Chapter 17: Radiography and imaging in otolaryngology

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Ever since their discovery around the turn of the century, X-rays have been used with variable success for the investigation of diseases of the ear, nose and throat. In the first half of the century, such imaging was limited to plain radiographic demonstration of bony structures of the petromastoid, sinuses and skull base, and to the assessment of normally air-filled structures in the upper aero-digestive tract. This was assisted by the administration of positive contrast agents, especially those containing barium, to show the pharynx and oesophagus. Air encephalography was the only means of demonstrating intracranial structures and lesions, but as vascular and intrathecal contrast agents became less toxic, angiography began to play a greater part.

Tomography, or sectional imaging, was a useful addition to these techniques, demonstrating specific anatomy and lesions without overlap of other bony structures. The highest refinement of this process is complex motion tomography using a spiral or hypocycloidal movement of the X-ray tube; and for small bony structures and canals of the ear, this method remains unsurpassed. In spite of many claims to the contrary, polytomography still gives a lower radiation dose to the eyes than any other craniofacial radiological technique. Unfortunately, polytomography requires expert interpretation, and the low photographic contrast of the pictures is hard to reproduce in the form of illustrations. Hence, for the figures in this account, computerized tomography sections have been used predominantly.

It is computerized tomography (CT) which has, in the last few years, made the most important contribution to radiology in otolaryngology. Initially, CT represented a great advance in soft tissue imaging because of its greatly improved density resolution. Recently, improved spatial resolution for structures of high inherent contrast, such as bone has meant that high resolution CT pictures have given good demonstration of fine bone detail equivalent to polytomography. The ability of CT to show soft tissue abnormalities with clear air-soft tissue interface and excellent surrounding bone detail makes this the optimum means of investigating soft tissue masses in the middle ear cavity, the sinuses and the postnasal space, while making contrast nasopharyngography and laryngography redundant.

More important than showing the outline of the nasopharynx is the new found ability to demonstrate tissue planes on either side in the infratemporal fossa and the parapharyngeal region. Air meatography - an examination whereby a few millilitres of air are introduced by lumbar puncture and CT is used to show the contents of the cerebellopontine angle and internal auditory meatus - is the definitive investigation for demonstrating or excluding small acoustic neuromata. In the future, magnetic resonance, which has already been shown to be superior to CT for demonstrating the posterior cranial fossa, may well replace it for the demonstration of all acoustic neuromata, whether large or small.

Reconstruction of an image from a set of measurements, rather than a direct recording of the image on film, is now a feature of many imaging techniques, especially that of CT. Proton magnetic resonance (MR) is used to produce sectional images not unlike those of CT, and the reconstruction methods are virtually identical. However, MR differs from CT in not
using an external source of ionizing radiation. MR images are derived from radio signals emitted by substances in the body in response to an alternating applied magnetic field. This technique will almost certainly have a much wider application in the future.

Barium studies with fluroscopic screening have for a long time been a standard means of investigation of the upper digestive tract and are particularly good at demonstrating lesions below the cricopharyngeus. It is believed by some that any complaint of a 'lump in the throat', as well as of true dysphagia, warrants a barium swallow, but it should never be forgotten that lesions of the oesophagus, hiatus hernia and even gastric neoplasms may present with unexpected symptoms. Lesions below the cricopharyngeus are more clearly demonstrated. Dynamic studies of swallowing using cine radiography have aided a new dimension to the investigation of dysphagia and are further discussed in Volume 5, Chapter 2, but a barium swallow is of rather dubious value in the identification of ingested foreign bodies.

Angiography has a limited subsidiary role in radiology in otolaryngology, especially now that CT gives a more satisfactory demonstration of the location and extent of tumours. Only for glomus jugulare tumours is angiography mandatory, whereas in the case of other tumours, it is probably only of value for those which show contrast enhancement with CT. The use of two relatively new angiographic techniques is increasing. These are as follows:

1. digital subtraction angiography, also called digital vascular imaging, provides a less detailed, but more convenient demonstration of vascular anatomy, often as an outpatient procedure

2. embolization techniques carried out preoperatively to reduce the blood supply to vascular tumours such as glomus jugulare and juvenile nasopharyngeal angiofibroma.

Imaging equipment and techniques

Plain radiography

It is possible to obtain good plain film views of the head and neck by using almost any basic radiographic unit; however, for maximum detail and contrast, a specialized skull unit, which keeps the film and incident X-ray beam central, is a distinct advantage. High energy X-ray tubes, with a fine focus and with small cones to limit the field size, also improve resolution. There are now advanced skull units available which allow the X-ray tube to be adjusted to any point on the surface of a sphere. The X-ray film is located opposite and perpendicular to the central beam, and the part of the skull to be investigated is positioned in the centre of the sphere. With the skull immobilized in the supine position, accurate angulation in three reference planes is easily reproduced and there is constant magnification with no distortion of the radiographs. For a base view, however, the head has to be extended from the fixed supine position, and the advantages of the fixed reference planes are forfeited if a special table is not used or if the examination is not done with the head supine. Mathematically, accurate positioning can be achieved using the reference planes, and a full description of the technique has been given by the Swedish authors, Radberg and Thibaut (1971).

Lines and planes used in basic skull radiography are as follows.
Radiographic baseline - orbitomeatal baseline

This is a line drawn from the outer canthus of the eye to the centre of the external auditory meatus. In the neutral position it is regarded as being always perpendicular to the film. It is raised by extending the head and lowered by flexing it. The base line is always kept at 90° to the film unless stated otherwise.

Infraorbital plane (also known as the Frankfurt plane)

This passes through the lower orbital margins and the roofs of the external auditory canals. An angle of 10° exists between the orbitomeatal baseline and the Frankfurt plane.

Auricular plane

This is at right angles to the infraorbital plane, and passes through the external auditory canals.

Median sagittal plane

A vertical plane running anteroposteriorly which bisects the skull into two equal halves. It must be aligned at right angles to the film for anteroposterior projections, and parallel to it for lateral projections. Rotation of the head around the vertical axis is referred to as rotation of the sagittal plane - the face being turned to whichever side is indicated.

Coronal plane

This is a vertical plane at right angles to the median sagittal plane, parallel to the film in anteroposterior projections. The meatal or auricular plane is a coronal plane passing through the external auditory meatus.

Tube angulation

This refers to the direction followed by the central ray emerging from the tube, which can be either 'cephalically', toward the head, or 'caudally', towards the feet. If fluid levels are being sought, a horizontal beam should be used, regardless of whether the patient is in a sitting or recumbent position.

Radiographic positions

These are named according to the direction of the central ray, with the part in contact with the film being positioned last; for example, 20° occipitofrontal means the central ray is angled 20° caudally, and directed through the occiput to emerge through the frontal bone positioned against the film.
Immobilization

The head must always be carefully immobilized, with either head bands or special clamps, and respiration must be arrested during exposure to reduce lack of sharpness caused by movement.

Film quality

Film definition (a combination of detail and contrast) is improved if:

1. a Potter-Bucky diaphragm or grid is used, to reduce the amount of scattered radiation reaching the film
2. the beam is collimated to include only the structures under examination
3. the patient's head is immobilized to prevent movement during exposure
4. the smallest focal spot is used compatible with acceptable exposure times, optimum exposure factors, and tube focus loading
5. suitable intensifying screens are used for optimum resolution consistent with the tube or generator output available. Rare earth screens may improve the diagnostic result if exposure factors are limited.

Conventional tomography

The basic radiograph is an image of the entire part being X-rayed with the result that structures of varying density through that body area are superimposed on each other. The tomograph consists of a radiograph visualizing just a horizontal slice of the area in question with the overlying and underlying structures blurred out by motion. This generally means that the tube and the film are the moving components while the patient remains still.

The simplest type of movement, which also has the shortest exposure time, is the linear. The linear is, therefore, most suitable for the larynx, which together with the tracheobronchial tree are the only areas examined by the present author using the linear mode.

Complex motion of the X-ray tube, either hypocycloidal or spiral, gives the most uniform blurring of structures outside the plane of the section, as well as producing thinner sections of 1-2 mm thickness.

The Polytome continues to be used for routine demonstration of the petrous temporal bone, as this specialist unit gives the best and most convenient demonstration of bone detail, especially of the internal auditory meatus, more cheaply and with less radiation to the patient's eyes than either plain films or computerized tomography. However, good radiographic technique and positioning are required, as well as the use of the optimum film/screen combination which, if a 0.3 mm focal spot tube is used, would appear to be the limiting factor to spatial resolution with the inherent low contrast of the picture. Various new general
purpose X-ray machines have a built-in facility for spiral tomography and, if access to CT is limited, they may be used for sectional demonstration of fine bone detail in the head.

**Computerized tomography**

Computerized tomography is the reconstruction by computer of a tomographic plane of an object (section or slice). It is developed from multiple absorption or attenuation measurements made around the periphery of the object (a scan). CT scanners use a highly collimated X-ray beam, but the radiographic film of conventional imaging has been replaced by a battery of ionization detectors which enable the required information to be obtained with maximum dose efficiency. The small volumes (voxels) of tissue, for which an attenuation value is derived, have a cross-sectional area normally less than 1 mm² and a depth equal to the thickness of the slice, which may be from 0.5 to 13 mm depending on the machine and the type of examination. The picture elements (pixels) are a two-dimensional reconstruction in the scan plane, displayed as a grey-scale picture on a television monitor. Computerized mathematical techniques are required to give accurate determination of the attenuation values at all points of the matrix within the section. These, as well as further considerations of how scanners function, are beyond the scope of this account. However, a brief consideration of image quality and limitation, as they affect radiology in otolaryngology, would seem to be pertinent.

The success of CT has been on account of the great sensitivity of the method for very small changes in X-ray attenuation. This is known as contrast resolution. The quality of the CT image, however, depends on a complex relationship between radiation dose, spatial resolution, contrast resolution and noise. Noise is the mottling or granularity which affects the image when there is insufficient information from the detectors available for assessment. To some extent, therefore, there is a trade-off between optimum contrast resolution and optimum spatial resolution (raising the radiation dose to unacceptable levels still only partially overcomes this problem). In practice, most scanners have two options for image production, namely standard resolution for optimum density discrimination, as when demonstrating brain tumours, and high resolution for fine detail discrimination, especially that of small bony structures in sinus and temporal bone. With the new rotate-only scanners, it is possible to obtain images in both soft tissue and bone resolution, using the same raw data, but, inevitably, the reprocessing increases the length of the examination.

Twenty years ago, the demonstration of fine detail in the ear was considered the ultimate achievement of polytomography. In some respects the same is now true of high resolution CT, and a brief consideration of some of the limiting factors of this technique for the examination of regions such as the middle ear seems desirable.

1) Partial volume averaging is a phenomenon that occurs with CT when the dimensions of the object being imaged are smaller than the slice thickness and the individual voxel. Non-representative attenuation values may be generated when all the densities within an individual voxel are averaged to produce a single attenuation coefficient. Bone or air in a voxel depicting soft tissue will significantly raise or lower the averaged attenuation reading of that voxel.
(2) Soft tissue silhouetting is the silhouetting of small dense structures which may occur when soft tissue densities such as normal adjacent brain, haemorrhage, tumour or fluid envelope are contiguous with a structure usually bordered by air. The difference in density between the structures and the background density may be insufficient for their visualization. This phenomenon is an event greater problem with the low contrast images of polytomography and is important in the evaluation of ossicular abnormalities in conjunction with soft tissue masses or small erosions. Some practical aspects of these two phenomena are demonstrated.

The standard axial or horizontal sections are used for almost all CT imaging in the ear, nose and throat, but further coronal views are often desirable, particularly for the sinuses and temporal bones. These may be obtained directly by elevating the patient's chin or by putting the head back. Direct CT imaging is not often used in other planes, but several projections for the temporal bones have been described in the literature (Zonnefeld et al, 1984). The alternative to direct imaging is reconstructed imaging from the raw data obtained from multiple axial sections. This can be done in any desired plane, but multiple axial images and, therefore, considerable extra irradiation are required. For the temporal bone, intervals of 1 mm are recommended. Even then, however, the quality of the 'reformatted' pictures will be inferior to direct imaging because of the interpolation process between adjacent slices and the problems of patient movement.

Administration of iodine-containing contrast agents, as used for many routine radiological investigations, such as excretion urography, was found in the earliest days to improve the demonstration of many intracranial pathological processes, especially that of tumours. 'Contrast enhancement', as it will henceforth be called, is still necessary for the demonstration of masses in the posterior cranial fossa. No brain scan investigation for suspected acoustic neuromata is complete without contrast enhancement. This enhancement is mainly a result of two factors:

(1) increased opacification of vessels

(2) extravasation into the extracellular spaces.

Outside the cranial cavity, the second phenomenon, in particular, is less apparent. Recently, the timing and degree of enhancement have been used in an attempt to differentiate tumours with little stroma, such as glomus tumours - which show instant enhancement in the vascular phase followed by rapid washout - from other vascular tumours, such as meningioma, where there is no such rapid enhancement, but a more pronounced and persistent opacification beyond the initial vascular phase (Mafee et al, 1983). Such rapid scans of the same slice, followed by a plot of time versus attenuation, are known as 'dynamic CT'. Because CT imaging involves computer assessment of X-ray attenuation, it is relatively easy to obtain attenuation values for any particular structure or discrete lesion, provided that partial volume averaging is avoided. It was hoped that this would be useful for differential diagnosis, but the results with or without contrast enhancement have been most disappointing.
Radiotherapy planning

Computerized tomography images provide accurate information on the extent and location of tumours, which would be difficult or impossible to detect with conventional X-ray apparatus. Until recently, the information obtained had to be entered manually into the planning system with the inevitable losses in time and accuracy. Various planning systems, which enable the CT slice data to be entered directly, have been developed. A sophisticated dose calculation model provides accurate calculation and optimization of the three-dimensional dose distribution. This appears to be particularly useful in the area of the paranasal sinuses and nasopharynx where, in one series, 86% of patients had the planned field enlarged on the basis of the CT planning scan (Adam et al, 1984). However, unless therapy scans can be taken in the treatment plane, they have little advantage over diagnostic CT scans which can be used to reconstruct the tumour limits on a simulator film. If the CT scans are to be used within a radiotherapy planning computer, it is important that the diagnostic images are taken with the same section orientation as will be used on the therapy equipment.

Magnetic resonance

Just as CT proved initially to be a valuable technique for imaging the brain, so proton magnetic resonance (MR) imaging has shown its main worth in the demonstration of neurological disease. A high level of contrast and an absence of artefacts characterize, in particular, the posterior cranial fossa, where MR is now proving superior to CT, especially as it makes possible direct coronal and sagittal imaging. Spatial resolution is improving rapidly, although it continues to be inferior to CT in most instances, and a particular disadvantage is that bone is not well demonstrated. Thus, CT is superior in the imaging of the temporal bone and sinuses because of its special ability to demonstrate soft tissue abnormalities together with fine bone detail. Magnetic resonance appears more useful for the infratemporal fossa and the parapharyngeal regions, where tumours are well demonstrated (Lloyd and Phelps, 1986). The relationship of masses to the various major blood vessels is better shown by MR than by contrast-enhanced CT. MR imaging relates almost exclusively to the behaviour of hydrogen protons. When the radiofrequency field which has disturbed a sample of protons is terminated, the protons return to their state of equilibrium and, in so doing, give a measurable MR signal. The magnitude of the signal is an indication of the number of protons affected and is referred to as the proton density. Only those hydrogen protons which are part of highly mobile molecules are affected; hence, at present, the technique is effectively limited to the display of water and mobile lipids. In most body tissues, it is the hydrogen of water which provides the biggest component of the MR signal. The other properties are the $T_1$ or longitudinal relaxation time, and $T_2$ or transverse relaxation time of these same protons.

Perhaps a more effective 'tissue characterization', so unsatisfactory with CT, may be possible with magnetic resonance using $T_1$ and $T_2$ relaxation times, together with proton density and other MR observable properties. As with CT, partial volume averaging is an additional problem affecting characterization of normal and abnormal tissues, and it does not seem that there will be much practical application of tissue characterization techniques in the near future. Meanwhile, magnetic resonance, in common with other sectional imaging, requires a profound knowledge of anatomy for an effective interpretation of the image.
Angiography

Apart from the recently developed digital vascular imaging, almost all angiography of the head and neck is now done by catheterization of the femoral artery, followed by manipulation of the tip of the catheter into the appropriate vessel under fluoroscopic control. High resolution image intensification together with rapid automatic film changing and advances in catheter technology have led to selective and super-selective examination of the area of interest. The success of computerized tomography has superseded the diagnostic role of angiography in some conditions and modified it in others. Angiography is now used principally in cases of cerebral ischaemia and of intracranial haemorrhage, and in the diagnosis of aneurysm and angiomatous malformation. It still has an important role for vascular malformation. It still has an important role for vascular tumours, particularly glomus jugulare; and there has recently been an increased therapeutic application, particularly in the treatment of glomus tumours. The types of investigation may be listed as follows:

(1) Arch aortography. This is used - although rarely now - for a demonstration of the major vessels of the neck.

(2) Common carotid injection.

(3) Internal carotid injection. This is used mainly for intracranial lesions.

(4) External carotid injection. This is used principally for lesions of the face, and for demonstrating the blood supply of meningioma. Super-selective demonstration of branches of the external carotid, particularly the ascending pharyngeal and the maxillary artery, is important for embolization techniques. Anastomoses with the internal carotid supply can also be demonstrated.

(5) Vertebral angiography. This was formerly used for diagnosing lesions in the posterior cranial fossa. Although it is no longer used in the diagnosis of acoustic neuromata, this type of investigation is considered advisable by many surgeons for showing the vascular architecture preoperatively.

(6) Retrograde jugulography. This is occasionally used to confirm the diagnosis of a glomus jugulare tumour and to show its lower limits. The sigmoid sinus and the jugular bulb can often be shown in the venous phase of a carotid angiogram.

Digital angiography

Digital subtraction angiography is a modified form of the subtraction technique used in vascular imaging. The essential difference between digital subtraction angiography and photographic subtraction lies in the digitization of the video signals from an image intensifier/television system. This is followed by subtraction contrast enhancement and reconversion to analogue signals, which are subjected to further enhancement by windowing and grey-scale manipulation methods similar to those used for viewing CT images. In some systems, image enhancement is performed digitally and the resultant data are subsequently converted into analogue form for the television display.
It was hoped initially that intravenous digital subtraction would completely replace intra-arterial procedures, but such techniques necessitate large doses of contrast agent, and movement by the patient is a problem. Movement downgrades the quality of the images recorded, but the problem can be partially overcome by what is called 're-registration' of the patient, whereby further views for the subtraction process are made during the examination.

The main applications of intravenous digital subtraction angiography are in the study of the extracranial cerebral arteries, of certain intracranial lesions, such as large aneurysms, and of arteriovenous malformations, and in the diagnosis of cerebral venous sinus disease.

Intra-arterial digital subtraction angiography allows a low concentration of contrast medium and finer catheters to be used, reducing the risk of arterial damage. The rapid subtraction with real time display and the ability to study selected frames make this an ideal preliminary to interventional studies, although the inferior resolution for small vessels can be a problem. The efficacy of embolization and any alterations of flow which might take place can be immediately assessed. Undoubtedly, the use of digital imaging for angiography will increase rapidly, although, at present the intra-arterial techniques appear more satisfactory than the intravenous ones, and are especially useful for children, where strict limitation of contrast dose is necessary.

**Embolization techniques**

Embolization is a technique of intravascular occlusion in which catheters are selectively manipulated into a pathological vascular territory for the purpose of injecting occlusive or embolic agents. Detachable balloons have been used to obliterate large vascular fistulae, and a great variety of embolic agents - such as Gelfoam, silicone spheres, tantalum powder and various chemical agents - have been used to obliterate feeding vessels of tumours, usually as a prelude to surgery. Super-selective catheterization is an essential preliminary. Occlusion of the nidus of the lesion, and not merely of the feeding pedicle, should be performed, and the distal migration of the emboli to the venous circulation, and beyond it, must be prevented. Such procedures should be carried out only in a few specialist neuroradiological centres.

**Subsidiary imaging techniques**

Radiological and other imaging investigations, which are sometimes used in otolaryngology but whose main application is in related specialties, will be briefly described.

**Xeroradiography**

A conventional source of X-rays is used for this technique; however, instead of recording on film, use is made of specially charged selenium plates to produce an image. Tomography can be used in the same way as with radiographic methods. Low contrast detail within the soft tissues is improved by the phenomenon of edge enhancement, providing a good demonstration of the air/soft tissue interface in the pharynx and larynx. The wide exposure latitude provides, in the same image, good detail of both soft tissue and bone, and xerotomography of the larynx has been advocated for radiotherapy planning of the treatment volume of laryngeal and related neck carcinomata (Julian, Noscoe and Berry, 1981).
disadvantages of xeroradiography are those of the increased radiation dose, which must be considered when examining children, the increased cost, and some loss of bone detail. Practical experience has shown that the improvement in soft tissue detail is useful in examining the pharynx and larynx, but there is little call for the technique in other areas, such as the sinuses, and therapy planning is not probably better done with CT.

Panoramic radiography (orthopantomography)

Synchronous and reciprocal movement of the X-ray tube and film cassette around the lower part of the head of the patient constitutes the basic design of the panoramic X-ray machine. The curved focal plane is engineered to correspond to the size and shape of the average dental arch. It is possible to achieve, on one film, a complete demonstration of all bony structures in upper and lower jaws, as well as of all teeth, both erupted and unerupted. These machines are now widely available, especially in dental clinics where their main use is for dental surveys; they are particularly useful to the orthodontist in the case of children with developmental abnormalities, as a comparison between the two sides can easily be made. The patient is examined standing or sitting when using the commonest type of orthopantomograph. A bite block or jaw support automatically positions the jaws within the focal plane, but some repositioning may be necessary to obtain views of the antra and the temporomandibular joints. Spring loaded or movable head-lamps are normally used because of the long X-ray exposure times (between 15 and 22s).

A quick and simple demonstration of the temporomandibular joints and parotid regions can be achieved, although the slightly oblique view of the temporomandibular joint demonstrates the neck and condyle of the mandible better than the articular fossa and eminence. A ‘reversed orthopantomograph’, an option available only on certain types of orthopantomograph, gives a rather better demonstration of the joint. However, the best demonstration of bone detail in the temporomandibular joint is by lateral complex motion tomography, but CT, MR or arthrography are necessary to show the state of the intra-articular disc.

The patient is examined in the supine position on a sophisticated and versatile, but more expensive, development of the basic panoramic X-ray machine. The panoramic image comes from a combination of linear and circular movements of the X-ray tube around the patient's head. The exposure is made throughout or during only certain segments of the tube movement and planned programmes for the middle third of face anatomy; temporomandibular joints (lateral view), cervical vertebrae, optic foramina and dentition are available. There is no need to turn or move the supine patient during the examination, and a good demonstration of facial anatomy makes this an excellent apparatus for assessing a badly injured patient. However, for dental surveys and demonstrations of the temporo-mandibular joints, this technique has no advantage over simpler panoramic X-ray machines. Other options available - such as views of the temporal bones - are, in the opinion of the author, of little value.

Attachments for cephalometric skull radiography are sometimes added to panoramic machines for use in dental clinics. Cephalometric radiographs are used primarily by orthodontists and oral and maxillofacial surgeons in the evaluation of facial growth and development. The lateral and posteroanterior radiographs are made at a standard anode film distance of 152 cm (60 inches); the patient's head should be stabilized to produce a true
lateral projection and the soft tissue profile of the face must be seen in addition to the skeletal structures. Such cephalometric methods have been used to estimate the size of the adenoid pad (Maw, Jeans and Fernando, 1981).

**Ultrasonography**

Although ultrasound has been used for the investigation of sinus disease, its practical value in otolaryngology is very limited and depends on its ability to identify fluid-filled cavities. Ultrasound may help, therefore, to confirm the cystic nature of masses in the neck - particularly in or around the thyroid gland - in the salivary glands and branchial cysts.

**Isotope scanning**

The introduction of radioactive tracer materials, especially the technetium phosphate analogues, together with improved camera techniques and better diagnostic image resolution, have today resulted in the ready adaptation of bone scanning to the diagnosis of a variety of clinical problems. The major role of bone scanning in medicine generally remains that of the search for occult bony metastases in patients harbouring cancers known to have a predilection for the bony skeleton (that is breast, lung and prostate). The bone scan demonstrates areas of increased osteoblastic activity; however, this is a non-specific finding which may indicate a variety of disease processes including fracture, osteomyelitis, arthropathy, bone dysplasia, or primary or secondary tumour in bone. Carcinoma of the oral cavity, and particularly of the floor of the mouth, frequently invades the mandible subclinically before there is any evidence of bone destruction on plain films or orthopantomography. The extent of surgical resection depends greatly on whether or not there is bone involvement by the tumour; osteoblastic reaction on delayed bone scanning is often the earliest indication.

Formerly, radionuclide studies had an important role in neuroradiology, where they were able to demonstrate approximately 80% of brain tumours. However, these investigations have now been almost completely superseded by computerized tomography and magnetic resonance. Dynamic and functional studies of the cerebrospinal fluid pathways, using labelled proteins or labelled inorganic chelating agents, still have a place; but CT, combined with cerebrospinal fluid water-soluble contrast agents, has the advantage of morphological display. Similarly, radionuclide cisternography has been used with variable success in the evolution of cerebrospinal fluid leaks - particularly rhinorrhoea. This technique is even less satisfactory for demonstrating fistulae through the ear, and it is not required if a congenital deformity of the labyrinth is demonstrated by tomography or CT and the discharge of cerebrospinal fluid is confirmed by analysis of the fluid or the use of fluorescein or other tracers (see Volume 6, Chapter 2).

Temporomandibular joint disorders can be usefully assessed by bone scanning. Most discomfort and/or pain in or about the temporomandibular joint relates to altered muscle tension about the joint by the powerful muscles of mastication, probably on account of dental malocclusion which causes a change in bite dynamics. Isotope studies have also been used for the assessment of facial fractures and osteomyelitis or to predict the likely growth rate of osteomata. The salivary glands normally concentrate technetium-99 sodium pertechnetate. Originally, this was considered to be a nuisance on brain scans, but it is now used for the functional assessment of the gland parenchyma. Hyperfunction is seen in acute sialadenitis,
granulomatous diseases, lymphoma and the sialoses; decreased activity with Sjögren's syndrome and most primary and metastatic tumours. Exceptions are Warthin's tumours and oncocytomas which intensely accumulate the radionuclide. The larynx is another organ which has been investigated with radioactive isotopes. Anterior extension of laryngeal cancer into the pre-epiglottic space is an important finding which may affect management of the disease. Extensive pre-epiglottic space involvement, sufficient to reach the hyoid bone, will incite a delayed osteoblastic response on the bone scan. For an account of this and other aspects of radionuclide scanning in otolaryngology, the reader is referred to the work of Noyek (1979).

**Dacryocystography**

Ultrafluid Lipiodol injected into the inferior canaliculus through a very fine catheter is used to demonstrate the patency of the canaliculi, lacrimal sac and the nasolacrimal duct. When disease is present, the site and degree of obstruction and the presence of fistulae, diverticula and concretions are shown. The exposure of the films is made during the actual injection of the contrast medium, and in normal patients will produce an image which is continuous throughout the duct system. Subtraction studies are particularly useful for demonstrating the common canaliculus. Common canaliculus blocks are characterized by the regurgitation of contrast medium through the upper punctum, and the outlining of both the upper and lower canaliculi on the radiographs, without filling of the lacrimal sac if the obstruction is complete. Complete or partial obstruction distally in the sac or nasolacrimal duct usually shows as dilation or 'mucocoele' of the lacrimal sac; it may be caused by congenital stenosis, inflammatory processes, trauma or neoplasms.

**Sialography**

Injection of radiopaque contrast medium into Stenson's or Wharton's duct to demonstrate the glandular duct system is still the principal means of investigation into diseases of the parotid and submandibular salivary glands.

Before the contrast medium is introduced, plain films are obtained to demonstrate any radiopaque calculi or calcification within the gland. For the parotid gland, lateral and oblique views should be obtained in the open mouth position. The lateral view for the submandibular gland should be taken with the floor of the mouth depressed by the patient's finger or a wooden spatula pressing the tongue downwards. An intraoral occlusal film is necessary to exclude a stone in Wharton's duct.

For the injection, either a water soluble or an oily contrast medium may be used. The present author used ultrafluid Lipiodol, which allows good filling of the smallest calibre salivary ducts, and, being more viscid than the water-soluble agents, is easier to keep in the ductal system. This is a desirable feature if, after the conventional sialogram, a CT sialogram is to be performed. A detailed description of the technique is given by Som and Saunders (1984) and only a brief account is given here.

The opening of Stenson's duct of the parotid gland is opposite the second molar tooth. The orifice of Wharton's duct of the submandibular gland lies under the tip of the tongue on the sublingual papilla, and is smaller than that of Stenson's duct. In either case, the opening needs to be gently dilated with suitable dilators of the lacrimal type. Cannulation is by
catheters or sialographic cannula, and a hand injection technique is used. A sialogram can be considered in three phases - ductal filling, acinar filling, and evacuation. Acinar filling can be accomplished in most patients. The patient should be warned that discomfort will be felt in the region of the injected gland, and should be told to signal when this occurs.

Conventional sialography is still the best examination for the duct architecture and for diseases of the duct system, such as sialectasis. It is less satisfactory for the demonstration of mass lesions, which appear as filling defects in the normal sialogram. Tumours within the parotid gland are better demonstrated and outlined by CT. The parotid glands usually show lower attenuation than the adjacent muscles, and this feature also occurs with intraparotid tumours. Parotid sialography may give a better demonstration of the situation and extent of such a mass; however, with the improved resolution of the latest scanners, it is now less necessary than it previously was.

Arthrography of the temporomandibular joint

The best demonstration of the bony components of the temporomandibular joint, that is condyle of mandible and articular fossa and eminence, is obtained with lateral complex motion tomography. Plain film views and panoramic tomography are less satisfactory, especially for showing the articular fossa. However, none of these conventional techniques will show the thin fibro-cartilaginous disc that divides this synovial joint into an upper and lower compartment. Recently, CT has been used to delineate the soft tissues of the temporomandibular joint, but positioning is difficult for direct sagittal sections and the definition of reformatted images is not really adequate. Magnetic resonance has also been used to show the disc.

In the meantime, arthrography, although not widely used, can be performed to provide evidence of disc displacement, disc perforation or both. The examination is most helpful diagnostically in those cases which have little or no bony abnormality shown on the tomograms, but in which the clinical features nevertheless suggest disc derangement. Either or both joint spaces may be injected, but usually just the lower compartment is opacified, although disc perforation will allow the upper compartment to fill as well. Further elaboration of the technique can be achieved by use of tomography, double contrast (using air as well as water-soluble contrast agents), fluoroscopy and cineradiography.

Conclusions

The foregoing is an account of the imaging techniques which are, or can be, used in the practice of otolaryngology for the demonstration of normal and abnormal anatomy; for showing the situation and extent of disease processes; and, in some instances, for indicating the nature of the lesion. Few, if any, should be considered routine examinations, and they should be requested only after an adequate clinical examination has been made. Most hospitals in the UK have open access to radiographic facilities for general practitioners, but whether such otolaryngological radiographic investigations should be ordered by general practitioners is debatable. A barium swallow is perhaps the only satisfactory investigation that may be undertaken without a prior otolaryngological opinion. The most frequent examination requested is that of plain film views of the sinuses in cases referred from general practitioners, otolaryngologists and other specialities, for a variety of symptoms, some of which are quite
non-specific. Clear sinus X-rays not uncommonly exist in the presence of a nasopharyngeal carcinoma; which can result in a false sense of security unless this is appreciated. The author believes that a radiological examination of the petrous bone should be requested only by a specialist in this field. Radiographs of the cervical spine in the case of dizziness in an elderly patient serve no purpose.

The greatest change in the last 5 years has been the development of computerized tomography, particularly in the high resolution mode. Radiologists can now demonstrate not only the bony changes that are produced by abnormalities of the head and neck, but also the soft tissue changes. The deep extent of a lesion can be shown by CT and not just the encroachment on the adjacent lumen. CT is now the optimum imaging mode for most aspects of otolaryngology, although its widespread application is still limited by cost and availability of equipment. CT is the optimum means of showing the soft tissue and bone abnormalities in sinus disease and in the middle ear; however, the author continues to use polytomography on account of its unsurpassed demonstration of bone detail in the inner ear. Demonstration of enlargement of the internal auditory meatus is still the best screening investigation for small acoustic neuromata (schwannomata). High resolution CT is now becoming available at district general hospital level, and the greatly improved demonstration of bone and soft tissue structures in the head and neck gives an added impetus for radiologists and otolaryngologists to become familiar with the sectional anatomy displayed.

The subsidiary techniques listed previously have only occasional application in otolaryngology and, depending on availability, need to be used after discussion with a radiologist in the attempt to solve a specific problem. The latest computer-assisted methods can readily be used to measure certain properties of the normal and abnormal tissues being imaged, particularly X-ray attenuation by CT, and proton density and relaxation times by magnetic resonance. However, the attempts to chart a limited range of such values without overlap and to provide a means of 'tissue characterization' have so far proved largely unsuccessful.

What of the future of imaging in otolaryngology? The rapid advance of new technology during the last 5 years is indicative of certain trends. The limitations of plain radiographs, the cost of silver and the problems of storage of X-ray film probably mean that the traditional imaging methods will be used less. Tomographic methods will have increasing application. The demand for increasing the spatial resolution in CT means increasing the number of detectors and, simultaneously, the concomitant radiation exposure of the patient. A possible solution to this problem is provided by partial scanning. The mathematical reconstruction is made over a limited target volume or all detectors are directed towards a limited region of interest within the body, and only this region is scanned. The procedure reduces X-ray exposure, and all the detectors can be used to provide a high-resolution image of the scanned region. However, slice reconstruction does pose some problems. Another solution is to use imaging with non-ionizing radiation. The ionizing effect of X-rays restricts their usefulness in diagnostic imaging, in view of the need to limit the radiation exposure received by the patient. Hence all kinds of imaging with non-ionizing radiation are attractive alternatives, provided that acceptable image quality can be achieved. In this context, image quality mainly means spatial resolution, a process which for magnetic resonance is being rapidly improved, although, generally speaking, the latter remains inferior to CT.
Digital radiography, the manipulation of digital data storage and the retrieval of pictorial information, will be increasingly used as a consequence of the availability of powerful small computers, very fast dedicated image processors and large storage capacity. The latest digital storage media could be the nucleus of an overall information system within a hospital. This could incorporate one year's image storage. The picture source can be any kind of imaging system, such as CT or ultrasound, and even conventional X-ray film can be converted into digital data, making basements full of 'old films' a thing of the past.