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MRI in acoustic neuroma: a review of 35 patients

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Summary. This retrospective study is aimed to assess the diagnostic efficacy of MRI in relation to contrast enhanced CT and air-CT-cisternography. MRI examinations were performed in 35 patients with suspected neurosensorial damage and suggestive of acoustic neuroma: 27 presented on MRI with unilateral tumors, 3 patients had a bilateral tumor and 5 patients were negative on all imaging modalities. The total number of acoustic neuromas detected was therefore 33. To date microscopic analysis has been performed on 12 tumors and histological data based on type Antoni A and Antoni B classification is available. Contrast enhanced CT detected 19 tumors, yielding an overall sensitivity rate of 58%. Air-CT cisternography identified an additional 5 tumors with a sensitivity rate of 100%. MRI identified 33 acoustic neuromas in 30 patients and was negative in 5 patients (sensitivity and accuracy 100%). Considering sensitivity in relation to location, MRI was much better than contrast enhanced CT for internal auditory canal (IAC) tumors (100% versus 36%) and better for cerebello-pontine angle tumors (CPA) tumors (100% versus 68%). The evolution of MRI technique, the various pulse sequences used and their actual selection is discussed. Seven patients received a paramagnetic contrast agent (Gadolinium-DTPA) with the additional benefit of a better demonstration of the tumor. The results suggest that MRI is the best non invasive technique for demonstrating acoustic neuromas.

Key words: Magnetic resonance imaging - Neuroma - Neuroradiology - Head - Computed tomography

Early detection, location and size evaluation of acoustic neuromas provide a challenge to neuroradiology. Increasing use of operating microscopes (with a translabyrinthine approach) facilitates the removal of small neuromas (less than 25 mm) which are either confined to the petrous bone or extend only slightly into the posterior fossa [1]. The post-operative morbidity and mortality rates are reduced in small acoustic neuromas in comparison to large ones to such an extent that for practical purposes small (25 mm) and large (equal to or more than 25 mm) tumors can be considered as two different entities.

Several pilot studies showed encouraging MRI results of acoustic neuromas. Tumors were directly demonstrated by MRI using IR sequences in anatomical areas affected by bone artefacts on CT studies [2]. The results of a later investigation suggested that minimal enlargement of the 8th nerve can be detected even in the internal auditory canal using saturation recovery (SR) and SE sequences [3]. More recent studies suggested that MRI might be as accurate as air-CT cisternography in demonstrating acoustic neuromas. Two groups used SE sequences exclusively [4, 5] and a third group used both IR and SE sequences [6].

This retrospective review of a large number of patients is meant to assess the diagnostic efficacy of MRI in terms of specificity, sensitivity and overall accuracy in comparison to contrast-enhanced CT and air-CT cisternography. The sensitivity was also examined in relation to the size and the anatomical location of the tumor. The technical aspect regarding the efficacy of different MR pulse sequences according to tumor location and size are considered as well. The initial diagnostic contribution of paramagnetic contrast agents is also described.

Patients and methods

Thirty-five patients presented with clinical symptoms of tinnitus and/or vertigo and unilateral or bilateral deafness of variable duration (Table 1). All patients also had positive audiometric tests (audio-

Table 1. Patients' data

No.	Sex	Age	Duration of symptoms	Location	CT results	Air-CT results	MRI results	Size of tumor (cm)
1	M	60	3 years	R CPA	–	NP	+	1.0 × 0.8
2	M	23	2 years	L CPA	+	NP	+	2.0 × 1.6
3	F	59	1 month	L CPA	–	NP	+	1.0 × 1.0
4	F	62	1 year	R IAC	+	NP	+	1.5 × 1.0
5	M	70	2 years	L CPA	+	NP	+	1.0 × 0.8
			1 year	R IAC	–	NP	+	0.8 × 0.8
6	M	43	1 year	R CPA	+	NP	+	1.5 × 1.0
7	F	61	3 years	L CPA	–	NP	+	1.5 × 1.0
8	F	50	6 months	R IAC	–	NP	+	0.8 × 0.8
9	F	50	5 years	L IAC	–	+	+	0.8 × 0.8
10	M	49	6 months	R IAC	+	NP	+	0.8 × 0.8
11	M	38	3 years	R CPA	+	NP	+	4.0 × 2.5
12	F	26	1 year	R CPA	+	NP	+	1.5 × 1.0
13	F	24	6 months	L CPA	+	NP	+	1.0 × 0.8
14	M	49	3 years	R IAC	+	NP	+	1.0 × 1.0
15	M	45	1 year	L CPA	–	NP	+	1.5 × 1.0
			20 years	R CPA	+	NP	+	1.0 × 1.0
16	M	44	2 years	L CPA	+	NP	+	1.0 × 0.8
17	M	76	1 year	L CPA	+	NP	+	3.0 × 2.0
18	F	45	6 months	R CPA	+	NP	+	1.5 × 1.0
19	F	40	6 months	R CPA	–	NP	+	0.8 × 0.8
20	M	47	1 year	L IAC	–	NP	+	0.8 × 0.6
21	F	40	2 years	L CPA	+	NP	+	0.8 × 0.8
			1 year	R IAC	–	NP	+	0.5 × 0.3
22	F	45	2 years	L CPA	+	NP	+	2.0 × 1.5
23*	F	43	2 years	R CPA	+	NP	+	0.5 × 0.5
24*	F	55	6 months	R IAC	–	+	+	0.8 × 0.8
25*	M	48	1 year	L CPA	–	+	+	0.8 × 0.8
26*	F	68	6 months	R IAC	+	NP	+	0.5 × 0.5
27*	M	42	1 year	R CPA	+	NP	+	1.0 × 0.8
28*	M	44	1 year	L IAC	–	+	+	0.5 × 0.5
29*	M	32	6 months	L CPA	–	+	+	0.5 × 0.3
30	M	15	6 months	L CPA	+	NP	+	2.0 × 1.5
31	M	45	1 year	–	–	–	–	–
32	M	18	6 months	–	–	–	–	–
33	F	25	6 months	–	–	–	–	–
34	F	18	1 year	–	–	–	–	–
35	M	23	1 year	–	–	–	–	–

* Had Gd-DTPA injection
CPA: Cerebello-pontine angle
IAC: Internal auditory canal
NP: Not performed

grams and acoustic reflex testing) as well as labyrinthine tests (vestibular response, electronystagmograms). Histological evidence of acoustic neuroma was available in 12 tumors. The microscopic analysis of the two types of Acoustic Neuromas Antoni A and B [1] has been studied. Two patients with bilateral tumors will not be operated at this stage. The remaining patients were considered as having acoustic neuromas on the basis of clinical, radiological and MRI findings, except for five patients who had clinical symptoms and positive laboratory tests but negative radiological and MRI examinations and were therefore considered as not having acoustic neuroma (Table 1).

All patients had had previous contrast-enhanced CT: air-CT cisternography was also performed in 10 patients. CT machines used for these patients were: Elscint Exel 905 (18 cases), GE 9800 (17 cases) and EMI 1010 (12 cases). Two patients had had repeat contrast enhanced CT examinations.

All MRI examinations were performed on a 0.15 T Picker International prototype machine previously described [7] and they conformed to the guidelines provided by the National Radiological Protection Board [8].

At an early stage (1981–82) the patients were examined using IR sequences with a short TI (i.e. TI up to 250 ms) and a TR of 1400 ms and three partial

saturation sequences (TR 1000, 400 and 200) with a slice thickness of 10 mm and a 128 × 128 matrix allowing for a spatial resolution of 3 mm. Later on, SE sequences were introduced, ranging from the long TE and long TR SE (such as SE 1580/80) used as a screening sequence of the brain, to the short TE and short TR SE (such as SE 544/44) used to reduce the signal from CSF in order to separate it from a possible intracanalicular component of the tumor.

Within a few months we applied a longer TI for our IR sequence: In order to increase contrast a TI of 400 ms was chosen, halfway between white matter (TI 350 ms) and gray matter (TI 450 ms). Further progress in resolution was achieved by introducing the 256 × 256 matrix and a 7 mm slice thickness (1983–84). The spatial resolution was then 1 mm.

The TI of the IR sequence was then increased to 500 ms to improve the overall signal to noise ratio although gray-white matter contrast was reduced. The TR was increased from 1400 ms to 1500 ms as well.

The criteria for normal anatomy was the demonstration of the normal seventh and eighth nerve complex. This was also demonstrated on the contralateral side of all patients with a single tumor, in the same axial section as for the affected side, as described in a recent series of patients and volunteers [3].

In addition to the range of IR and SE sequences available (Table 2) with the 256 × 256 high resolution display after 2D Fourier transformation, we also used a paramagnetic contrast agent in seven patients (Table 1). Gadolinium diethylene triamine pentaacetic acid (Gd-DTPA) prepared by Schering AG Berlin, was used [9, 10]. No patient presented any side-effects whatsoever.

Tumor sizes on the transverse plane were assessed in their maximum AP and lateral diameter.

Signal intensity numbers were measured for each region of interest for the most common sequences used: IR 1500/500/44, SE 1580/80 and SE 544/44 with the high resolution matrix (256 × 256). The regions of interest were: white matter, gray matter and acoustic neuroma. Relative signal intensity units were obtained by subtracting tumor readings from white and from gray matter readings (Fig. 1 a and b).

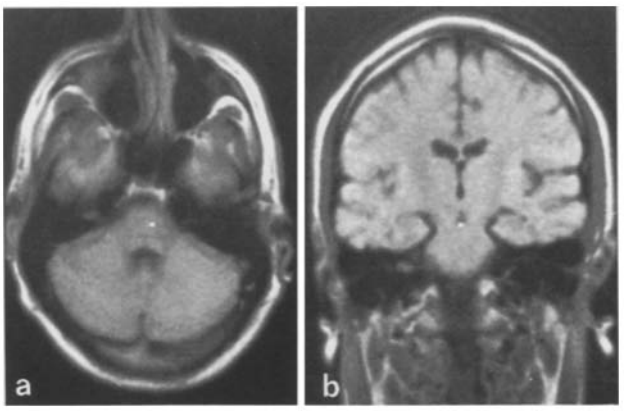

Fig. 1 a and b. Male, 47 years. L IAC acoustic neuroma. Axial **a** and coronal **b** SE 544/44

Table 2. Choice of sequences to show or to rule out an acoustic neuroma

Location	Sequences	Parameters		
		TR	TI	TE
IAC	$SE_{544/44}$	544		44
	$SE_{1500/80}$	1500		80
CPA	$SE_{1500/80}$	1500		80
	$IR_{1500/500/44}$	1500	500	44

IAC: Internal auditory canal
CPA: Cerebello-pontine angle

Results

Contrast-enhanced CT

With this method acoustic neuromas were detected in 19 out of 33 tumors, yielding an overall sensitivity rate of 58%. The sensitivity varied in relation to the anatomical location of the lesion. Contrast-enhanced CT detected 15 out of 22 tumors which were located anatomically at the cerebellopontine angle (sensitivity 68%) and 4 out of 11 which were in the internal auditory canal (sensitivity 36%). One false-positive acoustic tumor was diagnosed when the examination was performed on a first generation CT EMI machine. A repeat examination on a modern CT machine (GE 9800), together with air-CT cisternography and MRI, were negative. Therefore, the final specificity rate of contrast enhanced CT is 100%. The tumors were missed on 14 occasions. The non-diagnosed tumors (except for two) measured less than 1 cm in their major diameter as seen with MRI (s. Table 1 and 3). The tumors were more frequently missed in the IAC location (7/11) than at the CPA (7/22) s. Table 4).

Air-CT-cisternography

This method was performed in 10 patients who had had negative contrast enhanced CT and positive symptomatology. In 5 of the cases an acoustic tumor was identified (3 at the cerebellopontine angle and 2 in the internal auditory canal). Five cases had negative results (supported later by negative MRI as well). These results yielded a sensitivity, specificity and accuracy rate of 100% (s. Table 3).

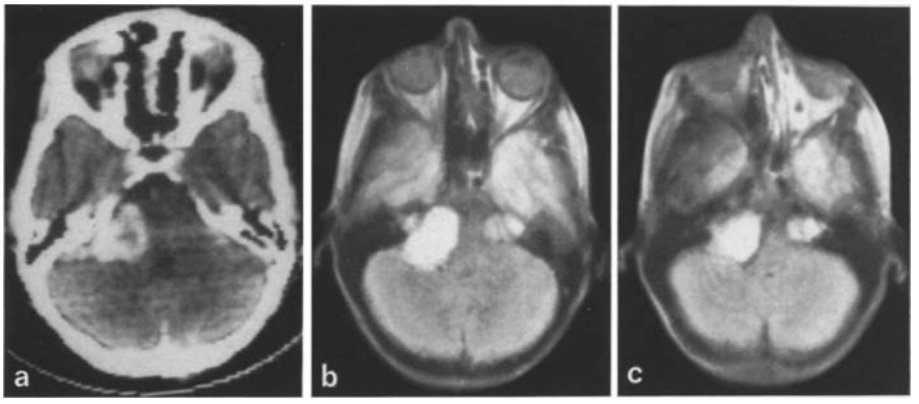

Fig. 2 a–c. Females, 40 years old **a** Bilateral acoustic neuroma. Contrast enhanced CT. **b, c** Axial higher level and axial −1 cm, SE 1580/80

Table 3. Sensitivity, specificity and accuracy of the techniques

	True positive	True negative	False positive	False negative	Sensitivity	Specificity	Accuracy
ce CT	19/33	5/5	0	14/33	58%	100%	65%
air-CT	5/5	5/5	0	0	100%	100%	100%
MRI	33/33	5/5	0	0	100%	100%	100%

ce CT: Contrast enhanced CT air-CT: Air-CT cisternography

Table 4. Sensitivity in relation to location for the three techniques

Location	No	ce CT No %	air-CT No %	MRI No %
CPA	22	15/22 (68%)	3/3 (100%)	22/22 (100%)
IAC	11	4/11 (36%)	2/2 (100%)	11/11 (100%)

ce CT: contrast enhanced CT
air-CT: air-CT cisternography
CPA: cerebello-pontine angle
IAC: internal auditory canal

Magnetic resonance imaging

MRI identified 33 acoustic tumor in 35 patients (sensitivity 100%) (Table 3). Three patients had repeated examinations (twice). Twenty-seven patients had unilateral tumors and 3 patients had bilateral tumors. In 5 patients examinations were negative.

Tumor size varied from 0.5×0.3 cm to 4.0×2.5 cm in diameter. Twenty-two tumors were located at the cerebellopontine angle and eleven in the internal auditory canal. The mean area index was 186 mm^2 for the cerebellopontine angle tumors and 62 mm^2 for the internal auditory canal ones. One tumor was missed on the first low resolution MRI scan (128×128 matrix); a repeat examination with a 256×256 high resolution matrix demonstrated the tumor. The final specificity was therefore considered as 100%.

The anatomy of the normal seventh and eighth nerve complex was demonstrated on the contralateral side of all patients with a single tumor and on both sides on the five patients with negative results. On the side of the tumor, the identification of the nerves is sometimes difficult, due to highlighted CSF in cases of obstructed canals.

The measurement of the difference in signal intensity units between the acoustic tumor and the normal white and gray matter allowed us to demonstrate three acoustic neuromas with particularly long T_1 and T_2 values suggestive of cystic components. Two of these three cases were later confirmed by histology (Figs. 1 a, b and Fig. 2).

Three other cases with particularly short T_1 and T_2 values suggestive of 'hard' components are demonstrated as well on these figures. These short T_1 and T_2 values tumors happen to belong to patients having long-lasting symptoms (3 years).

Most tumors displayed prolonged T_1 and T_2 values, appearing as decreased signal intensity areas on IR images and increased signal intensity areas on long TE and long TR SE images (Fig. 3). The tumors were increasingly highlighted by the prolongation of TR and TE (i.e. SE 1580/80), but since this sequence highlights CSF in the IAC as well, a short TE short TR SE (i.e. SE 544/44) was used to demonstrate the intracanalicular components. The short TR (T_1 - weighted) SE sequence kept the signal from CSF low (by not allowing longitudinal relaxation) while the tumor was highlighted.

Contrast enhancement was seen in all 7 patients when Gd-DTPA was used. The increase in signal

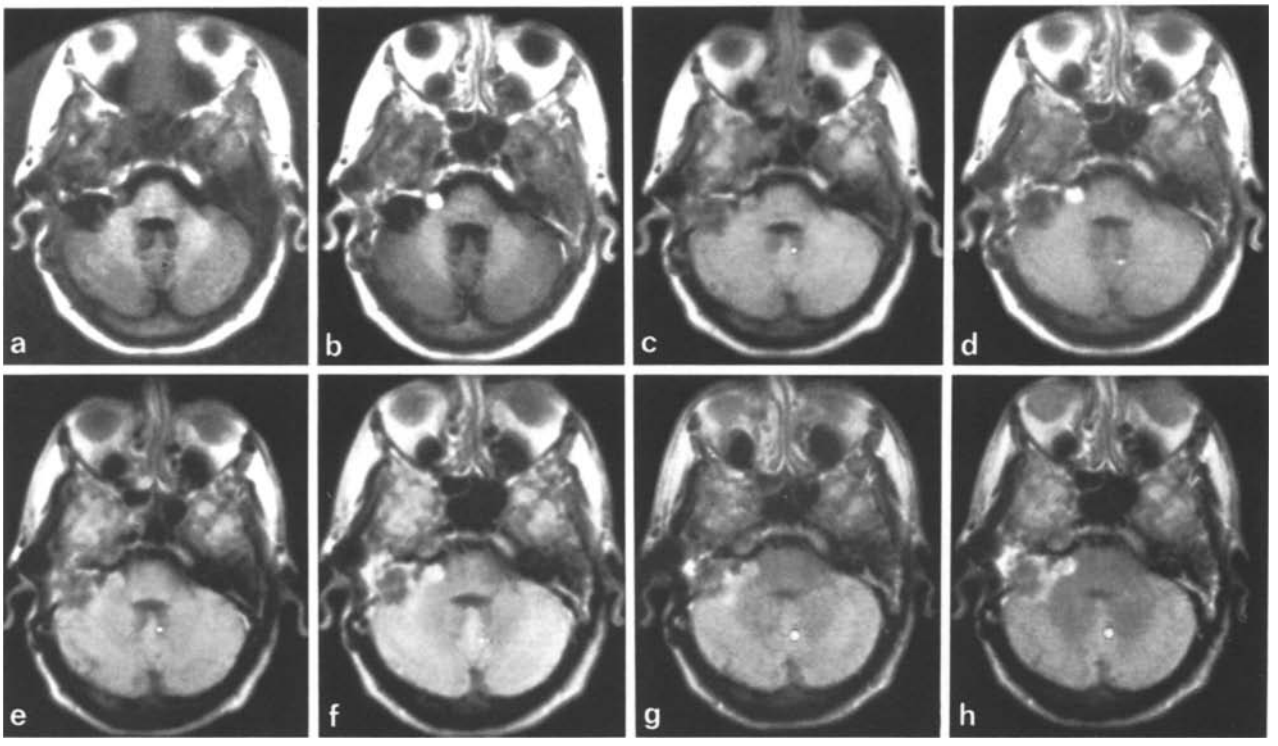

Fig. 3 a–h. Male, 58 years old. R CPA recurrent acoustic neuroma. Axial IR 1500/500/44 pre and post Gd-DTPA injection **a, b.** Axial SE 544/44 pre and post Gd-DTPA injection **c, d.** Axial SE 1500/44 pre and post Gd-DTPA injection **e, f.** Axial SE 1500/80 pre and post Gd-DTPA injection **g, h**

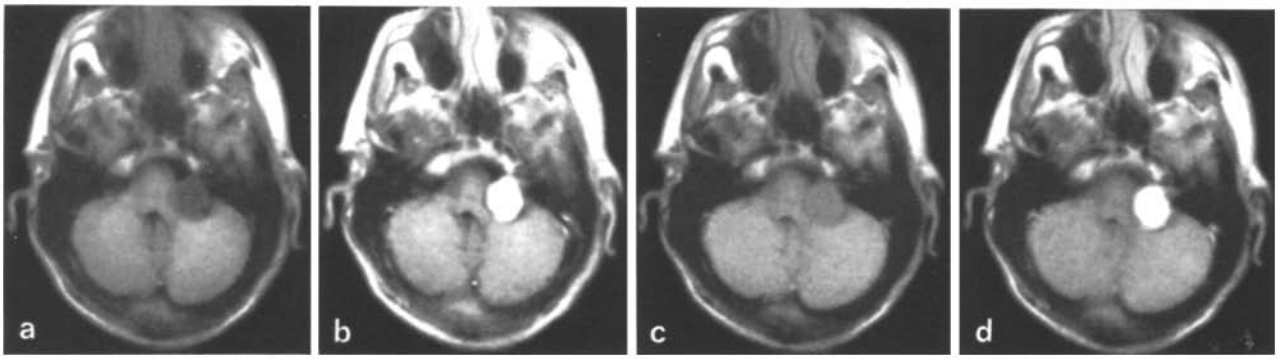

Fig. 4 a–d. Male, 37 years old. L CPA acoustic neuroma. Axial IR 1500/500/44 pre and post Gd-DTPA injection **a, b.** Axial SE 544/44 pre and post Gd-DTPA injection **c, d**

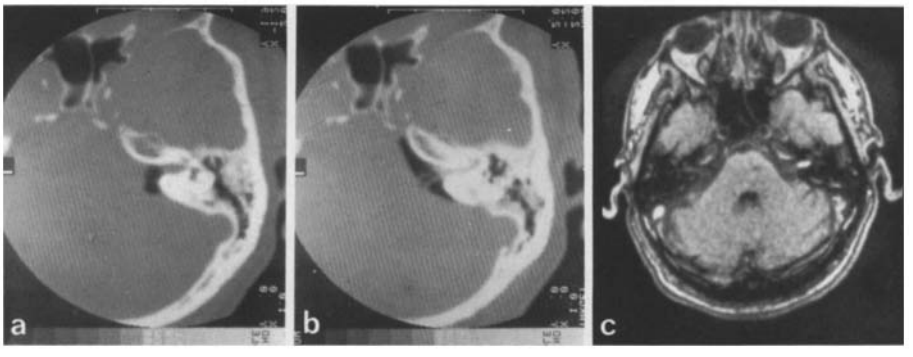

Fig. 5 a–c. Male, 56 years old. L IAC acoustic neuroma. **a** Air CT cisternography at the level of the IAC. **b** Air CT cisternography at the level of the CPA. Axial **c** SR 200 post Gd-DTPA injection

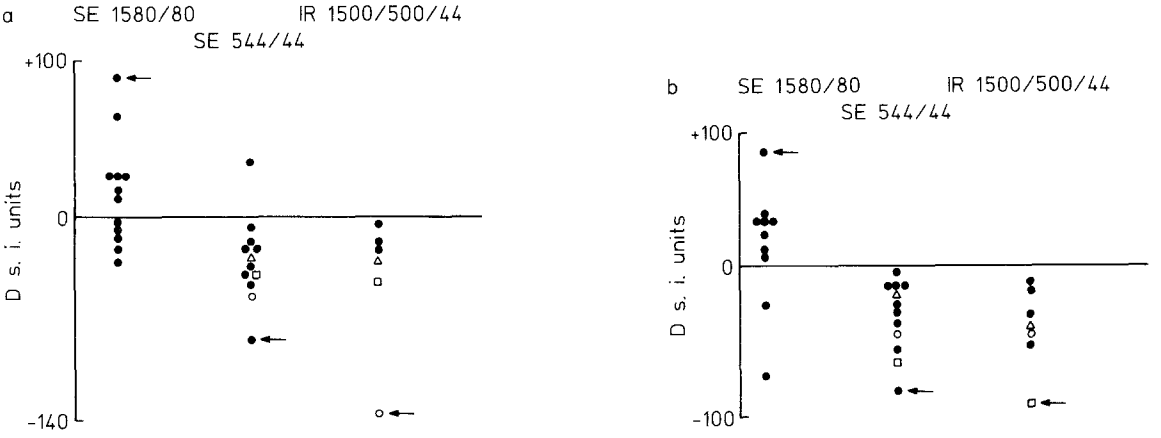

Fig. 6a and b. Display of signal intensity values: **a** Acoustic neuroma minus gray matter and **b** Acoustic neuroma minus white matter
△
□ patients reported in two sequences
○
← presence of a cystic component
D s.i. units: Difference in signal intensity units between acoustic neuroma and gray matter

intensity between pre and post-contrast sequences appeared higher with the IR sequence (IR 1500/500/44), followed by the short TE short TR SE sequence (SE 544/44). See Fig. 4.

Histological analysis of 12 tumors reveals that the Antoni A type of pattern dominates in 10/12 tumors and in only 2/12 is type B dominant (1 case) or equal to A (1 case).

Discussion

Acoustic neuromas account for 8% of all intracranial tumors and for about 80% of those occuring in the cerebellopontine angle [1]. Progressive unilateral deafness and tinnitus are the most common clinical features. Acoustic neuromas are identified in a small percentage (about 2%) of patients with sensorineural deafness [11] although random autopsies reveal an incidence of 1% acoustic neuromas in large post-mortem series [12].

The regime of neuroradiological investigations applied for these patients include: plain skull radiographs, coronal section tomograms of the internal auditory canal and contrast enhanced CT. These methods will definitely demonstrate tumors larger than 2 cm and some tumors larger than 1 cm [13]. For further investigations the more invasive procedure of air-CT cisternography is required. An example is shown in Fig. 5. This method is considered almost definitive in excluding tumors as it is very sensitive. Some reservations were made about the specificity related to the fact that the tumor is demonstrated indirectly by the presence of filling defects, with potential false positive diagnosis [14].

Comparative analysis of the results in this series confirm the limited sensitivity of contrast enhanced CT (58%) overall) (Tables 3 and 4) and especially in small internal auditory canal tumors (36%). Further investigation with air-CT cisternography and MRI revealed the presence of acoustic tumors in an additional 14 cases (Table 1). The advances in MRI, as previously described, certainly improved the sensitivity of the method and contributed to the detection of acoustic neuromas. In a patient presenting with bilateral symptoms we were able to demonstrate only one tumor in November 1982. In December 1983, a repeat MRI examination showed bilateral acoustic neuromas, the previously undetected one measuring 0.8×0.8 cm and although it could have grown in size it should have been detected with high resolution in the first instance provided it would have been available.

In our series the advantage of MRI was more obvious in internal auditory canal locations where the use of long TR SE sequences readily demonstrates the enlargement of the internal auditory canal and a complementary short TE short TR SE demonstrates the anatomy and separates the soft tissue components from CSF. Bilateral demonstration of the tumor was obtained by MRI in 3 patients using routine scans, whereas air-CT cisternography would require a prolonged examination in such cases.

After the progressive evolution of the techniques over the last four years we discuss the latest set of sequences used (Table 2) in order to assess or exclude an acoustic neuroma. These sequences are meant to cover all anatomical locations. For the study of the IAC, a long TE long TR SE sequence and a short TE short TR SE allow a good analysis of the canal and its anatomical components. For the study of the cerebellopontine angle, a long TE long TR SE or an IR demonstrate more specifically mass effect. On a

practical point of view, we start with a SE 1500/80 sequence as a screening sequence and add an SE 544/44 sequence to analyse the internal auditory canal. The addition of an IR sequence, i.e. IR 1500/44 in our studies, is a must if a paramagnetic contrast agent (i.e. Gd-DTPA) is used as this sequence displays a maximal increase in signal intensity units (Fig. 6) between pre and post-contrast sequences. A particular difficulty arises in obstructed IAC as the bound water effect [15] and the increased protein content [16] may shorten the relaxation times of the trapped intracanalicular fluid producing a difficulty in distinguishing acoustic neuroma from abnormal CSF.

This set of sequences also demonstrates a possible cystic component in a tumor and enables the neurosurgeon to perform a translabyrinthine approach with aspiration technique even with a larger tumor that would otherwise require a posterior fossa approach.

Using the latest set of sequences and the high resolution 256×256 matrix, MRI demonstrates either normal anatomy (7th and 8th nerves) or pathology with no false-positive diagnoses.

As a result of these studies, MRI appears to be the most sensitive, non invasive method for the examination of patients presenting with a suspicion of acoustic neuroma, especially for small tumors located in the internal auditory canal.

Since modern surgical management takes advantage of the earliest possible intervention with small tumors leading to a low morbidity and mortality and a better preservation of the seventh and eighth nerves, MRI appears to be an ideal diagnostic modality.

In view of these results, MRI examinations should be performed immediately after a positive audiometric and labyrinthine tests. At present, limitations in terms of availability of MRI machines suggest that a practical approach should be MRI after a negative contrast enhanced CT only, thereby aiming in the first instance at replacing the invasive air-CT cisternography.

Conclusion

Based on our results and on the recent experience of other groups, we summarize the MRI advantages in the diagnosis of acoustic neuroma as follows:

1. MRI with the use of a selection of 2-3 optimal sequences with high-resolution displays the best non invasive diagnostic technique.
2. MRI sensitivity, specificity and accuracy provides a means of early diagnosis, allowing therefore early and less hazardous surgical treatment.
3. MRI, being non invasive and non ionizing, is the best imaging screening test and should be performed immediately after audiometric and labyrinthine examinations instead of less sensitive contrast enhanced CT and invasive air-CT cisternography.

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