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Review Article

Lateral skull base surgery: a complicated pursuit?

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Abstract

The management of lesions of the lateral skull base is a highly sophisticated branch of surgery generally performed by otolaryngology–head and neck surgeons as part of a multi-disciplinary team. Assessment of patients with diseases affecting the lateral skull base can be complex, as can the application of the various treatment modalities and the management of the expected and unexpected side effects of that treatment.

A wide range of pathological conditions occur in the lateral skull base. Many operations and procedures have been described for dealing with them. There is not necessarily one correct solution to the management of any particular problem in the skull base, with multiple factors to be considered in planning and intervention.

As surgeons, we need to know how our own results and outcomes compare with pooled, published data concerning the implications and complications occurring as a result of intervention, in order to better advise our patients on their management.

Key words: Skull Base Surgery; Skull Base Neoplasm; Disease Management; Surgical Procedures

Introduction

The management of lesions of the lateral skull base is a highly sophisticated branch of surgery performed by otolaryngology–head and neck surgeons who have undertaken further specialist training. It is frequently undertaken in collaboration with other surgeons, particularly neurosurgeons and plastic and reconstructive surgeons.

Assessment of patients with diseases affecting the lateral skull base can be complex, as can the application of the various treatment modalities, and dealing with the implications and complications of that treatment.

Scope of the subspecialty

Pathological conditions

The range of conditions that are seen in the lateral skull base is broad and includes those listed in Table I.

Disease staging

Staging of extent and severity of disease is undertaken in order to guide treatment and to give an indication of likely outcome and prognosis.

For example, when assessing glomus tumours (paragangliomas) involving the lateral skull base, there are two commonly used systems, that of Glasscock *et al.*[1] and that of Fisch and colleagues.[2,3] These are summarised in Tables II and III, respectively.

Both classifications look complicated; however, they are logical and give the treating surgeon a better understanding of the extent of disease and the scope of the intervention that will be required to manage it.

Since 1993, I have used a simplified summary of Professor Fisch's classification when teaching our otolaryngology–head and neck surgery trainees and introducing them to the lateral skull base and its complexities. This has given them a simpler starting point on which to build their understanding of paragangliomas. This summary is outlined in Table IV.

The staging of acoustic neuromas is predominantly related to size. The largest dimension of the tumour seen on axial or coronal magnetic resonance imaging (MRI) scans is most commonly used in assessment and reporting of this condition and its treatment.[4] Some clinicians include the internal auditory canal component in the maximum dimension and some do not. That component can be small or large and is always significant, whether considering observation, treatment or long term follow up.

Others assess the 'invasiveness' or degree of brainstem mass effect in order to stage these tumours.[5] The most accurate method is likely to be volumetric measurement of the whole tumour based on

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TABLE I

PATHOLOGICAL CONDITIONS AFFECTING THE LATERAL SKULL BASE

Congenital or hereditary
e.g. Encephalocoele into middle-ear cleft
Neuro-cutaneous disorders (neurofibromatosis types I & II)
Acquired
Infection (bacterial, fungal, viral, TB, parasitic)
– incl H zoster, H simplex
– Complications of suppurative otitis media
– Petrous bone cholesteatoma
– Petrous apicitis
– Skull base osteomyelitis
Inflammation (vasculitis, granuloma)
Trauma (penetrating, blunt)
Vascular (anomaly, aneurysm)
Tumour
– Benign
– Cranial nerve schwannoma, neuroma
  – Meningioma
  – Paraganglioma
  – Lipoma, adenoma, haemangioma
  – Other (epidermoid, cranial bone disorders)
– Malignant
  – Primary
    – SCC
    – Chordoma
    – Chondroma, chondrosarcoma
    – Endolymphatic sac Ca
    – Other
  – Secondary
    – Skin (SCC, BCC, melanoma)
    – Salivary
    – Distal metastatic (e.g. renal, breast)

TB = tuberculosis; incl = including; SCC = squamous cell carcinoma; Ca = carcinoma; BCC = basal cell carcinoma

multislice MRI scanning, used for initial assessment and follow up.[6] However, this has not yet been generally accepted. There is a need for an accurate system to be used universally. This will result in better documentation, communication and comparison of patients and cohorts of patients undergoing assessment and treatment, particularly regarding the reporting and publishing of these data.

Staging of primary malignant lesions of the temporal bone (although these are relatively uncommon) must also be considered. Staging systems for these tumours have been developed over many years. Modifications to these systems have been suggested in recent years, based on greater experience derived from treating larger series of patients.[7]

TABLE II

GLOMUS TUMOUR CLASSIFICATION, GLASSCOCK *ET AL.*[1]

Type	Site
Glomus tympanicum	
1	Limited to promontory
2	Filling middle-ear space
3	Filling ME & extending to mastoid
4	ME, mastoid & extending to EAC or anterior to ICA
*Glomus jugulare**	
1	Jugular bulb, ME & mastoid
2	Below IAC
3	Petrous apex
4	Clivus or infratemporal fossa

*Types 2 to 4 may have intracranial extension. ME = middle ear; EAC = external auditory canal; ICA = internal carotid artery; IAC = internal auditory canal

TABLE III

GLOMUS TUMOUR CLASSIFICATION, FISCH AND COLLEAGUES[2,3]

Type	Site
A	Confined to promontory
B	ME and mastoid (Jugular bulb & carotid canal intact)
C	Originate in jugular bulb
	C1 Into carotid canal only
	C2 Vertical carotid
	C3 Horizontal carotid
	C4 Beyond foramen lacerum
D	De (Extradural) <2 cm / >2 cm
	Di (Intradural) <2 cm / >2 cm / unresectable

ME = middle ear

Surgical procedures

A large number of surgical procedures have been described for the treatment of diseases of the lateral skull base. A number of classifications have been developed for these interventions. One such description is that from the Gruppo Otologico in Italy.[8] This is summarised in Table V. Although seemingly complicated, it is both logical and useful in surgical planning.

Whilst not all surgeons in the field will perform every one of these procedures, and their variations, there is a group of procedures which the lateral skull base surgeon must master. These can be thought of as the 'workhorse' techniques and include: subtotal petrosectomy; mastoid obliteration with blind sac closure and sealing of eustachian tube; translabyrinthine exposure of the internal auditory canal and posterior cranial fossa; facial nerve decompression and re-routing; infratemporal fossa dissection and upper cervical exposure of the great vessels and lower cranial nerves; and middle fossa exposure of the internal auditory canal and facial nerve.

Clinical presentation and screening investigation

Conditions that affect the lateral skull base generally present with the common symptoms of hearing loss, tinnitus, imbalance or vertigo, pain or discomfort. There is usually little in the history and examination to help distinguish patients with common minor ear conditions from those with more significant or sinister diagnoses. Cranial nerve palsies tend to develop slowly. Patients will often present only when these

TABLE IV

SIMPLIFIED VERSION OF FISCH GLOMUS TUMOUR CLASSIFICATION

Type	Site
A (Air)	Tumour is surrounded by air of middle ear
B (Bone)	Bone of mastoid is involved
C (Carotid canal)	Tumour involves carotid canal
D (Deep/Dural)	Intracranial spread or dural penetration

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TABLE V

CLASSIFICATION OF LATERAL SKULL BASE APPROACHES[8]

Via labyrinth
Translabyrinthine
Transotic
Transcochlear
Transcochlear with modifications
Extralabyrinthine
Approaches passing above labyrinth
– Middle cranial fossa
– Extended middle cranial fossa
– Middle cranial fossa transpetrous
Approaches passing posterior to labyrinth
– Retrosigmoid (suboccipital)
– Retrolabyrinthine transtentorial (petrosal)
Approaches passing mainly inferior to labyrinth
– Petro-occipital transsigmoid
– Type A infratemporal fossa
– Extreme lateral to craniospinal junction
Approaches passing in front of labyrinth
– Type B infratemporal fossa
– Type C infratemporal fossa
– Subtemporal preauricular infratemporal fossa

palsies are advanced, affecting movement, sensation, speech or swallowing. Rare symptoms, such as episodic flushing and hypertension from catecholamine secretion, need to be actively sought whilst history-taking.

The challenge for all of us in daily clinical otolaryngology–head and neck surgical practice is to identify those patients whose presentation may be due to significant pathology and to investigate them appropriately. Unfortunately, large numbers of patients present with unilateral or asymmetrical hearing loss and tinnitus, and almost all will need an MRI scan to identify the small number who actually have an acoustic tumour.

Patients may also present with rather complicated histories related to their hearing and balance. Medical students are taught that all, or most, of a patient's presenting symptoms are likely to be due to one causative condition. However, it is a relatively common finding that multiple aetiologies exist for patients presenting with vertigo and imbalance. For example, benign positional vertigo is frequently present with other pathological vestibular conditions and may confound the diagnostic process.

The hearing loss detected in an audiogram is the result of all the diseases and influences on the ear experienced by the subject to that date. Having a condition such as otosclerosis or Ménière's disease does not preclude a patient from developing a skull base tumour that also affects hearing.

Figure 1 shows the audiogram of a middle-aged woman who had Ménière's disease in the left ear, with significant sensorineural hearing loss, and an added conductive loss resulting from endolymphatic sac surgery, also on that side. Later, the patient began to lose hearing on the right side, which was initially attributed also to hydrops. The right-sided hearing loss was predominantly in the high frequencies, however, and was eventually found to be due to an acoustic neuroma. By the time of scanning, it was 3 cm in maximum dimension. The tumour was removed successfully but with total loss of hearing on that side.

Figure 2 shows the audiogram of a young man who was referred for stapedectomy on the left, without investigation of the contralateral sensorineural hearing loss. An MRI scan was performed, revealing a right-sided acoustic neuroma. Fortunately, this was found before the patient was operated upon for the conductive loss – a procedure that may have left him with a tumour in the only hearing ear.

In our various practices, we need to have a high index of suspicion and a low threshold for investigating our patients, particularly using imaging modalities. This has important implications for the health budget, but the cost of one MRI scan is less than that incurred in following the patient with a series of computed tomography (CT) scans or various hearing assessments over a period of years and still missing the diagnosis. The cost of increased treatment complexity and morbidity associated with larger tumours, and of litigation for those that are

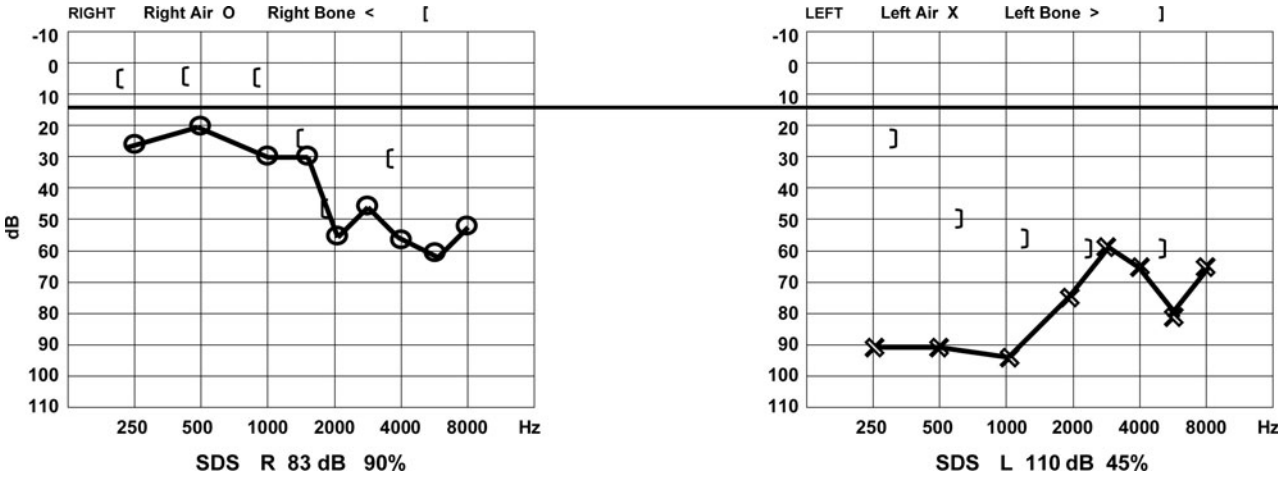

FIG. 1

Audiogram of patient with left-sided, mixed hearing loss due to Ménière's disease, and right-sided, sensorineural hearing loss due to an acoustic neuroma. SDS = speech discrimination score; R = right; L = left

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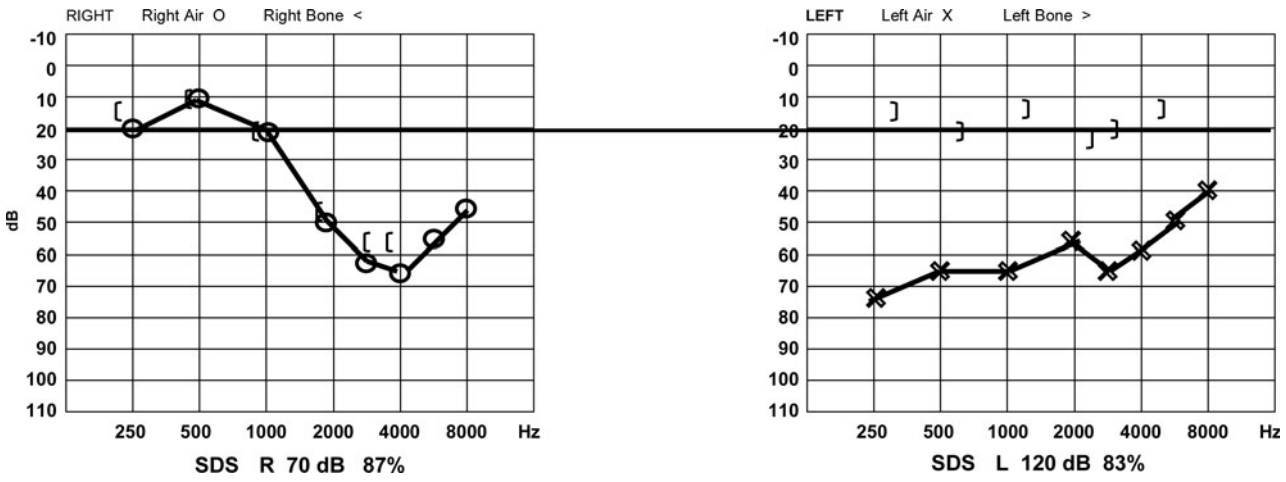

FIG. 2

Audiogram of patient referred for left stapedectomy, with unexplained right-sided sensorineural hearing loss due to an acoustic neuroma. SDS = speech discrimination score; R = right; L = left

initially missed, also well outweighs that of one MRI scan performed early in appropriate patients.

Apart from financial constraints, there are other issues that may influence the decision to request an MRI scan. The patient may have an absolute contraindication, such as a cerebral aneurysm clip or cardiac pacemaker. One may need to revert to older studies, such as a CT air cisternogram, in order to exclude a significant tumour. Claustrophobia may be a problem for some patients, but open magnet machines or sedation can usually overcome this. It is important to obtain a diagnosis and not be unnecessarily deterred from appropriate investigation by such factors.

The type of scan is also an issue. Should all patients have a full head MRI scan with contrast enhancement when screening for an acoustic neuroma? A high resolution scan using techniques such as Constructive Interference in the Steady State or 3D Fiesta is cheaper and quicker, and will find most acoustic tumours. Patients with inner-ear symptoms may have causes other than an acoustic tumour, however, and a full MRI brain scan with contrast will exclude other significant diagnoses, including brainstem lesions and central ischaemia.

Caution is needed when using gadolinium in patients with established or suspected renal disease.[9] Appropriate tests of renal function are now being recommended before using this agent in subjects over 60 years of age.

Magnetic resonance image scanning is not freely available in all communities. In Australia, only since 2000 has government subsidy for MRI scans been generally available, when the investigation is requested by a specialist doctor. This has led to better access for patients, both in large metropolitan areas and smaller rural and remote centres.

Detailed diagnostic investigations

High resolution, multislice CT scanning gives unsurpassed images of the temporal bone, with excellent detail of the middle-ear cleft and the inner ear. Excellent quality reconstructions can be made in any desired plane. This is valuable in a number of situations, such as demonstrating dehiscence of the superior semi-circular canal.

Three-dimensional CT reconstructions of the inner ear add useful information,[10] such as delineating which bone can be safely drilled out to expose the internal auditory canal in a retrosigmoid procedure and still preserve the inner ear.

Computed tomography has limitations in assessing intracranial pathology. For example, an en-plaque petroclival meningioma may still be missed with such a study. A contrast-enhanced MRI must be performed if significant pathology is suspected in this area. These two modalities should be regarded as complementary, rather than mutually exclusive. Frequently, both studies will be required in order to fully assess various pathological conditions in the lateral skull base.

The large vestibular aqueduct syndrome was described on CT radiological studies. In our experience, it is not always associated with a large endolymphatic sac or duct on MRI scanning. The investigation of such a patient presenting with asymmetrical sensorineural hearing loss will generally include an MRI to exclude a tumour and a CT to assess the aqueduct.

Another example of the superiority of MRI in this setting is seen in Figure 3a. This shows a CT scan performed in 1988 on a young man with an unexplained total hearing loss which had developed over two years. He was informed that nothing was found on the air contrast cisternogram. He presented again with unrelated symptoms in 1997, and was sent for a precautionary MRI scan (Figure 3b). His intracanalicular and intracochlear neuroma is shown with gadolinium enhancement. There is little doubt that it caused his loss of hearing. A transotic approach was used for its subsequent removal.

It is likely that there are other patients who had been 'cleared' of an acoustic neuroma on the basis of a CT air cisternogram prior to 1990, but who in reality had slowly growing tumours. This is another

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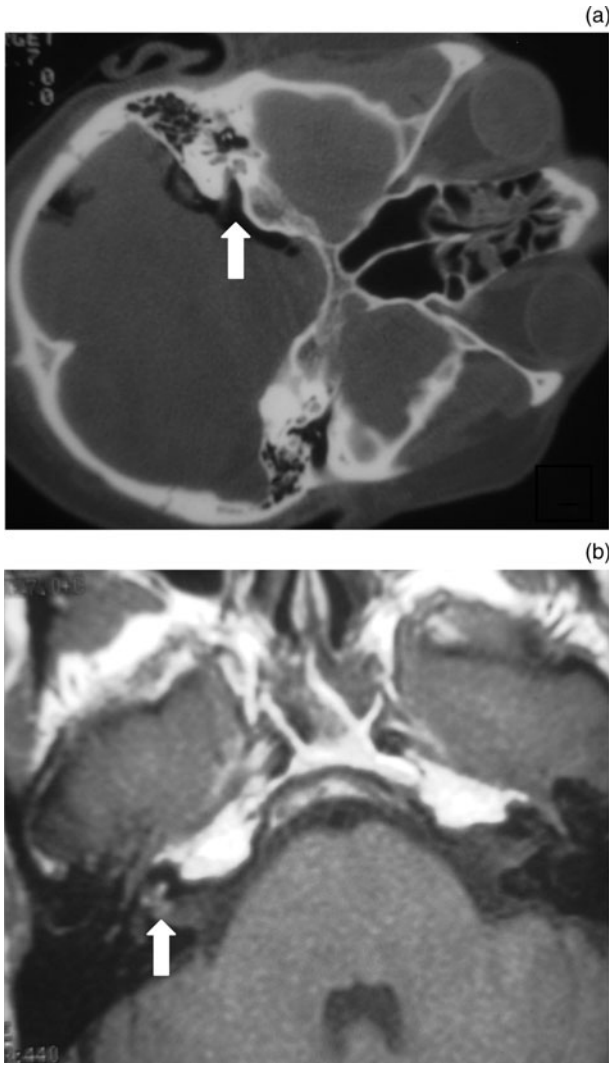

FIG. 3
(a) Computed tomography aircisternogram (1988) showing empty internal auditory canal (IAC) (arrow). (b) T1 magnetic resonance imaging scan with contrast (1997), showing tumour in IAC and cochlea (arrow).

complex issue in practice, and raises the question of whether there is a need to reinvestigate thousands of patients when new technology is introduced.

The ability to image the major intracranial vessels, without using contrast enhancement, with magnetic resonance arteriography and venography has been a very useful addition to the investigation of pulsatile tinnitus. Abnormal shunting is well shown.

Thrombosed dural venous sinuses may be identified with a contrast-enhanced CT scan, but will be much more elegantly shown with magnetic resonance venography.

When assessing the vascularity of a skull base tumour, there is now a range of techniques available. Computed tomography angiography will be used in some cases. Magnetic resonance angiography is very useful and frequently employed; however, if there are doubts, a formal contrast angiogram should be undertaken. Our policy, for example, is to progress to an angiogram if there is objective tinnitus and no diagnosis obtained from non-invasive imaging. Angiography will also be necessary if embolisation is to be performed, such as for the treatment of arterio-venous abnormalities, or pre-operatively for vascular tumours such as juvenile angiofibroma and glomus tumours.

Magnetic resonance imaging techniques are constantly evolving, and often seem complicated to the surgeon. New sequences have been introduced frequently, and many have shown benefit in this area.

An MRI sequence that has been shown to have specific uses in the skull base is the diffusion weighted image.[11] This can be very useful in identifying epidermoid tissue. An example of a cholesteatoma eroding into the inner ear and internal auditory canal is shown in Figure 4. This technique can also be useful in following the patient for recurrence after the petrous bone disease has been removed and the mastoid obliterated with fat. A significant volume of epidermoid material seems to be necessary, however, for a positive study. There may also be a role for following patients for small residual or recurrent cholesteatoma of the middle-ear cleft.

On the other hand, it had been hoped that enhanced scans might help us in the assessment

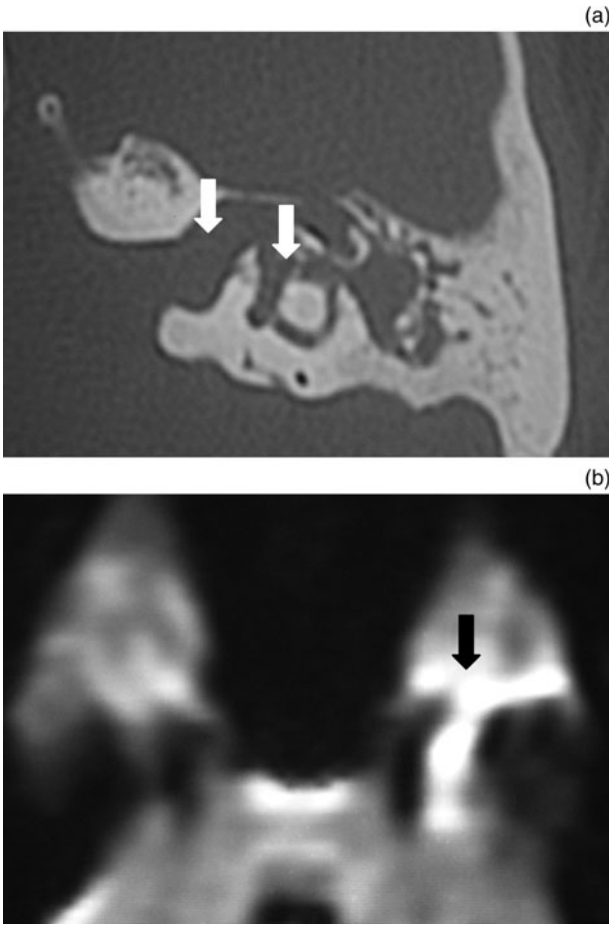

FIG. 4
(a) Computed tomography of cholesteatoma invading inner ear and internal auditory canal (arrows). (b) Magnetic resonance imaging, diffusion weighted image sequence, showing cholesteatoma (arrow).

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and localisation of facial nerve trauma, but we have not found this to be so.

Nuclear studies have certain specific roles. A combination of technetium and gallium scanning is needed to diagnose and follow skull base osteomyelitis. Pentetreotide and iodine-labelled metaiodobenzylguanidine scans can be useful for detecting multiple paragangliomas. Positron emission tomography scans are used for certain types of malignancy, both in diagnosis and for post-therapy surveillance.

Close collaboration with radiologists specialising in these imaging techniques is essential for the skull base surgical team. Such collaboration allows the application of state-of-the-art techniques in order to expose as much detail as possible of the anatomy and pathology of the condition under consideration. Working as part of the team, the radiologist understands the questions being asked by the treating clinicians, and is better able to assist in planning treatment and providing answers.

Specifically targetted testing, such as urinary catecholamine assay for a paraganglioma, needs to be understood. If such a tumour is a secretor, adrenergic-blocking techniques will be necessary in order to allow safe anaesthesia.

Genetic counselling is now an important part of patient management in certain skull base conditions, especially paragangliomas and neurofibromatosis type two.

Natural history of the condition

Knowledge of the natural history of the condition suspected or diagnosed is essential when advising the patient on an appropriate management plan. A small, intracanalicular acoustic neuroma can generally be safely observed and treatment offered if there is growth or further deterioration of hearing over time. On the other hand, a neuroma of 3 or 4 cm in the posterior fossa with significant brainstem compression must be treated, and surgery would generally be regarded as the most appropriate modality, assuming adequate fitness of the patient.

It is known that some acoustic tumours behave in a very indolent way, whereas others exhibit a much more aggressive growth pattern.[12] Recent work on neurofibromatosis type two has suggested a difference in genetic make-up between these two groups, even in sporadic neuromas, and it is suspected that they may over- or under-express different proteins that affect cell proliferation.[13] Such knowledge may enable us to better advise our patients on observation versus treatment early in their management. This will be made easier if these indicator proteins can be found in the blood.

Cystic acoustic neuromas can have a more rapid growth pattern and are associated with a less favourable surgical outcome.[14] They are probably best treated early.

Other skull base lesions, such as those of the jugular foramen and clivus, may also be diagnosed on presentation with relatively minor symptoms such as hearing loss and tinnitus. The implications and potential complications of extensive surgery on such patients, who may be neurologically intact, must be taken into account when planning management. In many cases, it may be better to wait for the tumour to show growth or cranial nerve involvement before recommending surgical intervention.

Cystic lesions of the petrous apex may be able to be followed with regular scanning. However, expansile lesions with significant bone erosion may need to be treated. Tumours in this region will normally be excised. There is not uniform agreement on the treatment of cystic lesions. Drainage into the mastoid air cell system is advocated by some and complete excision by others. In highly selected cases, there may even be the opportunity to drain cystic lesions into the sphenoid sinus.[15]

Any skull base tumour suspected or known to be malignant, or which exhibits aggressive growth, will be best treated early in order to minimise the adverse effects of the pathological process and to improve the long term outcome for the patient. Adjuvant radiation therapy will often be warranted, and a small number of lesions may respond to chemotherapy.

Patient focus

These days, patients are generally better informed about their condition and its potential management, due to ready access to vast amounts of data from the internet, albeit unfiltered and often inaccurate.

Once the diagnosis of a skull base tumour has been given to them, patients often come with a firm decision on what management they wish to have, whether observation or intervention. It is also not uncommon to have a patient refuse a particular form of treatment based on his or her reading, or on the experience of others with even unrelated conditions. Patients' wishes must be respected. Patients themselves need to be supported and followed up long term, even if the management plan they opt for is not what the surgeon has recommended or believes to be in their best interest.

Quality of life studies of patients after removal of acoustic neuroma,[16–18] and of those who have not yet had treatment,[19] have given us greater insight into what the patient can expect to experience. This information can aid us in deciding when and how to intervene. As mentioned above, it is not uncommon, in benign lateral skull base conditions, for the patient to have only minor symptoms and for his or her quality of life to be significantly altered after intervention, at least temporarily. Hearing loss and tinnitus may be swapped for vertigo or chronic vestibular insufficiency, facial weakness with synkinesis and chronic headache.[16,20]

The patient's informed consent to intervention is clearly very important, and has assumed greater importance in recent years. The patient needs to be given general, or pooled, data concerning the risks and expectations of any planned procedure. Many will want specific data concerning the experience and results of the treating surgeon or team. This should be available from the audit and peer review processes which surgeons are increasingly being required to undertake in order to ensure continued

medical registration and specialist surgical privileges. In recent years, printed information sheets have been developed in Australasia and the UK, and are seen as a useful adjunct in the consent process. Clear and detailed documentation of the diagnostic, investigative and consent processes has also become more important in recent years.

Skull base team

Skull base surgery is a team effort. This has been formalised in the UK, with the acceptance and support of multi-disciplinary teams along the lines of the combined head and neck oncology multi-disciplinary team.[21]

The skull base surgery team needs to have all the appropriate members with the required spread of expertise in order to evaluate the problem, to perform the tumour removal or resection, to reconstruct the consequent defects and to rehabilitate the patient. There will inevitably be different personalities, training, expertise and experience, and all members will bring their own preferences and biases.

When working in such a team, one may have to give way on certain things and compromise on occasions. However, it has been my experience, over the last 25 years, that the patient and the team members gain significant benefit from a collaborative approach.

Training young surgeons in skull base surgery

It is expected that all otolaryngology–head and neck surgery training schemes will include rotations through units that regularly perform skull base surgery, and that trainees will be exposed to this work. Trainees should be involved in the collaborative assessment and management of patients and be given the opportunity to assist in the performance of surgical procedures.

The formalised training of skull base surgeons is a major issue. Nowadays, there are dedicated fellowship positions in the field. It will be in the best interest of patients and surgeons that these posts, and those who receive training in them, are coordinated regionally or nationally, based on accurate workforce data. This will help ensure that there is an adequate provision of quality service in this subspecialty across the country, and that practising skull base surgeons have an appropriate caseload, work in well supported teams and are able to do meaningful research.

In the United States, fellowship positions in neurotology now extend over two years, and the American Board of Otolaryngology administers a certifying examination at the completion of this extra training.[22] Those responsible for surgical training in Australasia and the UK should probably aspire to a similar system.

Technology employed in surgery

In a highly technical field such as skull base surgery, it is inevitable that new procedures and new equipment will be regularly developed. Such innovations will need to be trialled in academic centres in order to assess their worth before general application. Dedicated units with training fellows and research support will enable proper assessment and trialling of new techniques and equipment.

Intra-operative cranial nerve monitoring is now commonly employed. Facial nerve monitoring can be regarded as a standard of care in lateral skull base surgery. Routine use of facial nerve monitoring in acoustic neuroma surgery has resulted in a House–Brackmann grade I or II result in more than 80 per cent of cases, with less than 5 per cent occurrence of a grade V or VI result.[23] Eighth nerve monitoring is frequently employed, and lower cranial nerve monitoring is also useful in appropriate cases.

Otolaryngologists have been familiar with the use of endoscopes for many years. Endoscopic techniques can be of benefit in surgery of the lateral skull base, complementing the field of vision offered by the operating microscope. This may aid in complete tumour excision, and in identifying potential problems, such as open mastoid air cells which may lead to cerebrospinal fluid leakage.

Newer intra-operative technology, such as CT- and MRI-based navigation, is finding a place in skull base surgery. Frameless image guidance is now regularly employed in surgery of the frontal sinus and anterior skull base. We have found it useful, particularly in approaches via the middle cranial fossa, and for confirming the position of the superior semi-circular canal (and on occasions the internal auditory canal).

Management options

The management choices for the broad range of diseases of the lateral skull base include observation, radiation, surgery, chemotherapy and various combinations of these modalities.

The team approach to treatment planning is important for all cases, but especially for the more complex and the less common conditions. This is not a 'decision by committee' but a coordinated undertaking by experienced medical and surgical specialists, with input from the relevant allied health and nursing personnel.

The aims of the treatment need to be considered.

In surgery for acoustic neuroma, the general aim is complete resection. Twenty years ago, this was practised almost despite the likely effects on the facial nerve. More recently, greater significance has been given to the benign nature of this tumour, and it has been shown that small remnants of pseudo-capsule or even tumour may be left with little problem, allowing better facial nerve outcome. The terms 'near total removal' refers to a very small amount of tumour being left, whereas 'sub-total removal' indicates significantly more.[24] There are even suggestions by some groups that we should electively operate on the cerebello-pontine angle component and irradiate the rest of the tumour. With such an approach, however, the patient would experience the problems of both types of treatment, at least some of which are likely to be unnecessary.

In the treatment of acoustic neuroma, the question of hearing preservation continues to cause great discussion among surgeons and radiation oncologists. In the case of a tumour less than 2 cm in size, with

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serviceable hearing in the affected ear, one may recommend a hearing preservation procedure. There is approximately a 60 per cent chance of maintaining useable hearing.[23] Those patients who lose the use of their hearing with early surgery may well feel they should have adopted an observational approach, at least for the short term.

On the other hand, if one waits initially, there may be progressive or even sudden loss of hearing to a level at which a hearing preservation approach is no longer possible. There is no right answer to the question of when best to intervene in smaller tumours. Patients and their medical advisors will have their own preferences and biases. Management decisions need to be based on fact, and the patient's wishes respected.

Radiation therapy for intermediate-sized acoustic tumours has gained acceptance around the developed world. It is certainly appropriate for the elderly and infirm. Tumour growth control is reported between 86 and 100 per cent of cases.[25] However, some studies comparing tumour control and the natural growth pattern of acoustic neuromas have questioned the efficacy of this modality.[25]

Radiation therapy, even when delivered stereotactically, can have significant complications,[26] and salvage surgery is generally regarded as more difficult, with worse facial nerve outcomes. The reduction in radiation dose in recent years may lead to fewer complications, but tumour control rates are still being assessed to judge whether they remain acceptable.

The controversy surrounding the treatment for paragangliomas, concerning surgery and radiation, continues, with the best centres for each of the modalities reporting excellent tumour removal or control.[27,28] Again, the natural history of these tumours needs to be understood, and the effects of treatment discussed comprehensively if accurate advice is to be given to the patient.

Malignant lesions of the lateral skull base require wide resection, and extensive reconstruction may also be necessary. In the temporal bone, this will not always be in an enbloc fashion. The resection must not be compromised by the inability of the surgeon to resect the lesion, to deal with the implications and complications of the procedure, and to reconstruct the defect with acceptable function and rehabilitation. Team collaboration, involving all the required surgical expertise, is the hallmark of modern lateral skull base surgery, and is particularly important in treating malignancy.

In some cases of malignancy, cure will not be possible and palliation will be the aim. Temporal bone resection may still have a role in reducing tumour bulk, controlling pain and thereby improving quality if not quantity of life. When coupled with vascularised flap reconstruction, further radiation treatment may also be possible.

Reporting results

In 1995, the American Academy of Otolaryngology–Head and Neck Surgery established firm guidelines for the reporting of hearing in relation to acoustic neuroma.[4] This system is used extensively, but there is still not universal agreement on the frequencies used for pure tone averages and other data to be reported.

The House–Brackmann facial nerve grading system was developed in the early 1980s.[29] It was designed only for cases of facial palsy in which the nerve remains anatomically intact, and should only be used after 12 months of recovery. It has gained wide acceptance but has its limitations, with other systems still being proposed regularly.

A study of over 100 papers reporting on a wide range of outcomes of acoustic neuroma management showed only lower levels of evidence (types III and IV) for the claims of the authors.[30] Further, controlled studies are called for but will rely on coordinated multi-centre programmes.

Implications and complications of treatment

Surgical procedures on the lateral skull base all have significant implications for the patient, and there are inevitable surgical and post-operative complications that do occur. These can occasionally be catastrophic in nature and devastating for the patient and their family.[5,31–33]

Facial paralysis with incomplete long term recovery may be regarded as an implication of removal of a large acoustic tumour; however, it is regarded by some as a complication of removal of an intracanalicular lesion. Facial nerve outcomes are generally better with smaller tumours, and worsen with increasing size of the tumour being treated. There are exceptions, however, and this needs to be explained to the patient in the pre-operative consent process.

There are robust published data concerning the common problems occurring as a result of surgery for acoustic neuroma; meta-analyses[23] provide relevant general guides to the effects a patient is likely to experience. Surgeons need to know how their own results and outcomes compare with the pooled data.

When auditing results, then presenting or publishing them, all cases need to be included in order to reveal the whole story. Leaving out selected cases, whether intentional or not, causes a bias that gives a false impression and sets an artificial benchmark for others to compare with or aspire to.

Patients should know what the risks and expectations really are. If there is a chance of major morbidity or mortality, even if statistically small, this is of material importance to each individual patient.

It is unrealistic to assume that surgeons will have no complications. It is hoped that they will learn from their own experience and that of others and will improve over time. It is human and understandable to make a bad decision from time to time, whether in planning or executing an operation. One must learn from the resulting outcome and prevent similar problems recurring. Improved surgical performance and outcomes from greater experience are reported in related areas.[34] The suggestion that every patient must be treated by 'the best' surgeon with the most experience is not realistic. Patients with disease of the lateral skull base should be treated by a multi-disciplinary team with the appropriate experience, expertise and caseload.

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Conclusion

The management of the various aspects of lateral skull base disease can be complex. In recent years, such management has increasingly come to include non-operative treatment, at least in the short term.

Surgery of the lateral skull base is a worthwhile pursuit with validated benefits, but it has inevitable implications and complications. Organised training of new surgeons, and clinical audit and practice review by established surgeons, will lead to better management planning and execution, whilst minimising morbidity and maximising patient outcome.

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