A rapid scan of the literature

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Screening for the early detection of acoustic neuroma in patients with asymmetric sensorineural hearing loss: a rapid literature scan of MRI and other surveillance methods

Dan Paech
Adele Weston
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Review Team

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Contact Details
Health Services Assessment Collaboration (HSAC)
Health Sciences Centre
University of Canterbury
Private Bag 4800
Christchurch 8140
New Zealand
Tel: +64 3 345 8147  Fax: +64 3 345 8191
Email: hsac@canterbury.ac.nz
Web Site: www.healthsac.net
Executive Summary

Introduction

This report provides a brief scan of the literature available on the role of magnetic resonance imaging (MRI) and comparative surveillance techniques in screening for the early detection of acoustic neuroma (AN) in patients with asymmetric sensorineural hearing loss (ASNHL). It was commissioned by the New Zealand Ministry of Health.

Methods

A systematic method of literature searching and study selection was employed in the preparation of this report. The literature was searched using the bibliographic databases of EMBASE and Medline. The Cochrane Database of Systematic Reviews and numerous health technology assessment websites were also searched to help identify existing reviews or clinical practice guidelines. In addition, the bibliographies of key included papers were examined for relevant studies. It is important to note that as this was a brief scan of the evidence, and not a full systematic review, detailed quality appraisal, data extraction and interpretation of the identified literature was not performed. The review relies heavily upon material reported in each publication’s abstract.

Key results

The search strategy identified a total of 451 citations, of which 289 were included for title/abstract review. After consideration of titles and abstracts using the study selection criteria, 53 citations were included in the review. Only the papers of the citations considered most relevant to the topic of interest were retrieved for more in-depth description. There was also one systematic review identified which is due for publication in April 2009. All available details of this review are provided.

The literature gathered in this report suggests that MRI is considered the ‘gold standard’ in detecting ANs in patients with ASNHL. Although auditory brainstem response (ABR) testing is also widely used, it has been shown to have insufficient sensitivity and specificity to be used as a sole screening test. There is particular concern around its ability to identify small sized tumours. Nonetheless, there appears to be significant variety in the way clinicians screen and manage patients presenting with ASNHL. This may be due to the fact that there are no universally accepted clinical practice guidelines, and because of the accessibility and cost issues of screening all patients with MRI. Whether or not MRI maintains its superiority once costs are taken into account has not been addressed in this report.

Conclusions

The review concludes with suggested directions of action and potential research questions for this topic.
# Table of Contents

Review Team ................................................................. i  
Copyright Statement & Disclaimer .................................. i  
Contact Details .................................................................. ii  
Executive Summary .......................................................... iii  
  Introduction ................................................................... iii  
  Methods ....................................................................... iii  
  Key results ..................................................................... iii  
  Conclusions ................................................................. iii  
Table of Contents ............................................................ iv  
List of Tables .................................................................... v  
Introduction ..................................................................... 1  
Literature Search ............................................................... 3  
Results ............................................................................ 7  
  Review of screening techniques ....................................... 7  
  Systematic review .......................................................... 7  
  Prospective studies ......................................................... 8  
  Retrospective studies ..................................................... 10  
  Reviews, patient management or clinical practice papers ...... 14  
  Cost based studies ........................................................ 17  
  Key publications ............................................................ 20  
  Published audiological screening protocols ...................... 24  
Summary and Recommendations ......................................... 27  
  Conclusions .................................................................. 27  
References ........................................................................ 29  
Appendix A: HTA websites searched .................................... 35  
Appendix B: Excluded studies annotated by reason for exclusion .... 37  

# List of Tables

| Table 1 | Summary of the literature search | 4 |
| Table 2 | Criteria for inclusion/exclusion in review | 4 |
| Table 3 | Prospective studies identified through the literature search | 9 |
| Table 4 | Summary of retrospective cohort studies | 11 |
| Table 5 | Summary of publications classified as a review, patient management or clinical practice paper | 14 |
| Table 6 | Summary of cost based studies | 17 |
| Table 7 | Results of MRI and ABR screening tests | 22 |
| Table 8 | A description of published decision-support protocols for acoustic neuroma | 25 |
Introduction

Hearing loss is the most prevalent sensory deficit reported by patients. In Australia, 10–20% of Australians have some hearing impairment and approximately 50% of those over 65 years of age are hearing impaired. Hearing loss can be conductive, sensorineural or mixed, with sensorineural occurring most frequently in adults (Angeli et al. 2005). Sensorineural hearing loss indicates defects in either the cochlea or in the neural transmission to the central nervous system. Asymmetric sensorineural hearing loss (ASNHL) is defined as binaural difference in conduction thresholds of >10 dB at two consecutive frequencies or >15 dB at one frequency (0.25–8.0 kHz) (Sabini and Sclafani 2000).

One pathology which may present as ASNHL is acoustic neuroma (AN), also known as vestibular schwannoma. Acoustic neuroma is a benign tumour arising from the Schwann cells in the vestibular portion of the eighth cranial nerve. However, the majority of patients who present with ASNHL do not have AN, the reported incidence being approximately 2% of all patients with ASNHL (Urben et al. 1999). As a result, selecting patients with ASNHL for further investigation continues to pose challenges, given the disparity between the number of symptomatic patients, and the low incidence of AN as the underlying cause (Nouraei et al. 2007).

When patients present with symptoms that may indicate an AN, magnetic resonance imaging (MRI) is often considered the diagnostic test of choice. However, there are some patients for whom MRI is inappropriate (e.g. patients with implanted electrical devices or a cerebral aneurysm clip), and increasingly there are cost and accessibility issues associated with MRI (Prasad and Cousins 2008). Contention also surrounds the most efficient MRI protocol to use in the investigation of suspected AN. Electrophysiological measurement of the auditory brainstem response (ABR) is another diagnostic technique which has been used to diagnose AN (National Institute of Health Research 2007). This report will gather the evidence on MRI, and the place of any other screening tests, in the early detection of AN.

An extensive literature search was conducted as is described below. The aim of the literature search was to provide a rapid overview of the available evidence for screening ASNHL patients for AN, with a particular focus on MRI.

The results of each identified study should be considered with the year of publication in mind, as significant advances in technology have occurred in AN diagnosis over the last 20 years.
Screening in ASNHL for acoustic neuroma
Literature Search

A search of the EMBASE, Medline and Cochrane database as well as numerous HTA websites (Appendix A) was conducted to identify any published guidelines, systematic reviews or publications pertaining to the screening of patients with ASNHL for the identification of acoustic neuromas. The literature source, search terms, number of citations identified and date of the search is outlined in Table 1. Many of the citations identified through the search of the Cochrane library and HTA websites were duplicates already identified through the EMBASE/Medline search, or were completely irrelevant to the topic of interest, and were therefore excluded before downloading into the Reference Manager database.
### Table 1  Summary of the literature search

<table>
<thead>
<tr>
<th>Source</th>
<th>Search terms</th>
<th>Citations</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMBASE.com (Includes EMBASE and Medline)</td>
<td>((‘acoustic neuroma’/exp OR ‘acoustic neuroma’) OR ‘vestibular schwannoma’ OR (‘neurinoma’/exp OR ‘neurinoma’)) AND (‘asymmetric sensorineural hearing loss’ OR ‘asymmetric sensorineural hearing loss’/exp OR ‘sensorineural hearing loss’ OR ‘sensori-neural hearing loss’ OR ‘asymmetrical sensorineural hearing loss’ OR ‘asymmetrical sensori-neural hearing loss’ OR (‘perception deafness’/exp OR ‘perception deafness’)) AND [english]/lim AND [humans]/lim</td>
<td>281</td>
<td>03/02/2009</td>
</tr>
<tr>
<td>Cochrane library</td>
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<td>86</td>
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<tr>
<td>CADTH</td>
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<tr>
<td>EuroScan</td>
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<td>National guideline clearinghouse</td>
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<td>03/02/2009</td>
</tr>
<tr>
<td>National Institute for Health Research</td>
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<td>6</td>
<td>03/02/2009</td>
</tr>
<tr>
<td>NICE</td>
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</tr>
<tr>
<td>INAHTA</td>
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<td>MSAC</td>
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<td>ANZHSN</td>
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<td>03/02/2009</td>
</tr>
<tr>
<td>AHRQ</td>
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<td>0</td>
<td>03/02/2009</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>451</strong></td>
<td><strong>03/02/2009</strong></td>
</tr>
</tbody>
</table>

*Abbreviations: AHRQ, Agency for Healthcare Research and Quality; ANZHSN, Australia and New Zealand Horizon Scanning Network; CADTH, Canadian Agency for Drugs and Technology in Health; INAHTA, International Network of Agencies for Health Technology Assessment; MSAC, medical Services Advisory Committee; NICE, National Institute for Clinical Excellence.*

In addition, a general internet search was performed to identify any additional publications, clinical practice guidelines or systematic reviews. There were 289 citations downloaded into the reference manager database from the various sources described above. The titles and abstracts (where available) were reviewed using the inclusion and exclusion criteria outlined below in Table 2.

### Table 2  Criteria for inclusion/exclusion in review

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>Number of citations excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect study type: case study (&lt;10 patients), opinion piece, letter</td>
<td>69</td>
</tr>
<tr>
<td>Incorrect patient population: not ASNHL</td>
<td>68</td>
</tr>
<tr>
<td>Incorrect disease: not acoustic neuroma</td>
<td>27</td>
</tr>
<tr>
<td>Incorrect intervention/outcomes: does not examine relevant screening technique for acoustic neuroma</td>
<td>72</td>
</tr>
<tr>
<td><strong>Included</strong></td>
<td><strong>53</strong></td>
</tr>
</tbody>
</table>

*Abbreviations: ASNHL, Asymmetric sensorineural hearing loss.*
After reviewing the citations, there were 53 that qualified for inclusion. One of these was a systematic review which is due for publication in April 2009. Further details on the types of publications retrieved and an in-depth description of the forthcoming systematic review is provided below. The excluded citations and reasons for exclusion are provided in Appendix B.
Screening in ASNHL for acoustic neuroma
Results

Review of screening techniques

The identified studies assessed a number of different surveillance techniques. These are discussed below.

The initial screening test for assessing patients with ASNHL was the pure tone audiogram (PTA) (Wareing 2002). Whilst there is no characteristic shape of audiogram, unexplained asymmetry between the ears warrants further investigation. In the past, other audiological screening tests such as loudness recruitment, tone decay, stapedial reflex thresholds and decay have been used as an initial screening measure although these are now only of historical interest.

Auditory brainstem response testing was first introduced in 1970 and has been used to identify retrocochlear lesions. It is a safe and painless test of the auditory pathway and brainstem function in response to auditory stimuli. The ABR test is widely used by audiologists as an initial screening tool in patients with sensorineural hearing loss. However, its success rate in ASNHL has been shown to be dependent on tumour size, with the test at its least sensitive in small and medially placed tumours, these being the tumours that an early diagnostic strategy aims to detect (Wareing 2002).

Magnetic resonance imaging with gadolinium enhancement has been considered the ‘gold standard’ for detection of ANs since 1991. It has been shown to have a near 100% diagnostic accuracy, being able to detect tumours as small as 3mm. More recently, screening scan procedures have been developed that either decrease the gadolinium dose or remove the need for it all together, using T2 fast spin echo (FSE) scanning protocols. However, some authors argue that using this approach is probably not justified since other alternative diagnoses may be missed due to the lack of contrast material. Nevertheless, high-resolution FSE T2-weighted MRI has proven to be a cost-saving alternative to contrast-enhanced MRI (Vossough 2003). The disadvantages of MRI relate to the cost of universal screening as well as access to the scanner.

The use of contrast enhanced computerised tomography (CT) has also been reported as useful in the diagnosis of AN. However, because bone has a positive signal, its ability to diagnose intracanalicular tumours is limited and possibly no better than ABR testing. Its role is currently limited to those patients in whom MRI is contraindicated (Wareing 2002).

Systematic review

There was one systematic review identified through the literature search. It is currently being undertaken by the National Institute of Health Research (NIHR) and is due for publication in April 2009. According to the NIHR webpage, the project is in the editorial review stage. The title of the systematic review is:

‘The role of magnetic resonance imaging in the identification of suspected acoustic neuroma: systematic review of clinical and cost effectiveness, and natural history’
The following summary of the project and proposed publication abstract are taken from the NIHR webpage.

**Summary**

Some patients presenting to their general practitioner with unilateral hearing loss and/or tinnitus may have a small tumour called an acoustic neuroma growing on the hearing (acoustic) nerve; estimated to be 3-7.5%. How these tumours grow and the effect they have on an individual varies. Identification of such tumours and assessment of their rate of growth is important clinical information which contributes to decisions on whether or how to treat them.

There exist several different tests that can be used for this assessment, each of which has different accuracy and different costs. There are no current guidelines on which is the most clinically- and cost-effective to use.

We propose to identify existing published and unpublished literature and to extract all the relevant evidence which will contribute to answering questions on how acoustic neuromas grow and affect individuals, which diagnostic tests are better and what are the costs involved. Only by evaluating the existing evidence can we see if there are gaps in our knowledge which need to be answered by further research. The proposed research will not raise ethical issues and will not require NHS ethical approval.

The base for the research will be the University of Nottingham. Co-applicants are based in Birmingham, Liverpool, Cambridge, Belfast, and Athens. Our team comprises experts in various aspects of this field, including methodological experts who will reach a consensus based on the evidence. Each will review aspects of the evidence for which they have expert knowledge and each will contribute to the final report. The costs requested are to employ a research assistant to carry out the searches and identify the available evidence. In addition we are requesting funds for consultancy for the expert reviewers and co-ordinators to allow them to dedicate sufficient time to the project, travel costs for meetings of the whole team and for consultancy meetings between the researcher and the experts, and consumable costs of acquiring the literature that is not available on the internet.

**Abstract**

The aim of the study is to (i) evaluate the clinical- and cost-effectiveness of a range of diagnostic strategies for investigating patients with unilateral hearing loss and/or sudden-onset tinnitus with a view to confirming or eliminating a diagnosis of acoustic neuroma, (ii) to describe the natural history of acoustic neuroma and (iii) to synthesise the findings from these two elements of the study to formulate guidelines for clinical practice and to identify priorities for future primary research in this area.

We propose to identify existing published and unpublished literature and to extract all the relevant evidence which will contribute to answering the questions of how do acoustic neuromas grow and affect individuals, the diagnostic accuracy and performance (e.g. yield) of different tests and combinations of tests that investigate unilateral hearing loss/tinnitus (i.e. magnetic resonance imaging, hearing tests, computed tomography scans, auditory brainstem response testing) including the outcomes of interventions and the cost-effectiveness of MRI compared with other diagnostic tests for the investigation of unilateral hearing loss and/or tinnitus. These questions will be examined in terms of different case definitions, tumour size and different protocols of tests. Each review will be conducted in accord with contemporary methodological standards for systematic reviews (e.g. Cochrane diagnostic screening Methods Group, NHS Centre for Reviews & Dissemination systematic review guidelines).

**Data source:** National Institute of Health Research 2009

**Abbreviations:** MRI, magnetic resonance imaging; NHS, National Health Service

**Prospective studies**

There were eight prospective studies assessing a number of different surveillance techniques identified through the literature search. The citation details for these, along with a summary of each publication are provided in Table 3. Where possible, publications are further grouped by screening intervention type.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Abstract / Summary</th>
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<tbody>
<tr>
<td><strong>ABR</strong></td>
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</table>
ABR testing and MRI are compared for the evaluation of patients with ASNHL. This study is a prospective, nonrandomised comparison of ABR and MRI for the evaluation of patients with asymmetric SNHL. Further details are provided under the Key Publications section. |
This study reports on the preliminary results of an ongoing prospective study on the evaluation of patients with ASNHL. All patients with asymmetry in two or more pure-tone thresholds of (greater-than or equal to)15 dB or asymmetry in speech discrimination scores of (greater-than or equal to)15% or both entered the study and underwent both an ABR examination and an enhanced MRI scan. Further details are provided under the Key Publications section. |
This study aimed to assess the efficiency of various tests in excluding CPA tumours with the minimum of unnecessary investigations. All patients received the full battery of ABR, acoustic reflex thresholds and decay, alternate binaural loudness balance and ENG and caloric testing. All patients who did not have normal ABR proceeded to high resolution CT scanning. The efficiency of these tests in a general ORL clinic is very much poorer than often suggested, due largely to the number of occasions on which the tests cannot be done, and to the very small proportion of the test population who have CPA tumours. |
| **MRI**  |  
Over a 22-month period the use of axial turbo-spin echo T2-weighted images (T2w) were prospectively compared with contrast-enhanced T1-weighted spin echo scans in the evaluation of 513 patients presenting with audiovestibular symptoms. With the 3-D sequence three ANs were all identified correctly with no false positive and only one false negative result. Authors concluded that mass lesions of the IAM/CPA can be reliably identified on T2w TSE imaging but labyrinthine lesions may be missed without contrast enhancement. |
In order to determine the utility of fast spin echo imaging, both gadolinium enhanced T1 weighted images and fast spin echo T2 weighted images were acquired in 1233 consecutive patients referred for exclusion of AN. Thirty three ANs were identified. Only 56% were confidently identified on fast spin echo T2 weighted images alone; gadolinium enhanced T1 weighted images were required to confirm the diagnosis in 44% of the cases, including 9 of the 10 intracanalicular tumours. It was concluded that an imaging strategy intended to identify small intracanalicular ANs cannot rely on fast spin echo T2 weighted imaging alone. |
### Table 3  Prospective studies identified through the literature search (continued)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Abstract / Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adler J, Atlas M and Shnier R. (1998) High resolution MRI and asymmetric sensori-neural hearing loss. <em>Australian Journal of Oto-Laryngology</em>, FindArticles.com. 09 Feb, 2009.</td>
<td><strong>FSE-MRI vs Gd-T1W MRI</strong>&lt;br&gt;The present study examined the suitability of a high resolution fast spin echo (FSE) sequence, combined with a whole head FSE sequence, in the screening evaluation of 39 consecutive patient's referred with a diagnosis of ASNHL. The efficacy of the sequences was compared with standard MRI which included T1 weighted gadolinium enhanced scans. Whilst there were no significant differences in the imaging diagnoses achieved with the FSE sequences when compared to standard protocols, the incidence of acoustic tumour in this unselected series (4%) was too low to allow a definitive judgement with respect to the value of the FSE sequences as a stand-alone screening tool.</td>
</tr>
<tr>
<td>Soulie D, Cordoliani YS, Vignaud J, and Cosnard G. (1997) MR imaging of acoustic neuroma with high resolution fast spin echo T2-weighted sequence. <em>European Journal of Radiology</em> 24:61-65.</td>
<td><strong>FSE-T2W MRI vs Gd-T1W MRI</strong>&lt;br&gt;The aim of this study was to assess the value of high resolution 2D fast spin echo T2-weighted sequence (HR 2D-FSE T2W) for evaluating the internal auditory meatus in patients with asymmetric or unilateral sensorineuronal hearing loss, vs. gadolinium-enhanced T1-weighted (T1w) sequence; to suggest a screening protocol to exclude the diagnosis of AN in a patient with isolated unilateral sensorineural hearing loss. Normal images using HR 2D-FSE T2w sequence can rule out the diagnosis of AN. Using this protocol authors could exclude the diagnosis of AN in case of normal HR 2D-FSE images and no additional gadolinium-enhanced T1w sequence is necessary.</td>
</tr>
<tr>
<td>Bassi P, Piazza P, Cusmano F, Menozzi R, Gandolfi A, and Zini C. (1989) MR cisternography of the cerebello-pontine angle and internal auditory canal in diagnosis of intracanalicular acoustic neuroma. <em>Neuroradiology</em> 31:486-491.</td>
<td><strong>T1W + T2W MRI</strong>&lt;br&gt;115 patients, suffering from SNHL were tested with a 1.5 T superconducting magnet. The authors describe utility of both T1-weighted multiple slice and T2-weighted multiple echo images for the evaluation of cerebello-pontine angle, internal auditory canal and their neurovascular content. In 73 cases MR cisternography was normal. The remaining 42 cases were subdivided into twenty extracanalicular masses, eleven small intra-extracanalicular and nine purely intracanalicular lesions. All the lesions were histologically proven ANs, except one intracanalicular mass which was a meningioma. Examination was inconclusive only in two cases and decision was then made to follow the clinical course. Advantages of MR cisternography over CT and air CT cisternography are pointed out.</td>
</tr>
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</table>

Abbreviations: ABR, audio brainstem response; ASNHL, asymmetric sensorineural hearing loss; CPA, cerebellopontine angle CT; computed tomography; ENG, electronystagmogram; FSE, fast spin echo; IAM, internal auditory meatus; MRI, magnetic resonance imaging; ORL, T2W, T-2 weighted; TSE, turbo spin echo.

### Retrospective studies

There were 17 studies which retrospectively assessed various surveillance techniques for AN. The citation details and a summary for each are shown below in Table 4. Again, publications have been grouped according to the screening intervention.
Table 4  Summary of retrospective cohort studies

<table>
<thead>
<tr>
<th>References</th>
<th>Abstract / Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABR</td>
<td>To contribute to the clinical use ABR, in particular with the aim of reducing the number of false positives, a retrospective study was carried out in two groups of patients affected by unilateral SNHL with ABR abnormalities: in the first group (50 cases: true positives) hearing loss was the expression of an AN shown by MRI, in the second group (130: false positives) MRI was negative. The study concluded it would not appear possible, based on current knowledge, to further improve the reliability of this test, and, therefore, its use in oto-neurological diagnostics remains limited.</td>
</tr>
<tr>
<td>Schmidt RJ, Sataloff RT, Newman J, Spiegel JR, Myers DL. (2001) The sensitivity of auditory brainstem response testing for the diagnosis of acoustic neuromas. <em>Archives of Otolaryngology, Head and Neck Surgery</em> 127(1):19-22.</td>
<td>ABR</td>
</tr>
<tr>
<td>El Kashlan HK, Eisenmann D, and Kileny PR. (2000) Auditory brain stem response in small acoustic neuromas. <em>Ear and Hearing</em> 21:257-262.</td>
<td>ABR</td>
</tr>
<tr>
<td>Saunders JE, Luxford WM, Devgan KK, and Fetterman BL. (1995) Sudden hearing loss in acoustic neuroma patients. <em>Otolaryngology - Head and Neck Surgery</em> 113:23-31.</td>
<td>ABR + Gd-MRI</td>
</tr>
<tr>
<td>Dornhoffer JL, Helms J, and Hoehmann DH. (1994) Presentation and diagnosis of small acoustic tumors. <em>Otolaryngology - Head and Neck Surgery</em> 111:232-235.</td>
<td>ABR</td>
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Table 4  Summary of retrospective cohort studies
(continued)

<table>
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<tr>
<th>References</th>
<th>Abstract / Summary</th>
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</table>
ABR has been believed as the most reliable test for the diagnosis of AN despite several reports of false-negatives. In this series, 4 tumours out of 18 tested had normal ABR. The false-negative rate was 22%, which is much higher than expected. In CT, only 11 tumours were recognised. Although the total number is not large, present results clearly suggest the limits of these examinations. At present, HR-MRI is the most reliable diagnostic method for ANs with no false-negative reported; ordinary MRI may have false-negatives. |
ABR testing has been a major breakthrough in audiologic screening for AN because of its high degree of sensitivity. Although it is not uncommon for other cerebellopontine angle masses to present with normal ABR findings, reports of eighth nerve tumours with false-negative ABR tests are quite rare. A series of 120 ANs re-sected at the University of Michigan was reviewed and revealed two such patients. These two patients presented with ASNHL and unilateral tinnitus and were found to have completely normal ABR. The diagnosis of AN would have been delayed if a comprehensive evaluation had not been pursued. |
The incidence of cases of AN that are manifested as sudden deafness or progressive sensorineural hearing loss was investigated. The findings of the SR test, the ABR test and the caloric test were analysed, and the procedure for the diagnosis of AN was discussed. |
This is a retrospective study of 100 consecutive patients who attended an ENT outpatient clinic in a 6 month-period. All of them presented with ASNHL. They were all investigated with MRI scan of the IAM and CPA. The pickup rate was 1% for CPA lesion which was vestibular schwannoma. Further details are provided under the Key Publications section. |
This study developed and validated a diagnostic model using a generalisation of neural networks, for detecting vestibular schwannomas from clinical and audiological data, and compared its performance with six previously published clinical and audiological decision-support screening protocols. The Gaussian Process Ordinal Regression Classifier increased the flexibility and specificity of the screening process for vestibular schwannoma when applied to a sample of matched patients with and without this condition. If applied prospectively, it could reduce the number of ‘normal’ magnetic resonance scans by as much as 30% without reducing detection sensitivity. Further details are provided under the Key Publications section. |
Table 4  Summary of retrospective cohort studies (continued)

<table>
<thead>
<tr>
<th>References</th>
<th>Abstract / Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker R, Stevens-King A, Bhat N, and Leong P. (2003) Should patients with asymmetrical noise-induced hearing loss be screened for vestibular schwannomas? Clinical Otolaryngology and Allied Sciences 28:346-351.</td>
<td>MRI Those patients with ASNHL are routinely screened for vestibular schwannomas by MRI scanning. Scan reports from the past 5 years have been reviewed and out of 152 scans, four revealed vestibular schwannomas giving a pick-up rate of 2.5%, which compares favourably with other published pick-up rates. Review of the audiograms in these cases suggests that they can be misleading in this context. The conclusion is that patients with noise-induced ASNHL should be screened for ANs.</td>
</tr>
<tr>
<td>Kubo T, Sakashita T, Kusuki M, Kyunai K, Ueno K, Hikawa C, Wada T, and Nakai Y. (2000) Evaluation of radiological examination for sensorineural hearing loss. Acta Oto-Laryngologica, Supplement :34-38.</td>
<td>X-ray, CT and MRI In this study, the clinical significance of radiological examinations for SNHL was evaluated and the value of their utilisation was reconsidered. A total of 1,276 ears of 724 patients who demonstrated unilateral or bilateral SNHL was studied retrospectively. Findings of radiological examinations such as plain X-ray (X-p), CT and MRI of the brain or the temporal bone were investigated. Temporal bone X-p was usually performed to rule out acoustic tumours. CT was further performed in 119 patients (16.4%) and MRI in 84 patients (11.6%) in total. Of five cases with AN, two with a small tumour exhibited normal findings for the internal auditory canal on temporal bone X-p. These small tumours were finally confirmed by MRI. These findings confirmed that MRI is very useful for detecting small acoustic tumours and suggested that MRI also reveals cerebral vascular insufficiency in patients with SNHL.</td>
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<tr>
<td>Manfre L, Angileri T, Ferrara S, Accardi M, Raineri R, and Lagalla R. (1997) The role of magnetic resonance imaging in central hearing deficits: Beyond the acoustic schwannoma. Rivista di Neuroradiologia 10:409-416.</td>
<td>MRI This study retrospectively examined 72 patients complaining of different clinical syndromes and SNHL or different kinds of acoustic impairment who underwent MRI brain study excluding the presence of acoustic schwannoma and other CPA masses. In conclusion, although AN was the most common cause of acquired hearing deficit, a lesion involving the neural centres of the acoustic pathway can also determine SNHL. Considering the high sensitivity of MRI in the detection of acoustic intra-axial pathway lesions, an in-depth MRI examination of the brain stem and the temporal lobe is mandatory when SNHL occur in patients not affected by acoustic schwannoma.</td>
</tr>
<tr>
<td>Levy RA and Arts HA. (1996) Predicting neuroradiologic outcome in patients referred for audiovestibular dysfunction. American Journal of Neuroradiology 17:1717-1724.</td>
<td>Audiovestibular testing and MRI This study retrospectively reviewed the neuroimaging studies, results of audiometric and vestibular testing, and medical records of 118 patients to rule out AN. Patients' presentation and results of audiometric and vestibular testing were associated with either a positive or negative neuroimaging outcome. Clinical presentation and audiovestibular testing could not sensitively predict the outcome of neuroimaging in our cohort of patients referred for audiovestibular dysfunction.</td>
</tr>
<tr>
<td>Stack JP, Ramsden RT, Antoun NM, Lye RH, Isherwood I, and Jenkins JP. (1988) Magnetic resonance imaging of acoustic neuromas: the role of gadolinium-DTPA. The British Journal of Radiology 61:800-805.</td>
<td>Gd-MRI MRI was performed in 20 patients with evidence on CT of 21 ANs before and after intravenous administration of gadolinium-diethylene-triamine-pentaacetic acid (Gd-DTPA). The authors concluded that MRI with gadolinium-DTPA is a relatively quick, safe, well tolerated and effective method for the diagnosis of AN.</td>
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Table 4  
Summary of retrospective cohort studies (continued)

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<th>References</th>
<th>Abstract / Summary</th>
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This retrospective study is aimed to assess the diagnostic efficacy of MRI in relation to contrast enhanced CT and air-CT-cisternography. The results suggested that MRI was the best non invasive technique for demonstrating ANs. |
This paper describes the incidence of AN presenting as sudden hearing loss (SHL) and the effectiveness of the discrimination (DISC) test, the brainstem-evoked response, and acoustic reflex (AR) test in predicting AN in patients with SHL. The DISC test is a useful screening tool for acoustic tumour, whereas the brainstem-evoked response test shows poorer results in affected patients with sensorineural hearing loss than in other subgroups with different signs of AN. Authors recommend that young patients presenting with mild SHL who have normal results on the AR and brainstem-evoked response tests undergo MRI to rule out CPA tumour. |

Abbreviations: ABR, audio brainstem response; AN, acoustic neuroma; ASNHL, asymmetric sensorineural hearing loss; CPA, cerebellopontine angle CT; computed tomography; DISC, discrimination; ENT, ear nose throat; IAM, internal auditory meatus; MRI, magnetic resonance imaging; SNHL, sensorineural hearing loss; SHL, sudden hearing loss; SR, stapedius reflex; X-p, X-ray.

Reviews, patient management or clinical practice papers

Of the 53 included citations, 15 were grouped under review, patient management, or clinical practice associated with the diagnosis of AN. The reference for the publication and a brief summary of the study is provided below in Table 5. Where possible, similar publications have been grouped together.

Table 5  
Summary of publications classified as a review, patient management or clinical practice paper

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<th>Reference</th>
<th>Abstract/Summary</th>
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ANs can now be detected when they are small, and early microsurgical removal results in the lowest overall morbidity. These authors examine the historical development of AN management; discuss current diagnosis and treatment, and present illustrative cases from recent experience. Complaints of tinnitus and hearing loss, especially when unilateral, require appropriate medical evaluation. |
This paper reviews the clinical features of hearing loss which suggest that imaging is warranted. The imaging features of the main causes of sensorineural deafness are reviewed, with particular focus on imaging vestibular schwannoma. The pathologies that result in tinnitus overlap with those causing sensorineural deafness. This article pays particular attention to the imaging of tinnitus caused by glomus tumours and vascular causes, such as aberrant vessels and arteriovenous malformations. |
Table 5  Summary of publications classified as a review, patient management or clinical practice paper (continued)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Abstract/Summary</th>
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<tr>
<td>Swartz JD. (2004) Lesions of the cerebellopontine angle and internal auditory canal: diagnosis and differential diagnosis. <em>Seminars in ultrasound, CT, and MR</em> 25:332-352.</td>
<td>Diagnostic review (R) There is a wide variety of differential diagnostic possibilities that must be considered when viewing images of patients with sensorineural hearing loss, vertigo, and dizziness. This communication was intended to provide the reader with an approach to this problem. Detailed anatomy of the region is also included in this communication.</td>
</tr>
<tr>
<td>Vossough A. (2003) Imaging evaluation of sensorineural hearing loss. <em>Applied Radiology</em> 32:6-14.</td>
<td>Diagnosis and management (PM) This article reviews the diagnosis and management of hearing loss with a particular focus on imaging findings in patients with SNHL.</td>
</tr>
<tr>
<td>Spoelhof GD. (1995) When to suspect an acoustic neuroma. <em>American Family Physician</em> 52:1768-1774.</td>
<td>Diagnosis and treatment (PM) This publication reviews diagnosis and treatment for patients with suspected AN. Patients with ASNHL or unilateral tinnitus should be evaluated expeditiously to prevent further neurologic damage. Gadolinium-enhanced MRI is the best tool for making the diagnosis of AN. Surgical removal using a translabyrinthine approach is the favoured treatment, although radiation therapy and expectant management may be chosen for patients at high surgical risk.</td>
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<tr>
<td>Obholzer RJ and Harcourt JP. (2004) Magnetic resonance imaging for vestibular schwannoma: analysis of published protocols. <em>The Journal of Laryngology and Otology</em>. 118:329-332.</td>
<td>Protocol for MRI selection (CP) This study seeks to define the most appropriate guidelines for selection of patients for MRI to exclude a vestibular schwannoma. All MRIs of the internal auditory meatus, performed during 2000, were reviewed. Further details are provided under the Key Publications section.</td>
</tr>
<tr>
<td>Sheppard IJ, Milford CA, and Anslow P. (1995) MRI in the detection of acoustic neuromas - a suggested protocol for screening. <em>Clinical Otolaryngology &amp; Allied Sciences</em> 21:301-304.</td>
<td>Protocol for MRI selection (CP) Authors suggest, based on a retrospective review of AN cases, that the entry protocol for MRI screening be limited to patients up to 70 years of age presenting with unilateral audiovestibular symptoms in the absence of significant neurological symptoms or signs, with an average difference in hearing threshold of 15 dB between normal and symptomatic ears or unilateral tinnitus with normal hearing. Further details are provided under the Key Publications section.</td>
</tr>
<tr>
<td>Thomsen J and Tos M. (1993) Management of acoustic neuromas. <em>Annales d’Oto-Laryngologie et de Chirurgie Cervico-Faciale</em> 110:179-191.</td>
<td>Protocol for screening (CP) A survey of the management of ANs in the broadest sense is given. The paper recommends all patients with hearing better than 70-80 dB should be subjected to ABR audiometry, and if there is any doubt about the normality of the response, the patient should proceed to MRI. Patients with poor hearing should go directly to MRI. The advantages and disadvantages of the different surgical approaches are described and an electric treatment algorithm is outlined.</td>
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<tr>
<td>Kanzaki J, Ogawa K, Tsuchihashi N, Yamamoto M, Ogawa S, and Uchi T. (1991) Diagnostic procedure for acoustic neuroma. <em>Acta Oto-Laryngologica, Supplement</em> 487:114-119.</td>
<td>Protocol for screening (CP) The authors' diagnostic procedure for unilateral AN and the reasoning behind it are explained. At present, pure tone audiometry and simple radiographic imaging of the internal auditory canal are first carried out. Then, if the hearing level (average hearing at 4 kHz and 8 kHz) is 70 dB or lower, ABR audiometry is carried out. If it is 71 dB or higher, the patient is examined by MRI or CT. Contrast-enhanced CT is carried out when MRI is not available.</td>
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### Table 5

**Summary of publications classified as a review, patient management or clinical practice paper (continued)**

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<th>Abstract/Summary</th>
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This paper reviews current protocol for preliminary screening for AN. The current method is a combination of caloric tests, tomography of the internal auditory meati and ABR audiometry with 2 positive results indicating the need for further investigation. This protocol, although sensitive, lacks specificity and results in a high incidence of normal CT air metagrams. Authors’ devised a weighted system of scoring to avoid subjecting large numbers of normal patients to CT air metagrapy. The proposed system was derived from screening 61 patients with unilateral sensorineural hearing loss, 24 of whom had an AN. This method reduced the false positive rate of CT air metagrapy from 68%, using the 2 out of 3 criteria, to 18%, whilst the false negative incidence remained at 8%. |
This article reviews the investigation of patients presenting with unilateral auditory symptoms including the diagnosis and treatment of abnormalities. |
This review looks at the early detection of vestibular schwannoma. Treatment of smaller tumours results in better outcomes. Advances in imaging, in particular the refinement of MRI techniques, have been responsible for the detection of smaller tumours with near 100% sensitivity. The ABR, previously the mainstay of screening, has been superseded in this role. The optimal protocol for patients suspected of a having a vestibular schwannoma is an MRI scan. |
A clinical practice study surveying New Zealand otorhinologist was conducted. Results indicated the preferred initial screening modality for diagnosing vestibular schwannoma is MRI. 57% proceed direct to MRI, 24% use ABR audiometry and/or CT to select for MRI, and 17% rely upon their clinical judgement supported by investigations such as speech audiometry, acoustic reflex thresholds and ABR audiometry before requesting further investigation. Further details are provided under the Key Publications section. |
This paper discusses audiological examinations in the diagnosis of AN. This paper proposes the most sensitive audiological examination is ABR audiometry. Its most useful parameter is the IT5. A U-shaped audiometric configuration suggests AN, since it is seen in 10% of patients with small tumours. Psychological audiometric tests can be excluded from the battery of screening tests since they have low rates of positive diagnosis. Nevertheless, the SR test can be employed as a screening device in cases in which the hearing level at 2 kHz and lower is 70 dB or lower, even if it is 71 dB or higher at 4 kHz and 8 kHz. |

Abbreviations: ABR, audio brainstem response; AN, acoustic neuroma; ASNHL, asymmetric sensorineural hearing loss; (CP) = clinical practice; CT, computed tomography; dB, decibel; KHZ, kilohertz; MRI, magnetic resonance imaging; (PM) = patient management; (R) = review; SNHL, sensorineural hearing loss; SR, stapedius reflex.
Cost based studies

Retrieved citations that mentioned costing, cost containment or cost-effectiveness in the diagnosis of AN were grouped together. These papers were identified through the clinical literature search and are shown below in Table 6. These studies have been further grouped by the type of screening intervention. The country that the study was conducted in has also been shown in the reference column of the table.

### Table 6  Summary of cost based studies

<table>
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<th>Reference</th>
<th>Abstract / Summary</th>
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<tr>
<td><strong>ABR and MRI</strong></td>
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<tr>
<td>Rupa V, Job A, George M, and Rajshekhar V. (2003) Cost-effective initial screening for vestibular schwannoma: auditory brainstem response or magnetic resonance imaging? Otolaryngology--head and neck surgery: official journal of American Academy of Otolaryngology-Head and Neck Surgery 128:823-828.</td>
<td><strong>ABR + Gd-MRI</strong> This study aimed to determine the cost-effectiveness of including ABR testing in a screening protocol for the diagnosis of vestibular schwannoma. Patients were investigated prospectively with both ABR and gadolinium-enhanced MRI (GdMRI). A protocol involving screening of all patients with asymmetric audiovestibular symptoms using ABR and only subjecting those patients with no responses or retrocochlear pathology to GdMRI would effect a savings of $1200 for every patient detected to have a VS. Further details are provided under the Key Publications section.</td>
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<tr>
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<td>Country of study: United States of America</td>
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<tr>
<td>Cheng G, Smith R and Tan AK. (2003) Cost comparison of auditory brainstem response versus magnetic resonance imaging of acoustic neuroma. <em>J Otolaryngol</em> 32(6):394-399.</td>
<td><strong>ABR + MRI/CT</strong> The cost-effectiveness of current diagnostic approaches employed in patients with suspected AN was evaluated. Currently, patients with signs and symptoms suggestive of AN, such as sudden unilateral hearing loss and/or tinnitus, undergo ABR screening tests to rule out this condition. If the ABR is normal, AN can be ruled out. However, if the ABR is abnormal, MRI or CT is necessary to confirm the diagnosis. The total costs of this approach were compared with the estimated costs of straight MRI screening performed on the same patient population.</td>
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<td>Country of study: United States of America</td>
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<tr>
<td>Robinette MS, Bauch CD, Olsen WO, and Cevette MJ. (2000) Auditory brainstem response and magnetic resonance imaging for acoustic neuromas: costs by prevalence (Brief record). <em>Archives of Otolaryngology. Head and Neck Surgery</em> 126:963-966.</td>
<td><strong>Gd-MRI vs ABR + Gd-MRI</strong> To compare hypothetical costs for identification of ANs when using MRI with gadolinium Gd 64 (MRI-(64)Gd) as a sole diagnostic test and when using ABR testing followed by MRI-(64)Gd (ABR + MRI-(64)Gd) for those with positive ABR findings. Authors concluded decisions regarding assessment of patients at risk for ANs must be made on a case-by-case basis. Use of ABR + MRI-(64)Gd allows considerable savings when patients are in the intermediate- or low-risk subgroups. New MRI and ABR testing techniques offer promise for reducing costs.</td>
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<td>Country of study: United States of America</td>
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<td>Reference</td>
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<td>Urben SL, Benninger MS, and Gibbens ND. (1999)</td>
<td>A retrospective study of all patients with ASNHL who were evaluated in a community-based general otolaryngology practice was performed. ASNHL was present in 325 patients The charge of diagnosis per AN was more than $41,000. In summary, a small percentage of patients with ASNHL have retrocochlear pathology, and the charge of diagnosis per AN can be excessive. A cost-containment approach for the evaluation and management of patients with ASNHL is proposed. Further details are provided under the Key Publications section.</td>
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<td>Country of study: United States of America</td>
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**MRI**

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<td>Murphy MR and Selesnick SH. (2002)</td>
<td>This study aimed to define the most sensitive techniques of AN diagnosis, to examine their relative costs, and to propose diagnostic modality selection given the rarity of AN incidence and given the other costs that society faces in more commonly encountered diseases. The review found that although MRI with gadolinium remains the most sensitive diagnostic modality in the discovery of AN, its cost may be prohibitive for some societies. The study suggested the modality to use in AN diagnosis is just as much a philosophical and macroeconomic question as a technological one. The cost of a timely diagnosis of ANs must be weighed against using resources for other, more pressing, health concerns.</td>
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<td>Verret DJ, Adelson R, and Defatta R. (2006)</td>
<td>The goal of this study was to determine if fast spin echo T2 MRI is similar to gadolinium-enhanced MRI in evaluating ASNHL in a county hospital population. This was a retrospective chart review of all outpatients who underwent gadolinium-enhanced MRI. Cost savings of over $100 000 would have been realised if only T2 FSE protocols had been used. Further details are provided under the Key Publications section.</td>
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<td>Daniels RL, Shelton C, and Hamsberger HR. (1998)</td>
<td>Cost analysis was done in the cases of 58 patients with sudden SNHL by comparing the costs for routine workup and screening of AN with the cost of fast spin echo MRI with the use of screening protocols based on literature review. The potential cost savings of evaluating patients with SSHL with fast spin echo MRI for AN was substantial, with a 54% reduction in screening costs. Authors state that fast spin echo MRI has become the most cost-effective method to screen suspected cases of AN at their institution. This is due to improved technology at reduced cost and through eliminating charges for impedance audiometry, ABR testing, and contrast-enhanced MRI.</td>
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<td>Country of study: United States of America</td>
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**Table 6**  
**Summary of cost based studies (continued)**
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<th>Reference</th>
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<tr>
<td>Carrier DA and Arriaga MA. (1997) Cost-effective evaluation of asymmetric sensorineural hearing loss with focused magnetic resonance imaging (Structured abstract), Otolaryngology. Head and Neck Surgery 116:567-574.</td>
<td><strong>T1 and T2 MRI</strong> This paper developed a focused MRI sequence for evaluation of patients with ASNHL. The protocol includes a T1-weighted sagittal, pregadolinium and postgadolinium T1-weighted 3-mm contiguous axial slices through the internal auditory canal and the region of the cerebellopontine angle, and T2-weighted axial images through the entire brain. Total scanning time was about 12 minutes, and the estimated cost was $300 to $500. Authors suggested that by eliminating the need for follow-up audiometric or electrophysiologic studies, a focused MRI-based diagnostic scheme is more cost-effective on a cost-per-patient basis.</td>
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<tr>
<td>Country of study: United States of America</td>
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<td>Ravi K, V and Wells SC. (1996) A cost effective screening protocol for vestibular schwannoma in the late 90s (Brief record), Journal of Laryngology. and Otology. 110:1129-1132.</td>
<td><strong>MRI</strong> In a retrospective study, the clinical records of all the patients who presented to the ENT department of Taunton and Somerset NHS Trust with suspected symptoms of VS during the year 1994 were analysed. The cost of confirming or refuting the diagnosis of VS in each patient ranged from £220.72 to £580.31 depending on the number of hospital visits and investigations performed. This study shows that the routine use of MR scanning for detection of VS is cost effective and more effective than the use of conventional tests.</td>
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<td>Country of study: United Kingdom</td>
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<td>Allen RW, Harnsberger HR, Shelton C, King B, Bell DA, Miller R, Parkin JL, Apfelbaum RI, and Parker D. (1996) Low-cost high-resolution fast spin-echo MR of acoustic schwannoma: An alternative to enhanced conventional spin-echo MRI American Journal of Neuroradiology 17:1205-1210.</td>
<td><strong>FSE-MRI vs T1W-MRI</strong> This paper reviewed the records of 25 patients with pathologically documented acoustic schwannoma and 25 control subjects, all of whom had undergone both enhanced conventional spin-echo MRI and unenhanced fast spin-echo MRI of the cerebellopontine angle/internal auditory canal region. They found no statistically significant difference in the sensitivity and specificity of unenhanced high-resolution fast spin-echo imaging and enhanced T1-weighted conventional spin-echo imaging in the detection of acoustic schwannoma. Authors concluded that the unenhanced high-resolution fast spin-echo technique provides a cost-effective method for the diagnosis of acoustic schwannoma.</td>
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<td>Country of study: United States of America</td>
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<td>Robson AK, Leighton SE, Anslow P, and Milford CA. (1993) MRI as a single screening procedure for acoustic neuroma: a cost effective protocol. Journal of the Royal Society of Medicine 86:455-457.</td>
<td><strong>Audiovestibular investigations vs MRI</strong> A prospective study was set up in a specially designated screening session to audit the cost effectiveness and accuracy of audiovestibular investigations compared to MRI. The total cost of the audiovestibular protocol was £12,545 compared to £12,900 for the MRI protocol, which is a diagnostic and well-tolerated procedure. This study shows that MRI can be cost effective, as well as accurate, when used as a single screening procedure for ANs.</td>
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### Table 6  Summary of cost based studies (continued)

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**Country of study:** Canada  

**Country of study:** NA  

### Abbreviations:
- ABR: audio brainstem response  
- AN: acoustic neuroma  
- ASNHL: asymmetric sensorineural hearing loss  
- CT: computed tomography  
- dB: decibel  
- ENT: ear nose throat  
- FSE: fast spin echo  
- GdMRI: gadolinium enhanced MRI  
- MRI: magnetic resonance imaging  
- NA: not available  
- NHS: National Health Service  
- SNHL: sensorineural hearing loss  
- VS: vestibular schwannoma

### Key publications

A selection of citations, which appeared to have the most relevance for the topic of interest were requested in full text. Further detail of each study is provided below.

**Positive findings on MRI in patients with asymmetrical SNHL (Mahrous and Kalepu 2008)**

This was a retrospective study of 100 patients who attended an ENT outpatient clinic in a six month period in 2006. All patients presented with ASNHL. The case notes of patients audiograms and symptoms, on which the decision to scan with MRI was made, were reviewed. There were no guidelines or protocols employed as to when to request MRI. The mean age of participants was 53 years and there were 53% males and 47% females. There was one patient diagnosed with acoustic neuroma which equates to a pick up rate of 1%, a figure lower than that published in other series. The patient diagnosed with AN was a 61 year old male, with gradual right SNHL for 3 years. The MRI showed a 18 x 16mm lesion in the right internal acoustic meatus displacing the cerebellum and pons. The authors suggest universal screening for AN is debatable due to the low pick up rate and high expense of MRI. They suggest applying a protocol to select patients for MRI is worth considering.

**Screening patients with sensorineural hearing loss for vestibular schwannoma using a Bayesian classifier (Nouraei et al. 2007)**

This study retrospectively examined records of 129 patients with a proven diagnosis of vestibular schwannoma based on MRI scans, and an equal number of patients in whom this diagnosis was suspected, but excluded on MRI. There were 130 males and 128 females and the average age at presentation was 53 ± 15 years (± sd; range 16–97 years). On direct questioning, 121 patients (46%) reported unilateral tinnitus and 79 (30%) episodic vertigo. There were significant overlaps in the degree of hearing threshold asymmetry between patients with and without a vestibular schwannoma across all frequencies. A Gaussian Process Ordinal Regression Classifier was used to predict the likelihood of a patient having or not having a vestibular schwannoma on
the basis of clinical and audiological data. Variables used for analysis included pure tone thresholds at 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz at the time of presentation, as well as patient age and sex, and the presence or absence of unilateral tinnitus or episodic vertigo. The study proved it possible to pre-select sensitivity and specificity, with an area under the curve of 0.8025. At 95% sensitivity, the trained system had a specificity of 56%, 30% better than audiological protocols with closest sensitivities. Authors concluded that if applied prospectively, it could reduce the number of ‘normal’ MRI scans by as much as 30% without reducing detection sensitivity.

Asymmetric sensorineural hearing loss evaluation with T2 FSE-MRI in a public hospital (Verret et al. 2006)

The records of patients with ASNHL presenting in a country hospital who underwent MRI evaluation were examined. As part of the screening process, a GD-enhanced MRI scan sequence was obtained; however this also included a non-GD-enhanced FSE T2 sequence. A total of 146 patients were identified with patients ranging from 20–84 years with a mean age of 55 years. There were 56 male and 90 female patients. Of the 146 MRI scans performed, abnormalities were seen on 71 of them, the majority of which were inconsequential (e.g. sinonasal disease, gray/white matter changes, and previous cerebrovascular disease or intracranial procedures). However, none of the abnormalities were retrocochlear or explained the etiology of the audiological findings. The authors estimated that the cost of GD-enhanced MRI was US$1200, with a T2 FSE protocol costing about $415. For this study population, a saving of US$114 610 would have been realised if only a T2 FSE protocol had been used. The authors concluded that T2-weighted FSE can be economically beneficial for screening patients with ASNHL without other neurological findings in a public hospital population.

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Magnetic resonance imaging for the evaluation of asymmetric sensorineural hearing loss (Cueva 2004)

This was a multi-institutional, prospective, non-randomised comparison of ABR and MRI with gadolinium for the evaluation of patients with ASNHL (defined as ≥15 dB in 2 or more pure tone thresholds or an asymmetry of ≥15% on speech discrimination score). There were 312 patients (between the ages of 18 and 87 years) who completed the study. Patients prospectively underwent both ABR and MRI with the primary outcome being the presence or absence of retrocochlear pathology. The results of the two screening tests are shown below in Table 7.

Table 7  
Results of MRI and ABR screening tests

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<th>MRI + Causative lesion</th>
<th>MRI - Causative lesion</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABR Abnormal</td>
<td>22</td>
<td>73</td>
<td>95</td>
</tr>
<tr>
<td>ABR Normal</td>
<td>9</td>
<td>208</td>
<td>217</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>281</td>
<td>312</td>
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</table>

Thirty-one (9.94%) patients of the study population of 312 were found on MRI to have lesions causing their SNHL. Of the 31 patients with causative lesions on MRI there were 24 vestibular schwannomas. Twenty-two of the 31 patients had abnormal ABRs, whereas 9 patients (7 with small vestibular schwannomas) had normal ABRs. This gives an overall false-negative rate for ABR of 29%. The false-positive rate was found to be 77%. Sensitivity of ABR as a screening test was 71%, and specificity was 74%. The ABR positive predictive value was 23% and negative predictive value was 96%. ABR was been demonstrated to have low sensitivity and specificity in the evaluation of these patients and cannot be relied on as a screening test for patients with asymmetric SNHL. Keeping the use of MRI conditional on the results of ABR will annually result in missed or delayed diagnosis of causative lesions in 29 patients per 1,000 screened. The author recommends abandoning ABR as a screening test for asymmetric SNHL and adoption of a focused MRI protocol as the screening test of choice.

Screening for vestibular schwannoma: current practice in New Zealand (Dawes 1999)

This study reported the results of a questionnaire survey of New Zealand otolaryngologists. Sixty seven questionnaires were sent. Forty-two replies were received, three other replies indicated that the member had retired from clinical practice. The results indicated that 41 clinicians preferred MRI testing for screening for AN. However, only 29 had locally available imaging equipment. Twenty-four clinicians used MRI as their first screening test, 10 used ABR and then MRI, 7 used clinical judgement and other investigations and one used CT scanning only. The survey also indicated that many clinicians still use ABR and CT as a preliminary screen to select for MRI because of financial or local political reasons. The author believes New Zealand would be best served by a single set of vestibular schwannoma screening guidelines.
MRI in the detection of acoustic neuromas - a suggested protocol for screening (Sheppard 1996)

During the period September 1990 to September 1993, 920 requests for MRI imaging of the IAM or cerebellopontine angle were made within the Oxford region. A total of 892 scans were successfully carried out. The symptoms of ENT patients scanned from the Oxford Department of Otolaryngology included sudden and gradual sensorineural hearing loss, tinnitus, vertigo, otalgia. Facial numbness and facial palsy. The decision to scan was based on the presence of asymmetrical audiovestibular symptoms as outlined by Robson et al. (1993). Initially, all patients had sagittal and axial T, weighted interleaved images performed after the administration of gadolinium. The current scanning protocol involves only 3 mm interleaved fast spin echo T, weighted axial scans. Four millimetres T, weighted images with gadolinium-DTPA enhancement are used if there is diagnostic doubt.

Of the total number of patients scanned (n = 892), an acoustic neuroma was detected in 38 (4.26%). Of these patients, 16 were men and 22 women. Of the 38, 18 were from non-Oxford clinics, 20 from Oxford clinics. Those from the Oxford clinic all had a degree of ASNHL ranging from 15 dB to 92 dB between normal and abnormal ears. The study suggested a protocol for the selection of MRI which was: those patients up to 70 years of age presenting with unilateral audiovestibular symptoms in the absence of significant neurological symptoms or signs, with an average difference in hearing threshold of 15 dB between normal and symptomatic ears or unilateral tinnitus with normal hearing.

A prospective study of ABR and MRI in the screening for vestibular schwannomas (Ruckenstein et al. 1996)

This was a prospective study of 47 patients with ASNHL. Adult patients (18 years or older) with asymmetry in two or more pure-tone thresholds of ≥15 dB were included. The mean age of patients was 56 years with 19% older than 65 years. All patients underwent an ABR and enhanced MRI scan. ABRs were considered abnormal if they demonstrated asymmetric IT5 latencies (asymmetry >0.2ms), abnormal absolute wave V latencies, or absent or poor waveform morphology. All MRI scans were reviewed by a neuroradiologist for the presence or absence of retrocochlear disease. The authors obtained a sensitivity of 63%, specificity of 64%, positive predictive value of 26%, and negative predictive value of 89% for the ABR test. The 3 ANs missed were all less than 2 cm. The authors concluded that ABR testing was not an ideal screening test, cautioning, however, that a larger sample size would be required for confirmation of this assertion.

Cost-effective initial screening for vestibular schwannoma: auditory brainstem response or magnetic resonance imaging? (Rupa et al. 2003)

This study aimed to determine the cost-effectiveness of including ABR testing in a screening protocol for the diagnosis of AN in patients with asymmetric auditory symptoms at the Christian Medical College and Hospital, Vellore, India, where, commonly, patients with AN have tumours greater than 2 cm at the time of diagnosis. Ninety patients who presented to the ENT Department with asymmetric auditory symptoms of hearing loss and tinnitus were prospectively evaluated by pure tone audiometry, ABR testing, and gadolinium-enhanced MRI (GdMRI) of the temporal bone and brain. Of a total of 90 patients enrolled in the study, 56 were males and 34
females (age range, 15 to 66 years). Of the 30 patients who were found to have retrocochlear pathology on ABR, 4 patients were diagnosed as having AN.

The study indicated that the cost of GdMRI was approximately 15 times the cost of ABR. Thus, if all 90 patients had undergone GdMRI alone, the total cost of investigation would have been $18,000. If only the 48 patients who had either no response or evidence of retrocochlear pathology on ABR underwent GdMRI, the cost of screening would have been $9,600. Therefore, a protocol involving screening all patients with ABR and only subjecting those patients with no response or retrocochlear pathology on ABR to MRI would save up to $7,200 in total. Because 6 patients with AN were identified, the saving in cost per patient diagnosed correctly was $1,200. This would be the approximate total cost of having the tumour surgically excised at this hospital. The authors concluded that the financial burden of identifying patients with AN could be considerably reduced with a screening protocol including ABR.

Asymmetric sensorineural hearing loss in a community-based population (Urben et al. 1999)

This was a 5-year retrospective study that examined patients older than 17 years with ASNHL (defined as an interaural difference in pure-tone thresholds ≥10 dB at 2 frequencies or ≥15 dB at 1 frequency. The study also conducted a cost analysis for diagnosing AN. All patients’ medical records and audiograms were reviewed for demographic, historic, and audiologic data and results from ABRs and radiologic studies. Of all the audiograms reviewed, 193 (21%) met the audiological criteria for ASNHL. Patients with ASNHL were a median age of 51 years, with 66% male and 34% female.

Among the 193 patients who had diagnostic studies, 4 were found to have ANs, for a prevalence of 2.1%. ABR tests were performed in 179 patients (55%), and 92% (164 of 179) were normal. Patients with abnormal or inconclusive ABR and patients with severe SNHL were evaluated with radiologic studies (46 patients). Of the 34 who had an MRI, 30 were normal and four were abnormal. All 19 CT scans were judged as normal.

To assess the cost of diagnosis per AN, the study determined the charges for diagnostic studies. Charges may differ from patient costs. Because audiograms were used in the inclusion criteria for the study, the charge for audiograms was excluded. The charges for diagnostic studies were multiplied by the number of studies performed, and a charge of $166,955 was incurred in identifying 4 patients with AN and ASNHL. The charge of diagnosis per AN was more than $41,000. The authors suggest a cost containment protocol for screening AN.

Published audiological screening protocols

Acoustic neuromas produce patterns of audiovestibular symptoms and in particular ASNHL, which tends to be different between patients with and without an AN. This difference has been used to develop a number of different decision-support protocols for clinicians, to assist in risk-stratifying patients, with those at higher risk being referred for an MRI. A brief description of published audiological screening protocols for AN is shown in Table 8.
### Table 8  
A description of published decision-support protocols for acoustic neuroma

<table>
<thead>
<tr>
<th>Name</th>
<th>Clinical criteria</th>
<th>Asymmetry of thresholds</th>
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<tbody>
<tr>
<td>Seattle (Mangham 1991)</td>
<td>Nil</td>
<td>≥15 dB between the average of 1-8 KHz</td>
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<tr>
<td>Charing cross (Obholzer et al. 2004)</td>
<td>Nil</td>
<td>≥15 dB in any two neighbouring frequencies if the average hearing threshold of the better ear ≤30 dB≥20 dB in any two neighbouring frequencies if the average hearing threshold of the better ear &gt;30 dB</td>
</tr>
<tr>
<td>Nashville (Welling et al. 1990)</td>
<td>Nil</td>
<td>≥15 dB at any frequency between 0.5 and 4 KHz</td>
</tr>
<tr>
<td>Oxford (Sheppard et al. 1996)</td>
<td>Unilateral tinnitus, age &lt; 70 years</td>
<td>≥15 dB between the average of 0.5 to 8 KHz</td>
</tr>
<tr>
<td>UK Department of Health (2002)</td>
<td>Vertigo</td>
<td>≥20 dB at any frequency between 0.5 and 4 KHz</td>
</tr>
<tr>
<td>Sunderland (Dawes et al. 1998)</td>
<td>Unilateral tinnitus or Meniere's disease symptoms</td>
<td>≥20 dB between two neighbouring frequencies</td>
</tr>
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</table>

Source: Nouraei et al. (2007), Table 1 page 251.

None of these protocols are universally accepted for screening AN in patients with ASNHL.
Summary and Recommendations

Conclusions
This preliminary report presents the evidence for the early detection of AN using MRI or other comparative diagnostic techniques in patients with ASNHL, albeit without critical appraisal. It appears there is a significant clinical argument to support the routine use of MRI. The test has been reported to have high sensitivity and specificity, higher than that of the ABR test. However, the widespread use of MRI in this patient population is problematic due to the high cost per diagnosis of AN (attributed to the high cost of MRI and low incidence rate of AN in ASNHL presenting patients), and issues surrounding accessibility to MRI equipment. Most papers suggest a protocol or guidelines be implemented to help select patients for MRI screening. However this approach accepts that there is a trade-off between cost efficiency, and the risk of missing some tumours.

Points to consider
As mentioned previously there is a systematic review due for publication by the NIHR in April 2009 titled:

‘The role of magnetic resonance imaging in the identification of suspected acoustic neuroma: systematic review of clinical and cost effectiveness, and natural history’

Alternatively a full systematic review could be considered on the use of MRI in screening patients with ASNHL for the early detection of AN.
Screening in ASNHL for acoustic neuroma
References


Screening in ASNHL for acoustic neuroma
Appendix A: HTA websites searched

HTA and systematic review databases to be searched for this project are:

- Health Technology Assessment Database (via the Cochrane Library):
  http://www3.interscience.wiley.com/cgi-bin/mrwhome/106568753/HOME

- INAHTA website database:
  http://www.inahta.org/Search2/?pub=1
  Note: Can search database and gain access to individual member websites.

Individual HTA groups:
- NZHTA: http://nzhta.chmeds.ac.nz/
- NICE: http://www.nice.org.uk/
- AHRQ/USPSTF: http://www.ahrq.gov/
- CADTH: http://www.cadth.ca/
Appendix B: Excluded studies annotated by reason for exclusion


**Reason for exclusion:** Incorrect study type


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Borg E and Lofqvist L. (1982) Auditory brainstem response (ABR) to rarefaction and condensation clicks in
normal and abnormal ears.  
Scandinavian Audiology 11:227-235.

**Reason for exclusion:** Incorrect patient population

Hinojosa R and Marion M. (1983)  

**Reason for exclusion:** Incorrect patient population

Jerger S and Jerger J. (1983)  

**Reason for exclusion:** Incorrect patient population


**Reason for exclusion:** Incorrect patient population

*Laryngoscope* 95:505-514.

**Reason for exclusion:** Incorrect patient population


**Reason for exclusion:** Incorrect patient population

Campbell KCM and Abbas PJ. (1987)  
The effect of stimulus repetition rate on the auditory brainstem response in tumor and nontumor patients.  

**Reason for exclusion:** Incorrect patient population

Interactions of age, gender, and sensorineural hearing loss on ABR latency.  

**Reason for exclusion:** Incorrect patient population

Evoked oto-acoustic emissions from adults and infants: Clinical applications.  

**Reason for exclusion:** Incorrect patient population

Tsirulnikov EM, Vartanyan IA,  
Gersuni GV, Rosenblyum AS, Pudov VI, and Gavrilov LR. (1988)  
Use of amplitude-modulated focused ultrasound for diagnosis of hearing disorders.  

**Reason for exclusion:** Incorrect patient population

Silverstein H, Norrell H, Smouha E,  
and Haberkamp T. (1988)  
The singular canal: A valuable landmark in surgery of the internal auditory canal.  

**Reason for exclusion:** Incorrect patient population

Dolan KD and Yuh WTC. (1989)  
Gadolinium-enhanced facial nerves:  
Accompanying bilateral acoustic tumors in a patient with neurofibromatosis.  

**Reason for exclusion:** Incorrect patient population

Almqvist U, Almqvist B, and Jonsson KE. (1989)  
Phase audiometry - A rapid method for detecting cerebello-pontine angle tumours.  
*Scandinavian Audiology* 18:155-159.

**Reason for exclusion:** Incorrect patient population

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Sugimoto T, Tsutsumi T, Noguchi Y, Tsunoda A, Kitamura K, and


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Screening in ASNHL for acoustic neuroma

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Gonul E, Izci Y, and Onguru O. (2007) Arachnoid cyst of the cerebellopontine angle associated with gliosis of the

Reason for exclusion: Incorrect disease


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Bu-Saba NY, Rebeiz EE, Salman SD, Thornton AR, and West C. (1994) Significance of false-positive auditory...
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