by the deposition of new bone. The postoperative antrum is often smaller than normal. Although CT differentiates well between bone and soft tissue, unfortunately it is not so satisfactory for excluding residual soft tissue disease such as loculated pus.
Tumours

The CT diagnosis of a tumour requires the presence of a soft-tissue tumour mass. Changes in the adjacent bones are secondary features. Categorizing the bone destruction seen on CT as either aggressive bone destruction or bone remodelling aids differential diagnosis. Bone remodelling or expansion reflects slow growth of the tumour. New bone is laid down on the outer surface of the sinus wall as erosion takes place from the inner wall adjacent to the tumour and differentiation from a mucocele or expansion by benign simple polyposis may be difficult.

A mass in the middle meatus of the nasal cavity extending into the antrum is highly suggestive of an inverting papilloma (Lund and Lloyd, 1984). Other features of this tumour which have been shown by CT are small areas of calcification within the tumour mass and sclerosis of the sinus walls, although the latter is a non-specific change most frequently seen in chronic sinus infection. More obvious extensive and dense calcification within an expansile mass is a feature of chondroma or chondrosarcoma. This calcification is an important feature in the diagnosis, well demonstrated by CT but not shown by MR. Lloyd and Phelps (1986) have shown significant advantages in entirely different ways for both CT and MR in the diagnosis and assessment of one particular rare benign tumour, namely juvenile angiofibroma. Thirty cases were described, all of whom had bone destruction at the base of the pterygoid lamina. The distinctive radiological features of these tumours are discussed in Volume 6, Chapter 2, and the radiological anatomy and pathology of the infratemporal fossa and parapharyngeal region in Volume 5, Chapter 2.

Malignant sinus neoplasms characteristically produce aggressive bone destruction: the bone is rapidly permeated and destroyed. Such destruction is seen primarily with squamous cell carcinoma which accounts for nearly 80% of all paranasal sinus malignancies (Some, 1985). Where plain sinus views are the usual primary means of imaging, it is most important for both radiologists and surgeons to look carefully for erosion of the bony margins of the sinuses, especially in the presence of suspicious clinical features.

Obliteration of fascial planes beyond the sinus walls is the most characteristic CT sign for the identification of malignancy. Whenever a soft tissue mass extends beyond the bony confines of a sinus, neoplasia should be ruled out by biopsy. Extension of sinus neoplasm into the orbit or cranial cavity affects the management of the disease. Coronal CT sections with contrast enhancement or equivalent MR views are necessary if initial clinical and radiological examinations indicate extension of disease up to the floor of the cranial cavity.

Bony tumours and bone dysplasia

Osteomata are common benign tumours which produce no symptoms unless they extend beyond the sinus, block the ostium, cause pressure on a nerve or displace other structures. They are commonest in the frontal sinuses and are readily demonstrated by plain radiographs.

Tomography or CT is sometimes required to show the point of attachment to the sinus wall and axial CT gives a good demonstration of the posterior extent. The density of the mass depends on the amount of ivory and cancellous bone present in the tumour. A benign bony
tumour which fills the sinus, with no radiographic features to suggest an osseous lesion, may cause problems in assessment. A large mass in the antrum which appeared to have arisen from the alveolus was histologically diagnosed as a giant-cell reparative granuloma and its true relation to the antrum only revealed at surgery. Other benign tumours of the jaws can produce a similar appearance on CT with destruction of the alveolus and evidence of spread into the soft tissues. Meningiomata may very rarely arise in the sinuses but are more likely to affect the sinuses by extension from within the cranial cavity. CT is the imaging investigation of choice, not only to demonstrate calcification within a tumour mass, but also to show the osseous sclerosis that occurs with meningioma. Nevertheless, differentiation of meningioma en plaque from developmental diseases such as fibrous dysplasia may be difficult. Fibrous dysplasia is either polyostotic or monostotic and usually develops early in life. The skull and facial bones may be affected singly or as part of a more generalized disease. Characteristically there is thickening and expansion of bone but the density of the lesion depends on the amount of fibrous tissue present; when this is high, a ‘ground glass’ appearance is seen. In other cases dense bone predominates and, less commonly, a mixed type with islands of dense bone in a fibrous matrix occurs.

The nasopharynx (postnasal space)

These alternative terms to describe the space behind the posterior choanae of the nose highlight the dilemma of whether the nasopharynx should be considered with the nose or the rest of the pharynx. Traditionally radiological examination of the nasopharynx was by lateral and submentovertical views to show soft tissue masses distorting or obstructing the airway or eroding the base of the skull. Complex motion tomography improves the assessment of these features and helps to demonstrate masses and base of skull erosion, but it has largely been supplanted by CT which is now the optimum means of demonstrating the nasopharynx. Although an excellent demonstration of the air mucosal interface is obtained, it should be remembered that this is better assessed clinically with a mirror or nasopharyngoscope. The characteristic shape of the nasopharynx on axial CT shows torus tubarius as the most prominent landmark. In front is the opening of the eustachian tube and behind the lateral pharyngeal recess, or fossa of Rosenmüller. What is more important, and a great advance in imaging, is the ability of CT to demonstrate the deep tissue planes which lie beneath the mucosa. The axial view of these planes complements the clinical examination because deep extension is the hallmark of malignancy in the nasopharynx. The pterygoid muscles attached to the lateral pterygoid plate and the deglutition muscles can be recognized as well as the fat in the paranasopharyngeal space between them. Further consideration of these parapharyngeal structures is given in Volume 5 on the pharynx. Diseases of the nasopharynx frequently obstruct the eustachian tube, and the subsequent opacity of the middle ear cleft is easily demonstrated by CT.

Malignant tumours of the nasopharynx

Almost all deeply infiltrating lesions of the nasopharynx will prove to be primary neoplasms, usually squamous cell carcinoma. The most important feature on the CT scan is obliteration of the paranasopharyngeal soft tissue planes and in particular the fat in the paranasopharyngeal space. The deep soft-tissue structures are normally very symmetrical so comparison between the two sides is useful. Such symmetry is not so constant in the normal outline of the mucosal surface.
Sometimes carcinomata of the upper aerodigestive tract are not apparent on examination of the mucosal surfaces because the tumour arises either submucosally or within a deep crypt and then extends into the deep tissue planes rather than the lumen. In one series (Mancuso and Hanafee, 1983) there were 19 mucosally inapparent carcinomata of the upper aerodigestive tract out of 160 cases examined. There may or may not be a mass bulging the wall of the nasopharynx but diagnosis can only be made by CT guided biopsy. Endoscopy and biopsy compromise the effectiveness of CT and therefore should be carried out after the CT examination.

Asymmetry of the muscle layers may be due to atrophy after radiotherapy or sometimes to neurogenic muscular atrophy from infiltration by a carcinoma. Occasionally nasopharyngeal carcinomata grow in a more exophytic manner into the lumen of the nasopharynx, but this is usually a feature of lymphomata.

Erosion of the skull base and extension of tumour into the cranial cavity along the carotid artery or through the foramen lacerum can be shown by enhanced CT, although the soft tissue intracranial extension is probably best demonstrated by magnetic resonance.

**Chordoma**

Chordomata are predominantly midline tumours. A large soft tissue mass in the postnasal space is associated with destruction of the basisphenoid and sometimes flecks of calcification best shown by CT. There is usually an associated intracranial mass and irregular destruction of adjacent bone depending on the site of origin (Jeans, 1984).

**Summary**

Conventional plain radiographs will continue to play a major role in the initial investigation of diseases of the paranasal sinuses, despite the limitations of this technique. Good radiographic method and positioning of the patient are important, as is the ability of the observer to detect early signs of disease such as erosion of the sinus walls. High resolution computerized tomography gives an excellent demonstration of both fine bone detail and soft tissue anatomy on the same sectional picture and is now the investigation of choice. CT can demonstrate a tumour early in the course of the disease and can be used to recognize the exact extent of the lesion for optimal staging prior to therapy. CT plays an important role in follow-up and can be used to show residual or recurrent disease. Magnetic resonance gives better soft tissue imaging in three planes and appears to be better than CT for showing extension of disease into the cranial cavity. However, bony structures are not imaged and therefore MR does not appear likely to replace CT for the investigation of diseases of the paranasal sinuses in the foreseeable future.