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MRI screening for acoustic neuroma: a comparison of fast spin echo and contrast enhanced imaging in 1233 patients

[1]I A ZEALLEY, FRCR, [1]R C COOPER, MBBS, [2]K M A CLIFFORD, FRCR, [2]R S D CAMPBELL, FRCR, [3]A J POTTERTON, FRCR, [1]I ZAMMIT-MAEMPEL, FRCR, [1]C J BAUDOUIN, FRCR and [3]A COULTHARD, FRCR

[1]*Department of Radiology, Freeman Hospital, Freeman Road, Newcastle upon Tyne, NE7 7DN,* [2]*Department of Radiology, South Cleveland Hospital, Marton Road, Middlesbrough TS4 3BW and* [3]*Department of Radiology, Royal Victoria Infirmary, Queen Victoria Road, Newcastle upon Tyne, NE1 4LP, England*

Abstract. Gadolinium enhanced MRI is the gold standard investigation for the detection of acoustic neuroma. Non-contrast MRI sequences have been suggested as an alternative for screening examinations. In order to determine the utility of fast spin echo imaging, both gadolinium enhanced T_1 weighted images and fast spin echo T_2 weighted images were acquired in 1233 consecutive patients referred for exclusion of acoustic neuroma. Two radiologists independently recorded their findings. Fast spin echo T_2 weighted images were evaluated with respect to the visibility of nerves within the internal auditory canals and allocated a confidence score for the presence or absence of acoustic neuroma. 33 acoustic neuromas were identified. Only 56% were confidently identified on fast spin echo T_2 weighted images alone; gadolinium enhanced T_1 weighted images were required to confirm the diagnosis in 44% of the cases, including 9 of the 10 intracanalicular tumours. However, when identification of two normal intracanalicular nerves is employed as the criterion of normality, the single fast spin echo T_2 weighted sequence excluded acoustic neuroma in 59% of this screened population. It is concluded that an imaging strategy intended to identify small intracanalicular acoustic neuromas cannot rely on fast spin echo T_2 weighted imaging alone. Gadolinium enhanced T_1 weighted imaging could be restricted to patients where fast spin echo images do not exclude acoustic neuroma but this strategy requires continuous supervision by an experienced radiologist. In most practices the screening examination should continue to include a gadolinium enhanced sequence in order to optimize the detection of small acoustic neuromas.

Magnetic resonance imaging (MRI) has largely replaced other radiological and clinical investigations in the screening of patients with audiovestibular symptoms for the presence of acoustic neuroma [1–3]. Smaller tumours can now be detected, leading to earlier surgical intervention with improved rates of hearing preservation [4–6]. Optimal MRI protocols for the detection of acoustic neuroma include intravenous (IV) gadolinium DTPA [7, 8], but considerable savings in cost and time might be achieved if a screening strategy limiting the use of IV contrast medium was shown to be equally accurate.

Thin section fast spin echo T_2 weighted sequences are capable of clearly demonstrating the auditory nerves (Figure 1) and, on the basis of small studies, this unenhanced MRI sequence has been advocated as a screening technique for detecting acoustic neuroma [9–13]. However, the prevalence of acoustic neuroma is low, even in the presence of audiovestibular symptoms [7, 9], and studies with large numbers of patients are required for the proper assessment of alternatives to gadolinium enhanced imaging for acoustic neuroma screening [14]. We have prospectively studied over 1200 patients with suspected acoustic neuroma who were referred for MRI, and have compared the diagnoses based on thin section fast spin echo T_2 weighted sequences alone with the diagnoses based on gadolinium enhanced MRI, in order to properly evaluate the performance of this non-contrast technique in a screening setting.

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Materials and methods

Patients

1233 consecutive patients were studied prospectively over a 2-year period. All the patients had audiovestibular symptoms and were referred from otolaryngology clinics for exclusion of acoustic

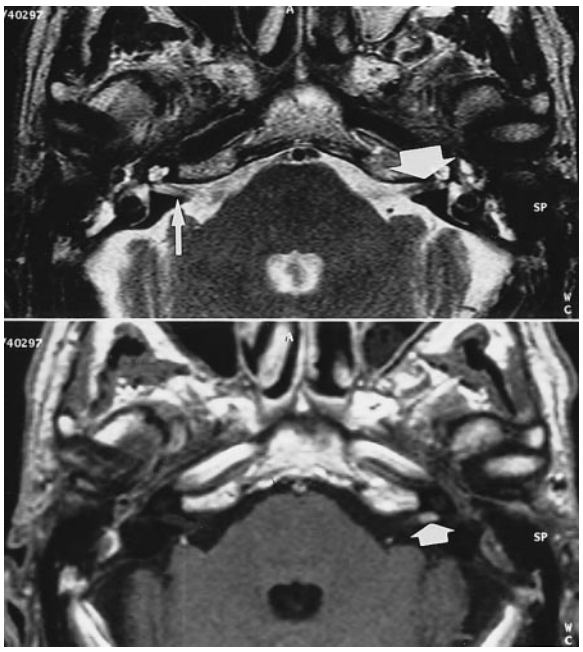

Figure 1. Axial fast spin echo T_2 weighted (top) and gadolinium enhanced T_1 weighted (bottom) images from one patient. On the right (thin arrow) there is good visualization of normal nerves within the internal auditory canal on the fast spin echo images. On the left (broad arrow) the fast spin echo images clearly demonstrate a 3 mm intracanalicular tumour arising from the vestibulocochlear nerve within the canal, manifest as a focus of abnormal enhancement on the contrast enhanced image (arrow).

neuroma. The average age was 50.6 years (median 52, range 14–81).

MRI technique

All studies were performed on 1.0 T Siemens Magnetom units (Siemens, Erlangen, Germany) at one of three MRI centres. All studies included a thin section fast spin echo T_2 weighted sequence (head coil, TR/TE=3300–4000/112–120, echo train length 15, slice thickness 3 mm, field of view 230–250 mm, matrix 210–396 × 512) and a gadolinium enhanced T_1 weighted sequence (head coil, TR/TE=450/15–17, slice thickness 3 mm, field of view 200–230 mm, matrix 192–220 × 256, with 10 ml of intravenous gadopentate meglumine (Magnevist, Schering)).

Image interpretation

Two radiologists at each centre independently recorded their findings on a standard proforma. They were not blinded to the clinical details of the patients. The fast spin echo images were read first, each radiologist recording whether or not the vestibulocochlear and facial nerves were both clearly visible within the internal auditory canal on each side. The reader then allocated a score of 1 to 5 (Table 1) for the degree of confidence with which he/she could exclude acoustic neuroma on these images. After recording their interpretation of the fast spin echo images, each radiologist then examined the gadolinium enhanced images and recorded the size and site of any acoustic neuromas that were demonstrated. The gadolinium enhanced images were regarded as the gold standard sequence for identification of acoustic neuroma.

Table 1. Confidence scores for fast spin echo images

1	Acoustic neuroma definitely not present
2	Acoustic neuroma probably not present
3	Uncertain
4	Acoustic neuroma probably present
5	Acoustic neuroma definitely present

Data were analysed by bar chart tabulation of results, by χ^2 testing for association, by κ-statistic analysis for interobserver variation and by calculation of sensitivity, specificity, false positive and false negative rates.

Results

Gadolinium enhanced images

33 acoustic neuromas were identified on gadolinium enhanced images, giving a tumour prevalence of 2.7% in the study population (centre 1: 15 tumours in 473 patients; centre 2: 15 in 484; centre 3: 3 in 276). The imaging characteristics of the 33 tumours are summarized in Table 2. 18 of these 33 patients underwent surgery. The surgical and pathological findings confirmed the diagnosis of acoustic neuroma in 17 of the 18; one 4 mm intracanalicular lesion was found on histological examination to be a meningioma. There was complete agreement between readers for the diagnosis of acoustic neuroma on gadolinium enhanced images. No tumours were detected on the contralateral side in patients with unilateral symptoms (1087/1233). Two cases of abnormal labyrinthine enhancement (Figure 2) were also identified.

Fast spin echo images

Confidence scores

The number of patients allocated by the readers to each of the five confidence levels is shown in

Table 2. Acoustic neuromas (33) identified on gadolinium enhanced imaging

	Purely intracanalicular	Predominantly extracanalicular
No.	10	23
Size range (mm)	3–12	6–58

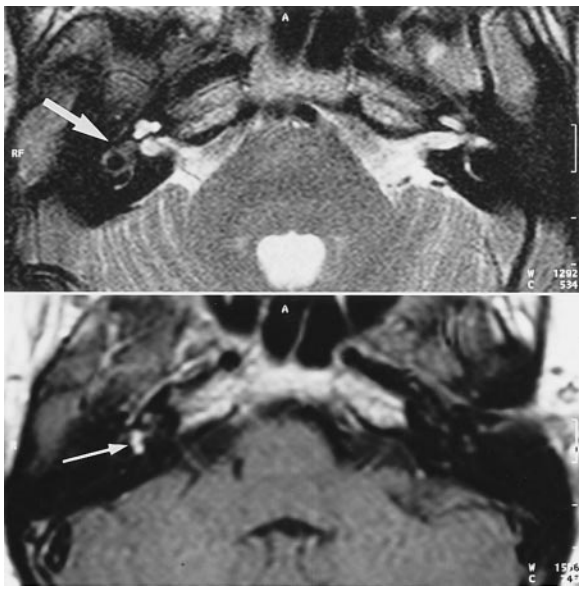

Figure 2. Axial fast spin echo T_2 weighted image (top) and gadolinium enhanced T_1 weighted image (bottom), demonstrating abnormal enhancement of the labyrinth on the right (thin arrow). This finding is associated with labyrinthitis when transient, and labyrinthine schwannomas if the enhancement persists on follow-up imaging several months later. In this particular case the labyrinthine pathology is also evident on the T_2 weighted images as abnormal signal within the labyrinth (thick arrow). However, T_2 weighted images do not always demonstrate abnormal signal in these cases.

Figure 3. The figures are based on the data from both readers (*i.e.* 2×1233 readings). Acoustic neuroma is assumed to be present if detected on gadolinium enhanced images. Figure 3 clearly demonstrates an association between a high confidence score on fast spin echo imaging and the presence of tumour (χ^2 test: association significant at $p<0.001$). Interobserver agreement for the allocation of the five confidence scores was moderate (κ, 0.476; 95% confidence interval (CI), 0.428–0.524). No tumours were identified in any case where a reader had allocated a confidence score of 1 (''acoustic neuroma definitely not present''). A confidence score of 1 was allocated to 1454 (59%) of the 2466 readings, with a range between the six readers of 45–77%.

Identification of nerves

No tumours were identified in any case where a reader had reported clear visualization of normal nerves within the internal auditory canal on the side(s) under clinical suspicion. Both nerves were reported to be clearly visible in the canal on the side(s) under clinical suspicion in 1433 (58%) of the 2466 readings, with a range between the readers of 46–74%. Interobserver agreement for the recording of satisfactory visualization of the two nerves within the internal auditory canals on

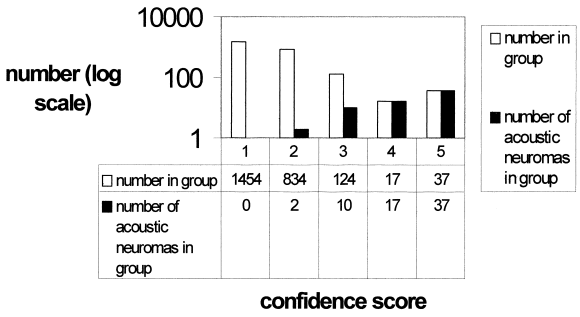

Figure 3. Confidence scores for fast spin echo T_2 weighted images.

the side(s) under clinical suspicion was good (κ, 0.636; 95% CI, 0.592–0.681).

Factors compromising diagnostic quality of fast spin echo images

All fast spin echo images that had been allocated a confidence score of 3 (''uncertain'') were reviewed. Partial volume artefact from bone was the most important factor compromising the diagnostic quality of these images, and contributed to the allocation of indeterminate confidence scores in 58% of these ''uncertain'' cases. This is a particular problem in patients with narrow internal auditory canals where there is little cerebrospinal fluid around the nerves to provide contrast within the canal (Figure 4). Artefacts generated by the flow of cerebrospinal fluid (Figure 5) and by patient movement were contributory in 35% and 21% of these indeterminate readings, respectively.

Discussion

In screening, the prevalence of acoustic neuroma is low, and appears to be falling, as clinicians increasingly forgo extensive audiovestibular investigations, preferring to refer patients directly for MRI. Only 1% of adults with sensorineural hearing loss will turn out to have acoustic neuroma, although 95% of patients with this tumour will have some deafness [7]. Despite low pick-up rates when screening for acoustic neuroma in patients with sensorineural hearing loss, contrast enhanced MRI is cost effective compared with audiovestibular investigations [15]. Recent reviews continue to advocate contrast enhanced MRI as the diagnostic test of choice in this setting [7, 8].

Some authors have suggested that cheaper, non-contrast fast spin echo imaging could largely replace contrast enhanced MRI for acoustic neuroma screening. Previous smaller studies have compared the performance of fast spin echo sequences against the benchmark of gadolinium enhanced imaging. A study of 157 patients

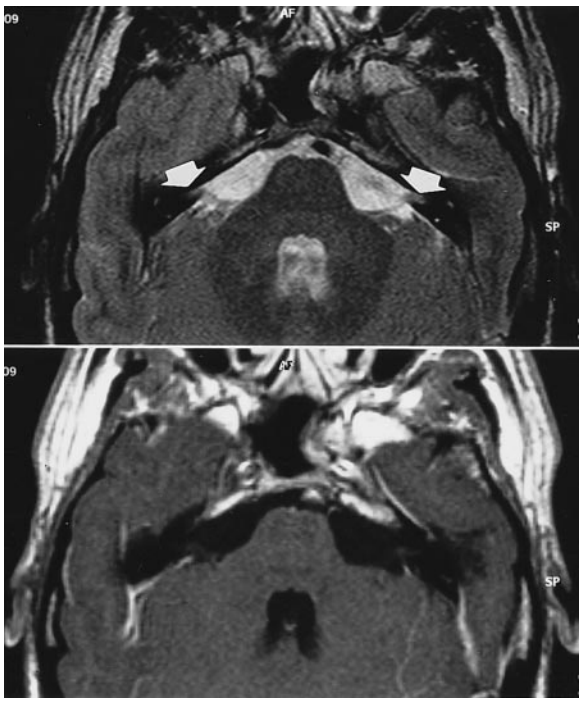

Figure 4. An axial fast spin echo T_2 weighted image (top) from a patient with narrow internal auditory canals (arrows). Visualization of the vestibulocochlear and facial nerves within the canals is dependent upon the presence of cerebrospinal fluid around the nerves, which provides the contrast on these T_2 weighted images. In such cases it is not possible to identify the normal nerves and to confidently exclude the presence of acoustic neuroma. The corresponding axial gadolinium enhanced T_1 weighted image (bottom) from the same patient, which does not demonstrate any abnormal intracanalicular enhancement, is required to exclude the presence of acoustic neuroma.

concluded that fast spin echo images alone were adequate for exclusion of acoustic neuroma in 43% of cases, with a tumour prevalence of 5.7% [9]. Another screening study of 100 patients, with a tumour prevalence of 8%, suggested that fast spin echo images might be sufficient in as many as 88% when individually tailored sequences are used for some patients [10]. More selective, non-screening studies, with tumour prevalence ranging from 47.8% to 100%, also indicated that fast spin echo imaging was potentially useful in the detection of acoustic neuroma [11–13]. Our large sample of unselected screening patients has allowed us to evaluate the performance of this alternative to contrast enhanced imaging in a typical clinical setting.

Performance of fast spin echo imaging

In this study, only 56% of tumours were confidently identified on fast spin echo imaging and allocated the highest possible confidence score by the reader. The remainder were allocated intermediate confidence scores, by one or both readers: nine of the 10 intracanalicular tumours

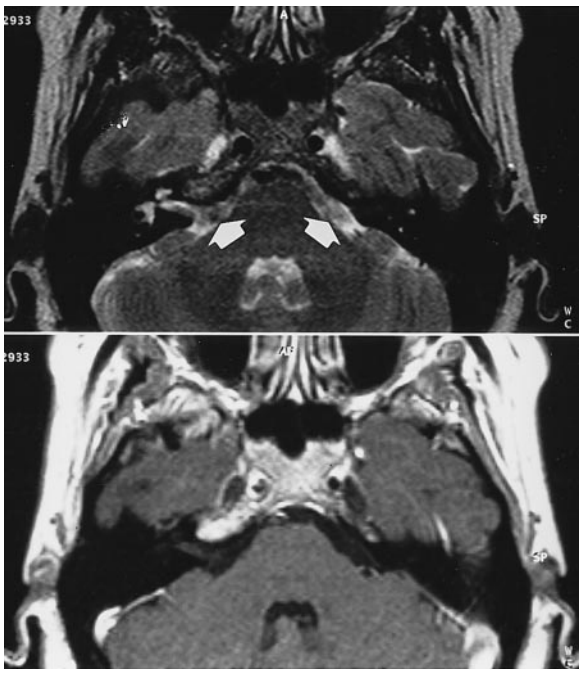

Figure 5. An axial fast spin echo T_2 weighted image (top) demonstrating the irregular low signal artefact in the cerebellopontine angles caused by turbulent flow of cerebrospinal fluid (arrows). This artefact may obscure a small lesion at the porus of the internal auditory canal. The corresponding axial gadolinium enhanced T_1 weighted images (bottom) are required to exclude the presence of acoustic neuroma in this case.

were in this group. Two of the smaller intracanalicular tumours (4 mm and 5 mm in size) were allocated a low confidence score by one of the two readers.

However, no tumours were identified on contrast enhanced images where any reader had considered that acoustic neuroma was definitely not present on the fast spin echo images: that is, when the reader was satisfied that two normal nerves were visible in the internal auditory canal(s) on the side(s) under clinical suspicion. Fast spin echo images which fulfil this criterion can therefore be regarded as having excluded the presence of any acoustic neuroma that is detectable with contrast enhanced imaging. These data indicate that the fast spin echo images alone would be sufficient to exclude acoustic neuroma in 59% of patients.

Possible imaging strategies for acoustic neuroma screening

While gadolinium enhanced MRI is the gold standard imaging technique for detection of small acoustic neuromas, it is clear that non-contrast fast spin echo imaging may also have some use. When considering an MRI strategy for acoustic neuroma detection several options are available.

Fast spin echo imaging alone

Because surgical intervention for small, intracanalicular tumours is associated with improved clinical outcome [4–6], the aim of screening for acoustic neuroma is to identify all tumours of this type, as well as the larger tumours extending into the cerebellopontine angle. In order to fulfil this objective a screening strategy cannot be based on fast spin echo imaging alone. In the present study, 44% of tumours were not confidently identified on these non-contrast enhanced images, including 9 of the 10 intracanalicular tumours. Volume acquisition sequences with selective reconstruction (constructive interference in the steady state (CISS), dual echo in the steady state (DESS) etc.) may identify more tumours than the robust and widely available fast spin echo sequence that we used but this has not been demonstrated in the screening setting, and it is still unlikely to match the sensitivity of gadolinium enhanced sequences for detection of the smallest tumours. In addition, the post-processing involved can be time consuming.

Gadolinium enhanced imaging alone

Performing contrast enhanced imaging alone will pick up all detectable acoustic neuromas [7, 8], as well as some other causes of abnormal enhancement. Some disease processes that may present with similar audiovestibular symptoms are more readily identifiable on gadolinium enhanced MRI than on non-contrast images [7, 16]. However, this strategy may overlook some other disease processes—for example, localized ischaemic changes or demyelination in the brain stem and cerebellum—which may be relevant to a patient's clinical presentation and which may only be evident on T_2 weighted images. Many radiologists and referring clinicians appreciate the additional information that the rapid, inexpensive, fast spin echo sequence provides.

Fast spin echo imaging with additional gadolinium enhanced imaging in selected patients

Satisfactory fast spin echo images, where two normal nerves are seen within the internal auditory canal on the symptomatic side, appear to exclude the presence of acoustic neuroma. We would expect to identify all detectable tumours if contrast enhanced images were only acquired in patients whose initial fast spin echo images did not fulfil this criterion. This strategy would yield a sensitivity of 100% for detection, and a negative predictive value of 100% for exclusion, of acoustic neuroma. The prevalence of acoustic neuroma in patients undergoing contrast enhanced imaging, that is the positive predictive value of a fast spin echo scan that has not excluded acoustic neuroma, would be 6.5%. Since T_2 weighted images are acquired in all patients, this strategy may also identify some other disease processes in the posterior fossa that could be overlooked if contrast enhanced imaging only were employed. On the other hand, this strategy may fail to identify some other causes of abnormal enhancement, apart from acoustic neuroma, that may mimic this tumour in their clinical presentation. Lesions causing abnormal labyrinthine enhancement, such as vestibular schwannoma or labyrinthine neuronitis, may present with symptoms identical to those of acoustic neuroma. However, other patients (for example, those with disseminated malignancy or meningeal sarcoidosis [16]) will generally exhibit atypical features that suggest more extensive neurological or bony involvement indicating a requirement for more rigorous imaging.

Unfortunately this approach necessitates the attendance of an experienced radiologist during imaging sessions to identify indeterminate cases at the time of the examination and determine the need for contrast enhanced imaging [8]. This strategy would prove impracticable at the many centres that do not employ continuous radiologist supervision for MRI sessions.

Fast spin echo and gadolinium enhanced imaging in all patients

This strategy has several advantages. All examinations should identify the causes of audiovestibular symptoms that may be identified on either fast spin echo or gadolinium enhanced imaging alone, and all detectable acoustic neuromas will be identified. As there is no requirement for radiologist supervision, the examination could be performed during relatively low cost imaging sessions dedicated to acoustic neuroma screening.

Conclusions

At a local level, clinicians and radiologists should discuss the relative merits of these different approaches in order to determine an acceptable imaging strategy for their own patients. An imaging strategy intended to identify small intracanalicular acoustic neuromas cannot rely on fast spin echo imaging alone. We believe that all screening examinations should include a fast spin echo T_2 weighted sequence followed by a gadolinium enhanced T_1 weighted sequence in order to optimize detection of acoustic neuromas, as well as other identifiable causes of audiovestibular symptoms, without any requirement for continuous radiologist supervision of imaging sessions.

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