Advances in ENT Imaging

I Zammit-Maempel

Over the last ten years or so radiology has shown dramatic technological developments especially in cross sectional imaging and the investigation and management of the complex ENT patient has benefitted enormously.

Plain radiographs are being utilised less and less as their limitations are becoming more apparent and various studies have shown for example a 75% discrepancy between plain sinus radiographs and coronal sinus CT in children[1,2].

Ultrasound

Developments in ultrasound technology have allowed images of extremely high quality and the relative low cost of these machines, availability and absence of any known side effects has resulted in ultrasound forming the initial investigation of masses in the neck.

High-resolution ultrasound is more sensitive in detecting malignant cervical adenopathy than clinical examination (92% vs 70%)[3] and has high specificity when combined with fine needle aspiration cytology (92.7%). Grey scale ultrasound allows evaluation of nodal morphology, internal architecture, shape and size. The development of power doppler has allowed reliable assessment of intranodal vascularity and thereby differentiation of benign from malignant cervical lymphadenopathy with a high degree of accuracy. Reactive nodes tend to have prominent hilar vascularity. Malignant nodes have a more variable vascular pattern with one or more of avascular areas, displacement of vessels, increased peripheral vessels and aberrant course of hilar vessels. Although malignant nodes have higher Resistive Index and Pulsatility Index values compared to benign nodes, the considerable overlap of these values in benign and malignant pathology renders them to be of limited use[4].

I Zammit-Maempel MB ChB, MRCP, FRCR
Consultant Radiologist
Freeman Hospital, Newcastle Upon Tyne, UK

Email: karzm@yahoo.com

The incorporation of small and flexible ultrasound transducers with high-resolution imaging into the tips of endoluminal catheters has allowed good quality endoluminal ultrasound. Recently endolaryngeal ultrasound has been clinically evaluated in 38 patients with a variety of laryngeal pathology including vocal fold polyps, laryngeal cysts, chronic laryngitis, epithelial dysplasia and cancer[5]. Using this technique tumour size and infiltration could be measured and involvement of the thyroid cartilage or anterior commissure could be visualised. Not surprisingly it was not able to detect any specific changes in the sonographic picture of patients suffering from chronic laryngitis, epithelial dysplasia or microinvasive cancer. Although these results are encouraging, its relative lack of availability will result in it only having a limited role in evaluating laryngeal pathology.

Computed Tomography (CT)

CT has shown enormous development since the original images obtained by Hounsfield in the early 1970s. In the mid 1980s, slip ring technology was developed allowing CT scanners to rotate continuously and thereby allow spiral or helical scanning. As a result a volume of data is acquired and this can then be reconstructed to provide multiplanar and 3 dimensional images. In 1998 multi-slice CT scanners, that use multiple detector rows and therefore acquire multiple slices per rotation, were introduced resulting in more speed, volume and detail. CT has proved particularly useful in sinus and middle ear disease as well as evaluating the skull base in combination with MRI.

There has been an increased demand for imaging the paranasal sinuses with coronal CT (Figure 1) because of Functional Endoscopic Sinus Surgery (FESS) where a road map of the sinus anatomy and extent of disease is an essential pre-operative investigation. This has resulted in the virtual demise of plain radiographs, which do not offer any detail of the osteomeatal complex or of potential surgical hazards. As sinus CT involves imaging high contrast structures such as air, bone and soft tissue, adequate image quality can be achieved using relative low dose techniques and thereby impart a low dose to the eye lens[6]. When using a low mAs technique on a spiral scanner the lens dose should not exceed 10mGy, a dose that is considerably less than that necessary to cause lens opacification (0.5-2Gy) while the thyroid gland dose at around 0.5mGy is minimal[7,8]. The initial single slice helical scanners allowed axially acquired data to be reconstructed coronally but were inferior to direct coronal images because of step artefacts within

the fine osseous structures[9]. The advent of multi-slice CT has allowed the option of isotropic imaging of the paranasal sinuses in the axial plane and the data then viewed in the coronal and sagittal planes with no loss of detail (Figure 2a&b). This is beneficial to patients who need not adopt the uncomfortable coronal position, cuts out artefact from dental amalgam and allows reproducible follow up images. It however results in a large amount of data that has to be post processed and a longer time to be reviewed and a larger radiation burden. The sagittal plane provides useful anatomical information and in particular shows detailed imaging of the frontal recess, a region that cannot be included entirely within a single coronal section. A further advantage of multislice and high specification single slice helical scanner technology is the use of virtual endoscopy reconstruction software on workstations to obtain virtual endoscopy images. This has been evaluated clinically in the cases of paranasal sinus mucocoeles in deciding puncture sites through an endonasal approach[10] and by providing detailed surgical landmarks, could potentially reduce the complication rate of FESS. Moreover, there are now surgical navigation systems on the market that provide real time intra-operative navigation via a computer generated virtual reality representation of the patient derived from archival high resolution CT images. These navigation systems are not, however, widely used clinically at present, as they are still expensive and really no substitute for a thorough anatomical knowledge.

CT has proved useful in detecting complications following FESS, in particular CSF leaks when the integrity of the cribriform plate, lateral lamella (at which site the anterior ethmoidal artery enters the olfactory fossa), fovea ethmoidalis, lamina papyracea, anterior skull fossa and skull base should be carefully evaluated. CT has a role in diagnosing complications of sinusitis such as subperiosteal and other orbital abscesses as well as intracranial complications.

Axial CT is the imaging modality of choice for diagnosing choanal stenosis / atresia while CT in both the axial and coronal planes can prove to be a useful tool in the imaging of the nasal cavity and nasal masses[11].

Figure 1: *Direct coronal CT of the paranasal sinuses showing widespread nasal polyposis and a pansinusitis.*

High resolution spiral CT allows exceptional detail of the middle ear cleft and is particularly useful in evaluating children with congenital ear disease e.g. outer and inner ear anomalies, the complications of cholesteatoma (Figure 3) and in the preoperative evaluation of suitability for cochlea implantation. CT is also the optimal imaging modality for the assessment of traumatic injuries to the petrous temporal bone, which occur in approximately 20% of patients injured in a major road traffic accident.

Clinical staging of head and neck cancer is upstaged by imaging and the speed of current scanners and the ability to scan the thorax for a synchronous primary at the same sitting has made CT the initial choice for the staging of laryngeal and hypopharyngeal tumours.
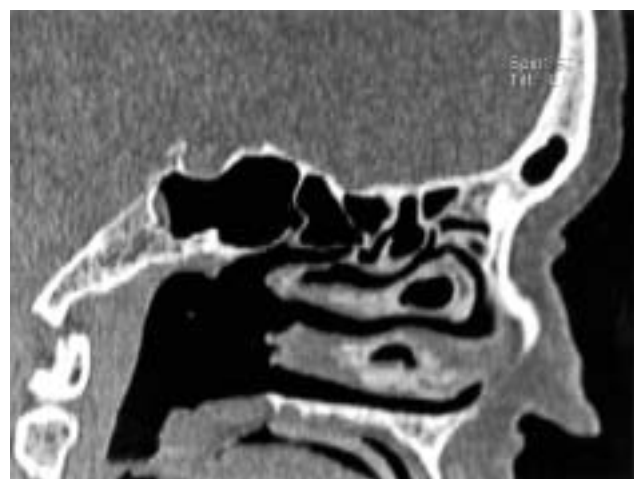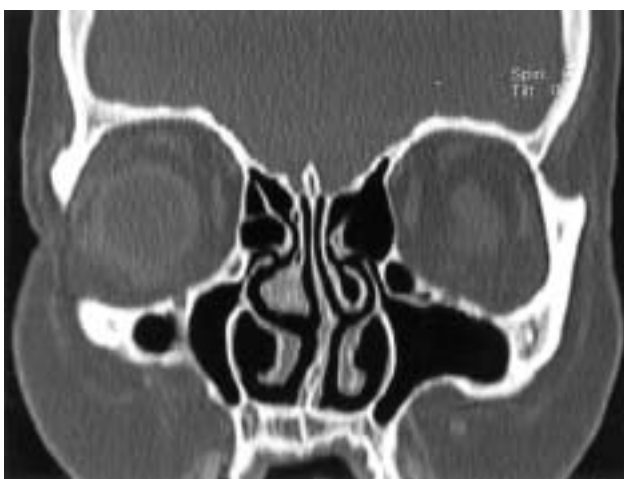

Figure 2: *Coronal (a) and sagittal (b) CT sinus reconstructions of axially acquired raw data using a multi-slice CT scanner. Note little difference in image quality compared to the directly acquired coronal image in Figure 1.*

Figure 3: Coronal CT of the middle ears showing a left cholesteatoma with erosion of the scutum and ossicles. Also note a partially dehiscent tegmen tympani.

Magnetic Resonance Imaging

MRI has revolutionised the study of soft tissue structures in the brain and neck by providing images with a detail comparable to anatomical textbooks. A great advantage of MRI is that it does not use ionising radiation and has no known side effects. There are however some contraindications to MRI including pacemakers, certain heart valves, aneurysm clips, cochlear implants and metallic foreign bodies, especially in the orbit.

The MR signal is produced by anatomic nuclei with an odd number of protons e.g. Hydrogen, Sodium and Phosphorous, which act as bar magnets. When placed in a static magnetic field, application of a radiofrequency pulse can induce resonance in particular sets of nuclei. Release of energy occurs as the RF pulse is turned off and is detected by a receiving coil and converted to an electrical signal, which provides data for a digital image. This relaxation time of nuclei in structures such as lipids, protein and water molecules are different, allowing the major anatomical distinctions to be made. Pathological conditions alter the relaxation times and tissue characteristics, making it possible to identify and describe the presence of diseased states. MR has at least ten tissue parameters which may contribute to an image. The two most frequently used tissue parameters are the T1 and T2 relaxation times. T1-weighted images show excellent anatomical detail while T2-weighted images are more sensitive in detection of pathology. Intravenously administered contrast agents with para-magnetic properties e.g. Gadolinium DTPA provide further differentiation in tissue characterisation and are frequently used in ENT imaging. The heart of a MRI system is a magnet, which provides a homogeneous static magnetic field. Higher field strength systems allow faster scan times and images with a greater signal to noise ratio.

MRI has proved extremely useful in the diagnosis of acoustic neuroma and has largely replaced other radiological and clinical investigations. Smaller tumours which are missed with contrast enhanced CT are detected by MRI (Figure 4a&b) leading to earlier surgical intervention with improved rates of hearing preservation. The great debate in the MR imaging of acoustic neuroma is currently whether intravenous (iv) gadolinium is necessary in all cases. Although optimal MRI protocols for the detection of acoustic neuroma include IV gadolinium, considerable savings in cost and time and thereby throughput can be achieved if a screening strategy limiting the use of contrast was
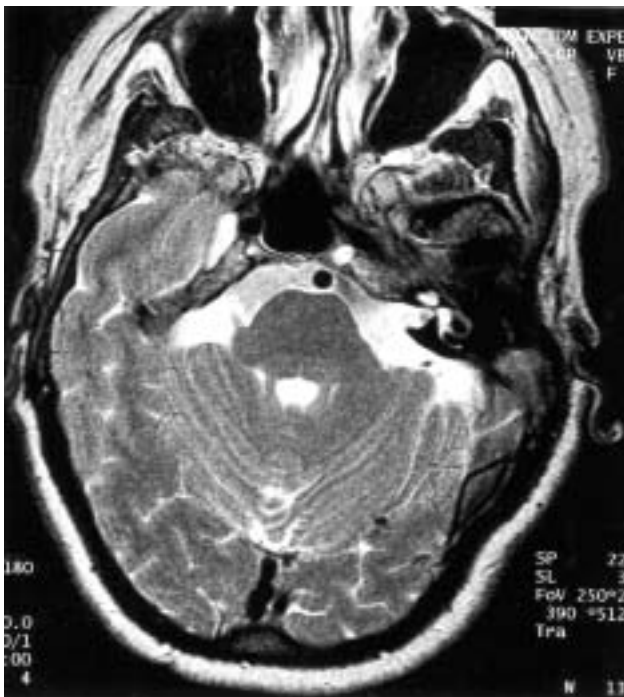

Figure 4: a) FSE T2-weighted axial MRI showing 3mm mass in left IAM; b) T1-weighted axial post gadolinium image showing intense enhancement of this small intracanalicular acoustic neuroma.
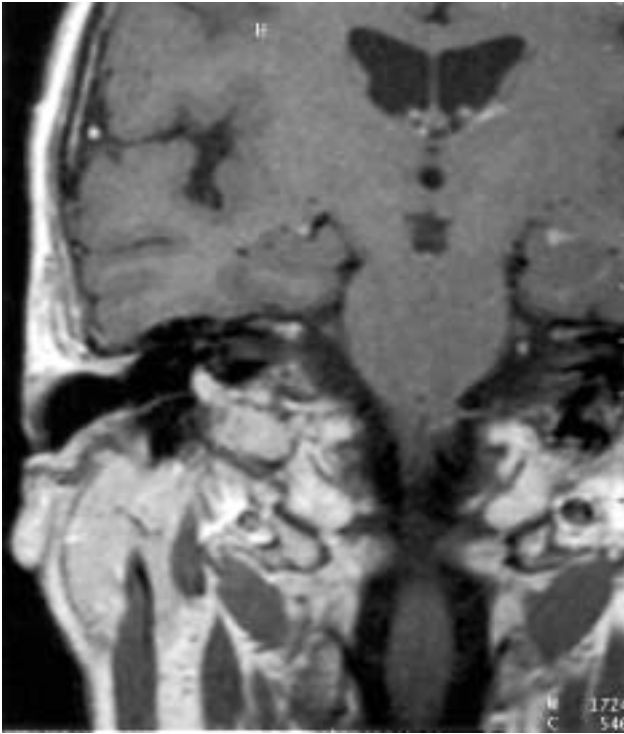
Figure 5: *T1-weighted post gadolinium coronal MRI showing a right glomus jugulare tumour with extension into the middle ear.*

shown to be effective.

Thin section fast spin echo (FSE) T2-weighted sequences are capable of clearly demonstrating the auditory nerves in their entire length from the internal auditory canal to the upper medulla and several small studies [12-16] have advocated the use of this unenhanced sequence as a screening tool for diagnosing acoustic neuroma. In a variable percentage of patients, however, partial volume artefact and CSF flow artefact result in the inability to definitely exclude a small intracanalicular acoustic neuroma. In fact Zealley et al[17] in a large series of patients showed that only 59% of acoustic neuromas could be confidently identified with a 3mm fast spin echo sequence compared to gadolinium enhanced images. However in their series no tumours were identified on contrast enhanced images where the fast spin echo sequence was thought to be definitely normal. The authors concluded that contrast could be restricted to patients where fast spin echo images do not exclude acoustic neuroma but this strategy would require continuous supervision by an experienced radiologist. Moreover, the authors emphasise that this strategy may fail to identify some other causes of abnormal enhancement, apart from acoustic neuroma, that may mimic this tumour in their clinical presentation. Gillespie[18] advocates using a 3D T2-weighted fast spin echo sequence and reconstructing 2mm slices every 1mm. With this technique he claims consistent visualisation of both nerves within the internal auditory meatus without resorting to intravenous contrast. It is likely that the decision to give intravenous gadolinium will vary from department to another depending on the strength of magnet and local discussions between
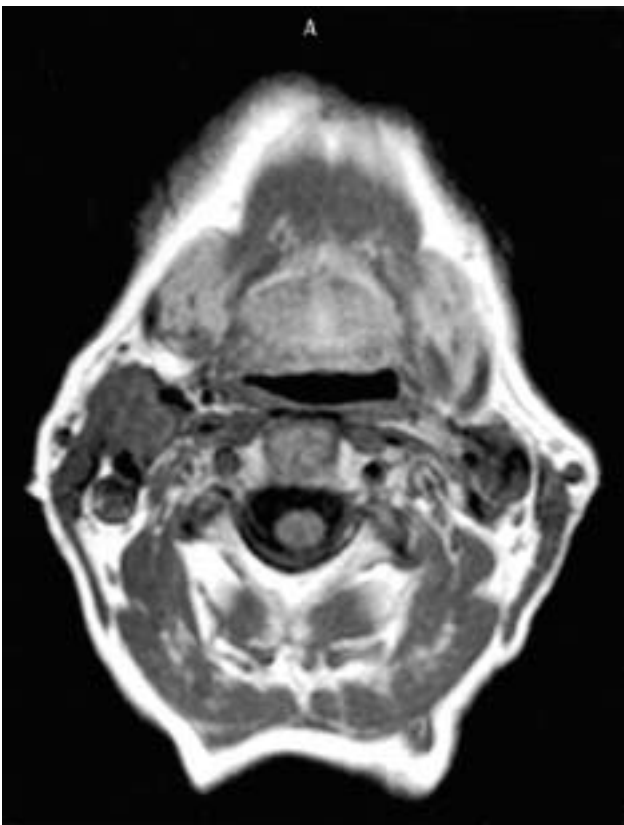

Figure 6: *a) T1-weighted axial MRI showing a right carotid body tumour; b) MR Angiogram showing splaying of the right internal and external carotid arteries by this carotid body tumour.*

radiologists and clinicians.

MRI is also useful in diagnosing petrous bone paragangliomas, highly vascular tumours that arise either in the middle ear adjacent to the cochlear promontory (glomus tympanicum) or in the jugular bulb (glomus jugulare). Often these latter tumours extend into the middle ear (Figure 5) and present with pulsatile tinnitus. High resolution CT is often combined with MRI for full evaluation of these tumours. The most common paraganglioma in the neck is the carotid body tumour, which is characteristically located at the bifurcation of the common carotid artery (Figure 6a). Magnetic Resonance Angiography without the use of any gadolinium will elegantly show splaying of the internal and external carotid arteries (Figure 6b) by such tumours.

Positron Emission Tomography (PET)

PET is a functional imaging modality that can demonstrate difference in tissue metabolism. It makes use of radionuclides that decay with emission of positively charged particles (positrons). These positrons travel short distances in tissue before combining with a negatively charged electron, converting mass into energy and releasing two high energy photons (gamma rays) which are emitted at approximately 180 degrees to each other. The simultaneous detection of these photons by opposing detectors is then used to reconstruct a three dimensional image of these events, the PET scan. The radionuclide labelled tracer can be used to measure different aspects of tissue function such as distribution of blood flow, oxygen utilisation, protein synthesis and glucose consumption. Cancer cells have increased glucose metabolism and the radionuclide labelled analogue of glucose, 2-(18F) fluoro-2-deoxy-D-glucose (FDG) can be used to investigate tumours in vivo by exploiting the increased glucose metabolism of malignant cells as compared to normal tissue.

PET scanning, previously regarded as a research tool, now has a significant role to play in the head and neck cancer patient especially in patients with an unknown primary presenting with cervical adenopathy and in the diagnosis of recurrent cancer in the post treatment neck[19-21]. The problems with PET is its difficulty in precisely localising lesions owing to paucity of anatomical references, current resolution of 5- 6mm and diagnostic pitfalls in the supraglottic region due to FDG secreted in saliva falsely elevating background activity.

Conclusion

Imaging techniques in ENT have advanced considerably over the last few years, allowing a wider diagnostic armamentarium and anatomical detail second to none. It is likely that the next few years will result in faster multislice CT scanners, better hardware and software in MRI and the proliferation of PET scanners, further enhancing ENT imaging.

References

1. McAlister WH, Lusk R, Muntz HR. Comparison of plain radiographs and coronal CT in infants and children with recurrent sinusitis. AJR 1989; 153: 1259-1264.
2. Lazar RH, Younis RT, Parvey LS. Comparison of plain radiographs and coronal CT and intraopertative findings in infants and children with chronic sinusitis. Otolaryngol Head Neck Surg 1992; 107(1): 29-34.
3. Bruneton JN, Roux P, Caramella E et al. Ear, nose and throat cancer: ultrasound diagnosis of metastasis to cervical nodes. Radiology 1984; 152: 771-3.
4. Ahuja A, Ying M, Ho S, Metreweli C. Distribution of intranodal vessels in differentiating benign from metastatic neck nodes. Clin Radiol 2001; 56: 197-201.
5. Arens C, Glanz H. Endoscopic high frequency ultrasound of the larynx. Eur. Arch Otolaryngol 1999; 256: 316-322.
6. Sohaib SA, Peppercorn PD, Horrocks JA et al. The effect of decreasing mAs on image quality and patient dose in sinus CT. Br J Radiol 2001; 74: 157-161.
7. Maclennan AC. Radiation dose to the lens from coronal CT scanning of the sinuses. Clin Rad 1995; 50: 265-267.
8. Zammit-Maempel I. Radiation dose to the lens of the eye and thyroid gland from coronal sinus CT. Br J Radiol Cong Supp 1996; 69: 191.
9. Bernhardt TM, Rapp-Bernhardt U, Fessel A et al. CT scanning of the paranasal sinuses: Axial helical CT with reconstruction in the coronal direction versus coronal helical CT. Br J Radiol 1998; 71: 846-851.
10. Nakasato T, Katoh K, Ehara S et al. Virtual CT endoscopy in determining safe surgical entrance points for paranasal mucoceles. J Comput Assist Tomogr 2000; 24(3): 486-492.
11. Grainger AJ, Zammit-Maempel I. Pictorial review. CT of unusual nasal masses. Br J Radiol 1999; 72: 313-316.
12. Renowden SA, Anslow P. The effective use of Magnetic Resonance Imaging in the diagnosis of acoustic neuroma. Clin Radiol 1993; 48: 25-8.
13. Phelps PD. Fast spin echo MRI in otology. J Laryngol Otol 1994; 108: 383-94.
14. Shelton C, Harnsberger HR, Allen R, King B. Fast spin echo magnetic resonance imaging: clinical application in screening for acoustic neuroma. Otolaryngol Head Neck surg 1996; 114: 71-6.
15. Allen RW, Harnsberger HR, Shelton C et al. Low-cost high-resolution fast spin –echo MR of acoustic schwannoma: an alternative to enhanced conventional spin-echo MR? Am J Neuroradiol 1996; 17: 1205-10.
16. Fukui MB, Weissman JL, Curtin HD, Kanal E. T2-weighted MR characteristics of internal auditory canal masses. Am J Neuroradiol 1996; 17: 1211-8.
17. Zealley IA, Cooper RC, Clifford KMA et al. MRI screening for acoustic neuroma: a comparison of fast spin echo and contrast enhanced imaging in 1233 patients. Br J Radiol 2000; 73: 242-247.
18. Gillespie JE. MRI screening for acoustic neuroma. Br J Radiol 2000; 73: 1129.
19. Wong W-L, Chevretton EB, McGurk M et al. A prospective study of PET-FDG imaging for the assessment of head and neck squamous cell carcinoma. Clin Otolaryngol 1997; 22: 209-214.
20. Paulus P, Sambon A, Vivegnis D et al. [18]FDG-PET for the assessment of primary head and neck tumours: clinical, computed tomography and histopatholgical correlation in 38 patients. Laryngoscope 1998; 108: 1578-1583.
21. Hanasono MM, Kunda LD, Segall GM, Ku GH, Terris DJ. Uses and limitations of FDG positron emission tomography in patients with head and neck cancer. Laryngoscope 1999; 109: 880-885.