Radiologic Imaging in Otorhinolaryngology

A'Delbert Bowen, Jocyline Ledesma-Medina, Mutsuhisa Fujioka, Kook Sang Oh, Lionel W. Young

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Technical Aspects and Advances

The radiographic technique is foremost among the methods of radiologic imaging, despite the potential biologic hazard of ionizing radiation in children. Irradiation can be decreased by close adherence to diagnostic indications, thus precluding unnecessary examinations. However, for specific clinical problems, many of which exist in otorhinolaryngology, the radiographic technique is the only available method of evaluation.

Effective and noninjurious immobilization of the child is important as the first step in the special effort that must be made to eliminate unnecessary irradiation. Collimation of the x-ray beam is another. Recent technologic advances in radiologic imaging have provided additional means for reducing irradiation. For the past five years we have been using a high speed film screen system (the Kodak Lanex rare earth screen with Ortho G film) for most pediatric roentgenographic examinations. This green sensitive film with rare earth screen system decreases irradiation by almost half, as compared to the radiation needed for a par speed film system. The use of carbon fiber for radiographic tables and screens, although expensive, offers another substantial decrease in radiation exposure.

Video fluoroscopic evaluation is often mandatory in evaluating the upper airway, swallowing function, and phonation. We use a low-dose video fluoroscopic system in which only 30 to 40 mrad/min are required to obtain fluoroscopic images of satisfactory diagnostic quality in small children. This videotape fluoroscopic recording system offers a substantial reduction in irradiation by eliminating the need for repetitive fluoroscopy for diagnostic evaluation or for teaching.

Recent advances in computed tomography (CT) which are especially important for pediatric patients include reduction in radiation exposure and shorter scanning times. The images of 1.5 mm sections of temporal bones obtained by specially designed CT modifications have better resolution than those obtained by conventional thin section tomography.

Because no ionizing radiation is involved, ultrasound is uniquely useful in pediatric imaging and improvements are ongoing. Recently, ultrasound has been widely accepted as an important method for evaluating intracranial lesions in young infants.

Radionuclide imaging in otorhinolaryngology is limited, but can be used to evaluate neoplasms or inflammatory lesions affecting bone. Radiation dosage to the patient is relatively low in these procedures.

Close collaboration between clinicians and radiologists is necessary for the optimal choice of available imaging modalities.

Airway Obstruction

In this discussion, obstruction of the airway is defined as an impediment to ingress or egress of air occurring between the mouth or nose and the main bronchi. Airway obstruction may be congenital or acquired.

Congenital Obstruction

Congenital airway problems amenable to radiologic diagnosis are choanal atresia, Pierre-Robin anomalad, and congenital stridor. The Pierre-Robin anomalad and bilateral choanal atresia are apt to cause life-threatening respiratory distress from birth. A lateral radiograph of the nasopharynx in the Pierre-Robin anomalad will suffice to confirm mandibular hypoplasia and to show the degree of airway occlusion caused by glossoptosis. Choanal atresia is confirmed by demonstrating that a small amount of sterile propyliodine oil suspension (Dionsil Oily) instilled into the nasal cavity does not pass into the posterior nasopharynx. This procedure is preferably done under video fluoroscopic control with a horizontal x-ray beam, raising the table to an upright position, and placing the infant supine on the footboard. Choanography is facilitated by removing excess secretions and instilling a few drops of 0.25 or 0.5 per cent phenylephrine hydrochloride before injecting contrast medium.

Floppy aryepiglottic folds, misleadingly known as "laryngomalacia", is by far the most common cause of neonatal stridor. Fluoroscopy in the lateral view may show characteristic infolding of the epiglottis and aryepiglottic folds on inspiration, but a radiologic diagnosis can only be made if the infant exhibits stridor during video fluoroscopy.

Radiographs may show vocal cord paralysis, tracheal stenosis, laryngeal web, or a soft tissue mass causing respiratory distress in the newborn. Supraglottic and glottic masses include ectopic thyroid and thyroglossal, branchial cleft, glottic, and aryepiglottic cysts. Hemangioma and mucocele are characteristically subglottic in location.

Acquired Obstruction

Most acquired airway obstructions occur in the hypopharynx or larynx and produce stridor. Croup (laryngotracheobronchitis) and acute epiglottitis are most common. If the degree of obstruction is not of such severity that immediate endotracheal intubation is necessary, anteroposterior (AP) and lateral radiographic finding in croup is the *steeple sign,* a tapered narrowing of the subglottic portion of the trachea in the AP view. The caliber of the trachea in the lateral view may not be obviously diminished. In bacterial tracheitis ("membranous croup") radiographs may show concentric tracheal narrowing and irregular filling defects within the tracheal lumen.

A radiographic finding common to all lesions that impede the entry of air at or below the epiglottic level is ballooning of the hypopharynx. Marked ballooning reflects a more severe degree of obstruction and often is absent when obstruction is mild.

Acute bacterial epiglottitis causes a broadening of the epiglottic shadow in the lateral view of the neck. Involvement of the aryepiglottic folds and surrounding tissues has prompted

the suggestion that *supraglottitis* may be a more precise term. Other causes of epiglottic swelling include traumatic hematoma, angioneurotic edema, and caustic burns.

Laryngeal papilloma, the most common laryngeal tumor of childhood, may be visible on radiographs. Pulmonary spread of papillomas has been reported.

An aspirated foreign body lodging in the hypopharynx, larynx, or upper trachea may produce stridor. Metallic objects of heavy density are easily seen on plain radiographs. Objects of plastic, aluminium, or vegetable matter, similar in density to soft tissue, may be visible when surrounded by air. Very small objects, especially those of soft tissue density, may not be distinguishable with conventional radiographic technique. Xeroradiography may show objects that escape detection on conventional radiographs.

A foreign body lodged in the distal trachea or bronchus may produce wheezing rather than stridor. An esophageal foreign body large enough to compress the adjacent trachea also may cause respiratory distress. Incomplete occlusion of a bronchus most often produces a ball-valve type of obstruction, permitting air to enter but not to exit the distal segments. This produces air trapping (obstructive emphysema) in the involved lobe or segment, or in the entire lung if the occlusion involves a main bronchus. Complete bronchial occlusion eventually causes atelectasis.

When severe, obstructive emphysema produces obvious hyperinflation in the involved portion of the lung on a full-inspiratory frontal radiograph of the chest. The cardiomediastinal structures are displaced toward the contralateral side and the volume of the contralateral normal lung appears diminished. These findings are sometimes misinterpreted as representing atelectasis involving the unobstructed lung. If air trapping is not severe the findings may be subtle. A radiograph obtained in full expiration may unmask obstructive emphysema that is not apparent on the inspiratory radiograph. An expiratory radiograph is easily obtained in a cooperative child, but in a younger child or one who is breathing rapidly it may be necessary to produce forced expiration by pressing upon the child's abdomen with a lead-gloved hand during the radiographic exposure.

Video fluoroscopy of the chest is more sensitive for detecting minimal unilateral air trapping than are plain inspiratory-expiratory radiographs. Video fluoroscopic findings of obstructive emphysema are displacement of the mediastinum toward the normal lung during expiration, returning toward the midline on inspiration; diminished excursion of the hemidiaphragm on the abnormal side; and hyperinflation of the obstructed portion of the lung during expiration. The fluoroscopic findings may be very subtle, with slight displacement of the mediastinum apparent only when the child is crying or sobbing. In our experience, use of right and left decubitus views to detect obstructive emphysema is less satisfactory than video fluoroscopy.

If a foreign body lodged above the carina or in the esophagus produces ball-valve tracheal obstruction, chest fluoroscopy will confirm only that there is ineffective emptying of both lungs, indistinguishable from diffuse air trapping of bronchospasm.

Radiographic Evaluation of Upper Airway Obstruction

Frontal and lateral views of the chest and neck are essential baseline radiographs for evaluating upper airway obstruction. The neck can be included in the frontal view of the chest if the child's head is positioned so that the chin does not obscure the upper airway. A lateral view of the chest, with shoulders abducted and arms held behind the patient (Pancoast position), also affords a clear view of the neck in the lateral projection, although in older children we prefer a separate lateral view centered on the pharynx. If there is great urgency because of severe respiratory distress a lateral view alone (often obtained in the emergency department with portable radiographic equipment) will serve to confirm or exclude epiglottitis or the presence of a radiopaque foreign body in the upper airway.

Joseph et al devised a radiographic technique using high kilovoltage, filtration, and magnification to overcome the usual difficulty visualizing the trachea superimposed on the cervical spine in the AP view. Their results were impressive, but we have had no experience with the technique. Xeroradiography or tomography may be useful when conventional radiographs have not satisfactorily shown the larynx or trachea. However, both of these methods result in greater radiation exposure than conventional radiographs and therefore are not used routinely.

With any of these radiographic techniques careful attention must be paid to good positioning. Poor inspiration or flexion of the neck may cause normal buckling of the infant's trachea. Slight rotation of the neck in the lateral view may simulate epiglottic swelling. The normal omega-shaped infantile epiglottis also may be confused with epiglottic swelling.

Evaluation of the larynx with radiopaque contrast medium is rarely indicated in children. Satisfactory radiographic detail of the laryngeal structures can usually be obtained, when necessary, by thin section tomography or CT using the normally present air as the contrast medium.

The chest radiograph is a valuable adjunct in the child with airway obstruction. Pulmonary edema may occur concurrently with the obstruction or may develop after insertion of an airway to relieve obstruction (see related discussion by Davis et al elsewhere in this issue).

Disorders of Swallowing

Pharyngeal Incoordination

Pharyngeal incoordination refers to any functional disturbance of propulsion of ingested material from the mouth into the esophagus. Clinical manifestations include nasal regurgitation of feedings and choking, coughing, or gagging. Abnormal function of the cricopharyngeus muscle, the pharyngoesophageal constrictor, is the underlying problem in many of these patients. The cricopharyngeus may relax sluggishly when the bolus reaches it, as in dysautonomia, or the cricopharyngeus may be hypertonic throughout swallowing. Whether this abnormal tone is called "achalasia" or "spasm" depends upon the manometric pressure pattern.

The video fluoroscopic findings in cricopharyngeal spasm or achalasia are specific and easily recognized. Swallowing of barium is observed in the lateral view. When the swallowed bolus reaches the cricopharyngeus the sphincter fails to open completely and part of the bolus is retained in the hypopharynx. The retained portion of the bolus may be regurgitated into the mouth or nose, may be aspirated into the trachea, or may simply pool in the hypopharynx despite repeated swallowing efforts by the child.

The key finding is an abnormal constriction at the level of the pharyngoesophageal sphincter as the bolus passes from the hypopharynx into the esophagus. This can be a relatively long segment of concentric narrowing or a short, transverse, bar-like posterior indentation on the barium column. Giedion and Nolte observed in some infants a prominent cricopharyngeus impression that did not cause obstruction and this they regarded as a normal physiologic variation.

Fatigue aspiration is a phenomenon in which otherwise normal infants may begin to aspirate toward the end of feedings. The pathophysiology is unknown. Esophagographic confirmation requires that the quantity of barium given be sufficient to simulate a normal feeding.

Swallowing disorders are best studied radiographically by recording the examination on videotape, which permits repeated slow-motion observation of swallowing without subjecting the child to excessive fluoroscopic irradiation. We also use a videodisc that records ont to 15 still-frames per second and can be replayed for evaluation at slower frame rates or as single frames.

Cervical Esophageal Disorders

Many of the problems involving the intrathoracic portion of the esophagus that produce swallowing disturbances are, for want of space, outside the scope of this communication. Laryngotracheoesophageal cleft and pharyngeal diverticulum are two uncommon congenital lesions that pose considerable diagnostic difficulty. Pharyngeal diverticulum may simulate esophageal atresia clinically but can be demonstrated by an esophagogram. It is likely that some reported "congenital" diverticula actually were unrecognized traumatic pseudodiverticula. Laryngotracheoesophageal cleft both clinically and radiographically mimics H-type tracheoesophageal fistula. Barium inundating the trachea through the cleft makes esophagography difficult and somewhat hazardous. The endoscopist hardly fares better, many clefts having been missed on laryngoscopy. Felman and Talbert recommend esophagography with an endotracheal tube in place.

By far the most common acquired lesion of the esophagus is an impacted foreign body. Whenever an ingested foreign body is suspected we obtain radiographs to include the entire alimentary tract from mouth to rectum. If these do not reveal an opaque foreign body, and signs and symptoms persist, an esophagogram is performed. The three sites where esophageal foreign bodies most often lodge are the thoracic inlet, the indentation on the esophagus produced by the left main bronchus, and the diaphragmatic hiatus. Sharp objects often catch in the pyriform sinuses. Some radiologists use an inflated Foley cather technique to extract blunt foreign bodies from the esophagus, but our surgeons prefer endoscopic extraction.

Acquired stricture of the esophagus may result from ingested caustics or from peptic reflux esophagitis. Food or other swallowed objects impacting at a stricture can acutely obstruct the esophagus. The location and extent of strictures, and the effect of therapeutic esophageal dilatation, are well evaluated by barium esophagography. We use water-soluble contrast media only when esophageal perforation is suspected.

A *traumatic pseudodiverticulum* results from laceration of the posterior pharyngeal wall, often by instrumentation such as forceful passage of a nasogastric tube. There may be an associated cricopharyngeal spasm identical to neurogenic cricopharyngeal achalasia.

Retropharyngeal abscess widens the prevertebral soft tissues in the lateral view of the nasopharynx. Either flexion of the neck or the expiratory phase of respiration may produce considerable forward bulging of the prevertebral soft tissues in the normal infant. An equivocal finding may be resolved by repeating the radiograph with careful attention to good inspiration and extension of the neck, or by having the child swallow a small amount of barium under video fluoroscopic observation.

The barium esophagogram is the key to radiographic evaluation of swallowing disorders, regardless of the suspected cause. The single exception is a radiopaque foreign body identified on plain films, for which an esophagogram is superfluous. However, if a foreign body has lodged in an unusual location it is prudent following removal of the object to obtain an esophagogram which may reveal an unsuspected stricture.

Soft Tissue Masses in the Neck

Whether or not to evaluate soft tissue swelling in the neck with radiography is a decision that must be based on clinical circumstances. In most instances of superficial soft tissue inflammation or lymphadenopathy there is little to be gained from plain radiographs. However, with soft tissue swellings or masses of less certain etiology, or those obstructing the airway by extrinsic compression, radiographs and other imaging modalities may give useful information. The displacement of normal air-filled structures in frontal and lateral radiographs of the neck may indicate the extent of soft tissue masses. Contrast medium given by mouth will show if the cervical esohagus or hypopharyngeal structures are displaced. Cystic hygroma, ectopic goiter, teratoma, lymphadenopathy, and neoplasms may produce radiographic widening of the prevertebral soft tissues indistinguishable from retropharyngeal abscess.

Computed tomography (CT) with intravenous contrast enhancement can indicate the vascularity of a lesion as well as demonstrate fat content or calcification that may not be apparent on plain radiographs. CT has proven useful for evaluating both laryngeal disorders and neck masses.

Most soft tissue masses in the neck are accessible to ultrasound, and state-of-the-ear instrumentation affords superb anatomic definition. Ultrasound is used widely for the evaluation of thyroid enlargement or nodules, but we believe that this modality is underutilized for cervical masses. Ultrasound delineates the size and cystic or solid nature of a mass without the potential radiation hazard of CT. Ultrasound might become valuable as the initial imaging procedure for cervical masses as it often is for abdominal masses.

An enlarged salvary gland is commonly subjected to radiographic assessment. Plain radiographs may show a salivary duct stone. Sialography, the injection of oily contrast medium into a salivary duct, can confirm a clinical diagnosis of sialadenitis or can outline a salivary gland tumour. Ultrasound of the salivary gland is potentially useful.

Complications of Tracheostomy: Radiographic Evaluation

Tracheostomy, one of the most ancient of operative procedures, has undergone dramatic improvements in technique as well as in cannula design and materials. Although the incidence of acute complications has decreased considerably in recent years, a substantial risk of late complications still exists following tracheostomy in infants and children. The combined incidence of tracheal stenosis and granuloma after tracheostomy ranges from 1.9 to 4.3 per vrny, but in a recent prospective study the incidence of tracheostomy-induced complications was 26 per cent.

After decannulation slight irregularities of the trachea can persist normally for about 4 weeks in infants and for as long as over a year in young children. Tracheal stenosis and granuloma can occur almost any time after tracheostomy; granulomas can grow slowly over a number of years. These obstructive lesions occur most commonly at two specific sites: the upper margins of the stoma and that place in the trachea where the distal tip of the tracheostomy tube rubs. Granuloma occurs most often at the superior anterior margin of the stoma. After decannulation, periodic follow-up radiographic evaluation is essential to confirm normal healing without complications.

The lateral radiographic view usually shows the findings to better advantage, although the AP view is also needed for complete evaluation. High kilovoltage (140 KVP) technique may improve visualization in the AP view. Xeroradiography can be of additional value because of its edge enhancement effect if the conventional radiographs show equivocal findings. Tracheobronchography is rarely indicated, and can best be done with tantalum powder for which one needs a license from the US Food and Drug Administration. Posttracheostomy tracheomalacia may occur with or without tracheal stenosis or granuloma. Video fluoroscopy is the best method to evaluate tracheomalacia. We suspect that the incidence of tracheomalacia is at least as high as that of the obstructive lesions, but the true incidence of segmental tracheomalacia following tracheostomy has not been adequately documented.

Voice Disorders

Video-velopharyngography (VVPG), a fluoroscopic examination recorded on videotape with simultaneous voice recording, is a most useful method of evaluating patients with speech problems. Adequate coordination of complex motions of the tongue, soft palate, and lateral pharyngeal walls is essential for normal speech. Closure of the velopharyngeal portal during phonation is the result of two types of motion: midsagittal velopharyngeal contact by elevation and posterior extension of the soft palate, and medial motion of localized regions of both lateral pharyngeal walls.

The VVPG is performed by a radiologist in close collaboration with the speech pathologist. Before starting, the VVPG is explained to and rehearsed with the patient, whose

full cooperation is essential in this examination. The standard procedure and observations are as follows: (1) Lateral view: the patient is positioned erect and gross anatomy of the facial bones and nasopharyngeal air passage are examined. (2) Injection of radiopaque contrast material: a barium mixture (approximately 120 volume per cent) is used to coat the pharyngeal mucosa. About 3 to 4 mL of the barium mixture is injected into each nostril with hyperextension of the neck to facilitate coating. (3) Frontal views: the patient is examined erect with the chin slightly up. Medial movement of the lateral pharyngeal walls is examined. Symmetric approximation of the upper part of the lateral pharyngeal walls occurs in normal children. During swallowing of the pharynx completely contracts. (4) Lateral view: the size and configuration of barium-coated adenoids and soft palate are well examined in this projection. Complete closure of the velopharyngeal portal should occur during phonation of "P", "K", and "S" sounds. However, the medial motion of lateral pharyngeal walls may contribute to velopharyngeal closure even when velopharyngeal closure is incomplete in this projection. (5) Lateral hyperextension view: in this projection the velopharyngeal gap, if present, may be more pronounced. Passavant's ridge, a local protrusion of a portion of the posterior pharyngeal wall, can be seen well in this position. (6) Basilar view: the patient is placed prone and the neck and head are hyperextended to obtain a tangential projection at the level of velopharyngeal closure. Either a circular or an oval shaped velopharyngeal approximation may be observed depending upon which motion, transverse or sagittal, is mainly responsible for its closure. This view is the most important for evaluation of patients with cleft palate who have had pharyngeal flap surgery, because the velopharyngeal openings are lateral to the flap and are demonstrated only in this projection.

The consultative discussion might include, in addition to the radiologist and speech pathologist, the pediatrician, the plastic surgeon, and the otolaryngologist.

Radiographic Evaluation of the Paranasal Sinuses

The paranasal sinuses (PNS) are pneumatized cavities which communicate with the nasal cavities and are lined by respiratory epithelium. The maxillary and ethmoidal sinuses, although small, are fully developed at birth. By three years of age the maxillary sinuses may be as large as 2 mL in volume and radiologic evaluation is feasible. The frontal sinuses begin their ascent into the frontal bone at two years, reach the nasion at three years, and become radiographically visible at six years of age. They are not fully developed until adolescence. The frontal sinuses may be absent or hypoplastic in a few normal children. The sphenoidal sinuses begin to pneumatize between two to six years and are fully developed at adolescence. Like the frontal sinuses, the sphenoidal sinuses are commonly asymmetric and septated.

The conventional radiographic examination of the PNS is the simplest, least expensive, and most practical examination. It includes the frontal (Caldwell), occipitomental (Waters), and lateral erect views. The basal (submentovertex, axial) view is done on selected patients whose ethmoidal or sphenoidal sinuses are equivocally abnormal in the routine views. A reverse Waters view is performed in children younger than five years. The techniques for all these views are described by Darling. Limitation of space does not allow a detailed description of normal radiographic anatomy.

The interpretation of PNS radiographs in children younger than three years is limited by the smallsize, nonpneumatization, redundancy of mucosal lining, or presence of tears in

the maxillary sinuses. These limitations are compounded by superimposition of roentgen images. Thin section tomography (TST) is a radiographic method which allows examination of a thin body section. This modality has tremendously enhanced knowledge of both normal and abnormal roentgen anatomy and supplements the features that are seen on the plain radiographs. TST is closely monitored by a radiologist who should know the clinical problem prior to the examination. Leaded eyeglasses are used on all patients (whenever possible) to reduce eye lens irradiation. The indications for TST are: (1) to further define an obscure abnormal finding suspected on plain radiographs; (2) to define the extent of injury in multiple facial fractures; (3) to evaluate congenital anomalies; (4) to determine the size and extent of a tumor in relation to adjacent structures; and (5) to evaluate postoperative changes, tumor recurrence, and efficacy of treatment.

The radiographic signs of PNS disease include variable degrees of opacification, mucosal thickening, air-fluid levels, bony erosion, mass lesion (solid or cystic), foreign body, calcification, and fracture. Meaningful interpretation of these roentgen findings rests on correlation with the clinical signs and symptoms.

Congenital Anomalies

Congenital anomalies of the PNS are usually associated with the first and second branchial arch syndromes (Treacher-Collins, cleft palate, and so on). Isolated hypoplasia or agenesis of the maxillary or ethmoidal sinuses are uncommon and can mimic mucosal thickening or opacification on the radiographs. Aplasia of sphenoidal sinuses is extremely rare. When pneumatization of the sphenoidal sinuses is not clearly shown on routine radiographs in patients with nonspecific intracranial symptoms, TST is indicated.

Infections

Sinusitis, the most common PNS disease in children, is an inflammation of the sinus mucosal lining which is continuous with the nasal cavity. The maxillary and ethmoidal sinuses are the most commonly involved, singly or in combination. The radiographic findings of variable degrees of opacification, air-fluid levels, or mucosal thickening are not specific for sinusitis. Correlation with the clinical findings is necessary for a definitive diagnosis.

The maxillary sinuses are closely related to dentition. Unerupted molars can mimic masses, partial opacification, or air-fluid levels in the antra. In older childeren, maxillary sinusitis may result from extension of an alveolar abscess. Orthopanographic examination is an excellent diagnostic aid.

Homogeneous opacification of the maxillary and ethmoidal sinuses is an almost constant finding in patients with cystic fibrosis. This may be caused by tenacious secretions, mucosal redundancy, infection, or by polyps obstructing the ostia.

Acute ethmoidal sinusitis is a major cause of periorbital cellulitis and orbital abscess. The plain radiographic finding of diffuse opacification of the ethmoidal and/or maxillary sinuses associated with the characteristic clinical findings (lid edema, proptosis, ophthalmoplegia, and abnormal vision) are sufficient to make the diagnosis. However, TST

and CT are extremely helpful in demonstrating the site and extent of subperiosteal abscess or extension into the intracranial structures.

Acute frontal sinusitis, more commonly seen in older chiledren, is an important disease because of the high incidence of intracranial extension. The mucoperiosteal borders and air and fluid content should be carefully evaluated. CT is the method of choice to evaluate intracranial extension.

Isolated infection of the sphenoidal sinuses is rare but sphenoidal involvement in pansinusitis is not uncommon. The vital structures around the sphenoidal sinus make early diagnosis of sphenoidal sinus disease extremely important. Air-fluid levels in the sphenoidal sinuses may occur in infection, posttraumatic hemorrhage, or from accumulated secretions during prolonged recumbency.

Overgrowth of the paranasal sinuses is a common finding in patients with mental retardation. It is also seen after ventriculoperitoneal shunting. Unilateral overgrowth of the sinuses is a characteristic finding in patients with Dyke-Davidoff syndrome (unilateral cerebral atrophy with ipsilateral thickening of diploic space, hypertrophy of PNS, and elevation of petrous bone).

Tumors

A soft tissue mass in a PNS may be either a polyp or a mucous retention cyst. A polyp may obstruct the ostium or cause bony erosion. TST is indicated for evaluation of the extent of bony abnormality before surgery. Polyps occur in 10 to 30 per cent of patients with cystic fibrosis. Mucous retention cysts are very common in children. These cysts frequently occur at the floor and occasionally at the roof of a maxillary sinus. In the Waters view retention cysts appear as semicircular shadows of increased density without associated bony destruction.

A primary neoplasm of the PNS is extremely rare in children. Malignant neoplasms, such as lymphoepithelioma, rhabdomyosarcoma, and lymphosarcoma may invade the sinuses. The plain radiographic findings include a soft tissue mass, erosion of adjacent bone, and sclerosis. TST and CT usually define the size of the neoplasm and the extent of bone destruction. Nonmalignant diseases such as anterior meningocele, Wegener's granulomatosis, mucormycosis, and juvenile nasopharyngeal angiofibroma can invade the PNS and deform or destroy their walls.

Fractures

Maxillofacial trauma in children differs from that in adults. Unerupted and mixed dentition gives stability and elasticity to the facial bones, thus greater force is required to fracture these bones. Multiple fractures should be carefully looked for.

Blowout fracture is a result of a blow to the orbit transmitting force to the globe and increasing intraorbital pressure. The weakest point in the orbital wall is the floor medial to the infraorbital foramen. Fracture at this point may permit herniation of the orbital contents into the maxillary sinus. Clinical signs are ecchymosis, diplopia, and ophthalmoplegia. The

plain radiographic findings are a soft tissue mass in the antral roof, haziness of the maxillary sinus owing to overlying soft tissue swelling or hemorrhage into the sinus, and fracture. Tomography is usually done to define a fracture when one is not clearly shown on plain radiographs.

The Le Fort classification of multiple facial fractures is very useful. Plain radiographic examination is limited because of marked soft tissue swelling or hematoma. TST defines the fractures and displacement of fragments.

Maxillary Sinus Ultrasound

A few reports have indicated that A-mode ultrasound is useful for detecting the presence of fluid in the maxillary sinuses. An investigation currently underway will correlate clinical, radiographic, and sonographic findings with the bacteriologic data from sinus aspirates in children suspected of having maxillary sinusitis (see discussion by Wald et al elsewhere in this issue). In our first 44 subjects, sinuses that were completely opaque on radiographs have invariably produced an abnormal ultrasound pattern but we have not yet established any other meaningful correlations. Several pitfalls in sinus sonography have surfaced. A few patients with mucosal thickening on radiographs and positive aspirates have had no discernible sonographic abnormality. Technical sources of error abound and we have had difficulty distinguishing normal from abnormal ultrasound patterns in young children. Any conclusions regarding the value of ultrasound for evaluating children's maxillary sinuses must await further experience with the method.

Radiologic Evaluation of Hearing Disorders and Related Problems

Congenital Anomalies

Detailed clinical evaluation and various audiologic tests are supplemented by TST. In preoperative evaluation of congenital abnormalities patency of the external auditory canal, the size of the tympanic cavity, integrity of the ossicular chain, course of the facial nerve canal, and presence of the internal ear structures are necessary information. Fitz and Harwood-Nash listed 20 syndromes associated with temporal bone anomalies. Membranous anomalies of the inner ear cannot be identified on radiographs. The type of hearing loss (conductive, neurosensory, or combined) is important information to the radiologist evaluating the radiographic findings.

Infections

Infection is the most common cause of acquired hearing loss in children. Serous otitis media, acute suppurative otitis media, and mastoiditis may produce abnormal findings on plain radiographs (Towne, Laws, Stenvers, and lateral nasopharyngeal views). The degree of mastoid cell pneumatization, presence of bony erosion in the epitympanic space, and size of the adenoids are important findings. Enlarged adenoids can obstruct the upper airway and eustachian tube. Obstruction of the latter can cause serous otitis media. The anterior and inferior margins of the adenoidal mass are well outlined by air on a lateral nasopharyngeal radiograph. Adenoidal-nasopharyngeal (AN) ratio is a simple and accurate method to objectively evaluate adenoid size. An AN ratio above 0.80 indicates enlarged adenoids.

Chronic otitis media with secondarily acquired cholesteatoma is best evaluated with TST. The characteristic findings are destruction of the attic spur (scutum) and lateral attic wall, haziness (with or without soft tissue mass) in the tympanic cavity, and destruction or displacement of the ossicles. In chronic ear infections, complications such as brain abscess, otitic meningitis, Gradenigo syndrome, and dural sinus thrombosis are evaluated with TST or CT scan. Repeated episodes of meningitis may be caused by a fistula in the oval window, CSF leak caused by trauma, or chronic mastoiditis.

Trauma

Clinically, fractures involving the temporal bones present with bleeding from the ears, CSF otorrhea, hearing loss, facial nerve paralysis, or Battle's sign. The two kinds of temporal bone fractures are longitudinal (85 to 90 per cent) and transverse (10 to 15 per cent). Longitudinal fractures lie parallel to the petrous bone and involve the ossicles and walls of the external auditory canal and tympanic cavity. These fractures are best seen in the lateral tomogram. Transverse fractures lie transversely through the axis of the petrous bone and usually result from a direct blow to the occiput and severe trauma to the anterior and middle cranial fossae. The internal ear structures bear the brunt of temporal bone trauma and are best seen in the frontal tomogram.

The plain radiographic findings are opaque mastoid air cells, diastasis of the lambdoid or occipitomastoid sutures, and a fracture line. TST in two projections is indicated. In the frontal tomogram decreased air content in the external auditory canal and tympanic cavity, ossicular chain disruption, or radiolucent defects in the tegmen tympani or inner ear structures indicate presence of a fracture. In the lateral tomogram, fracture of the external auditory canal wall, ossicular disruption, and opacity or soft tissue mass in the tympanic cavity are characteristic findings. When facial nerve paralysis is present the facial nerve canal should be evaluated in both views.

Tumors

Deafness caused by temporal bone tumors is rare in children. Acoustic neuroma, histiocytosis X, rhabdomyosarcoma, and epidermoid cyst are the four major tumors that affect the temporal bone. Definitive diagnosis of these lesions rests on histologic examination. The plain radiographic findings of acoustic neuroma include asymmetry (difference of more than 2 mm in height) of the internal auditory canal (IAC), erosion of the IAC's porus acusticus, and sclerosis around the IAC. A small extracanalicular acoustic neuroma may produce subtle changes around the porus acusticus. Thin section tomography and/or CT increase the diagnostic accuracy. The findings on CT are mass of increased density in the cerebellopontine angle, obliteration and displacement of the fourt ventricle, and widened cisternal angle. More sophisticated CT equipment may obviate the use of invasive procedures such as arteriography, posterior fossa myelography, and amipaque CT cisternography in the future.

Eosinophilic granuloma affects the temporal bone in 25 per cent of the cases. On plain radiographs a radiolucent defect with no significant reactive sclerosis is seen as an isolated lesion in the petrous bone or as part of multiple skull lesions. Similar lesions may involvd the remainder of the skeleton.

Fifty per cent of embryonal rhabdomyosarcomas are located in the head and neck. Only 7 per cent of these affect the ear. This neoplasm commonly masquerades as chronic otitis media, inflammatory polyp, or granulation tissue in the external or middle ear. Plain radiographs may be normal. TST shows mass effect and bony erosion, and CT shows a contrast-enhancing mass.

Epidermoid cysts are commonly located inthe midline but those that are laterally located involve the base of the brain or temporal bone. These are round masses or cysts lined by epithelial tissues. On plain radiography, they appear as round radiolucent defects with sclerotic borders. CT is valuable in demonstrating extension of the cyst into the intracranial structures. The major CT finding is a mass that does not enhance with intravenous contrast medium.