Neuroradiology (1986) 28: 203-207

Neuroradiology

Volume growth rate of acoustic neurinomas

E. M. Laasonen and H. Troupp

Department of Neurosurgery, Helsinki University Central Hospital, Helsinki, Finland

Summary. Of 79 acoustic neurinomas seen between June 1980 and June 1984, at least two CT scans were available for each of 23 tumours (21 patients); the scans were performed at intervals of at least 6 months. The volume growth rate of the tumours was either moderate, with a volume doubling time ranging from 205 to 545 days, or slow, with a doubling time ranging from 1090 days to no observable growth. No single clinical, radiological or histological feature correlated with any type of growth rate. However, some conclusions were drawn. If a primary CT scan is negative, at least 1 year should elapse before it is worthwhile taking another scan, even though audiological findings suggest growth; after an an apparently radical removal, at least 3 years should elapse before a check CT scan is worthwhile; and if a small acoustic neurinoma is diagnosed, but for some reason not operated upon, a second CT scan should be carried out 1 year later in order to reassess the case.

Key words: Acoustic neurinoma - Cerebellopontine angle, neoplasms - Computed tomography, head - Neurofibromatosis - Tumour doubling time - Volume growth rate

Radiological diagnosis of acoustic neurinoma is very accurate nowadays [1-6] and will obviously continue to improve [7-10]. Audiological diagnosis has also improved [2, 11]. It is important to find these tumours when they are small, as the operation is so much easier and success has even been reported with removal of small acoustic neurinomas with preservation of hearing [12-15]. However, there are still so many risk factors in these sensitive operations that it is a moot point whether to advise operation for the patient whose small acoustic neurinoma has just been diagnosed and who has useful hearing in that ear. Furthermore, these patients with small tumours may have had symptoms for years, and there is no clear-cut correlation between tumour size and the duration of symptoms [15-17]. These considerations led us to try to assess the growth rate of a series of acoustic neurinomas.

Patients and methods

A total of 79 acoustic neurinomas were diagnosed in the Division of Radiology, Department of Neurosurgery, Helsinki University Central Hospital, in the 4 years from June 1980 to June 1984. These numbers include patients in whom the primary CT scan was done in another hospital. In 21 of these patients, 6 men and 15 women, no operation was performed, or it was delayed for at least 6 months, and a second CT scan was done, permitting calculation of the volume growth rate of the tumour. Between them these 21 patients have (or have had) 28 acoustic neurinomas altogether, 5 of which had been operated on earlier, leaving 23 neurinomas for our study.

The reasons for not operating were as follows: 2 patients had, and 5 had had, bilateral tumours, so that there was delay with the operation for the other one; in 9 instances the patient wanted time to decide in favour of or against an operation; 4 patients were either too old or too ill with some other disease; and in one instance a 0.38 cm^3 tumour was not diagnosed at first, in another hospital.

The CT scans were done with nine different scanners, ranging over seven different brands from EMI Mk II to GE 8800; the majority, however, were done with the Philips Tomoscan 300 of this division.

Table 1. Tumour doubling time in 23 acoustic neurinomas, measured from two subsequent CT investigations

Patient no.	Sex	Age (years)	Interval between CTs ($t_2 - t_1$, days)	Initial volume (V_1, cm^3)	Second volume (V_2, cm^3)	Tumour doubling time (T_d, days)	Comments
1.	F	43	254	0.80[a]	1.92	205	Rck[b]
2.	F	11	660	0.41	3.46	220	Rck, left side
3.	M	57	434	0.38[a]	1.44	225	
4.	M	17	252	1.45[a]	2.94[a]	240	Rck
5.	F	20	318	0.88	2.00	250	Rck
6.	F	64	170	29.2[a]	47.0	265	
7.	F	58	326	(0.13)[c]	0.30	270	
2a.[d]	F	11	660	0.26	1.24	295	Rck, right side
8.	M	43	356	2.16	4.52	330	
9.	F	61	436	0.06[a]	0.14[a]	385	
10.	F	16	484	0.07	0.18	390	Rck
11.	F	61	310	0.25[a]	0.44	395	
12.	F	15	166	7.55[a]	9.75[a]	455	Rck
13.	F	50	354	0.31[a]	0.52	455	
14.	F	62	292	1.08[a]	1.70[a]	465	
15.	F	57	892	7.05[a]	21.7	545	
16.	M	43	198	1.71	1.92	1090	
17.	M	26	970	1.19	2.16	1130	Rck, left side
17a.	M	26	970	0.87	1.41	1370	Rck, right side
18.	F	55	336	(0.80)[c]	0.92	1700	
19.	F	66	392	3.00[a]	3.61	2900	
20.	F	71	190	(29.0)[c]	28.7[a]	∞	
21.	M	44	174	0.11	0.09	∞	

[a] Tumour volume was calculated from the three diameters and from the specific enlargement factor of the CT equipment
[b] Neurofibromatosis Recklinghausen
[c] Initial volume V_1 extrapolated from the second volume V_2 on the basis of the perpendicular heights of the tumour
[d] Another side of patient no. 2

Tumour volumes were measured on contrast-enhanced scans taken within 5 min of the injection [18, 19]. The slice thickness varied from 1.5 to 8 mm. Seven computer tomographic air cisternograms were also available, but could not be directly compared to ordinary CT scans. In examinations with our own scanner - 27 scans - volume measurements were done with a built-in programme [20]. For 16 scans done elsewhere, we measured three perpendicular diameters of the tumour, calculated the volume, and applied the enlargement factor specific to every scanner [21]. In the remaining three scans the thickness of the tumour perpendicular to the posterior surface of the petrous bone was the only measure that was reasonably certain, so it was used as the basis of the volume calculation. With the Tomoscan 300 programme the volume was measured three times from every slice and the averages were then added together [22-24]. The tumour doubling time in days, T_d, was calculated according to the formula:

$$T_d = \frac{\log_{10} 2 (t_2 - t_1)}{\log_{10} V_2 - \log_{10} V_1},$$

in which t_1 and t_2 are the dates of the CT scans, and V_1 and V_2 the extracanalicular volumes of the tumours measured from the CTs [25, 26]. The intracanalicular part of the tumour was left out of these calculations in every instance, as the measurement of this space appeared to be rather uncertain. However, in two young patients the porus and meatus definitely became wider between CT scans, within 16 and 22 months, respectively.

Results

The tumour doubling times, T_d, for 23 acoustic neurinomas in 21 patients are shown in Table 1. The tumours are divided into two categories: 16 tumours with a moderate volume growth rate, T_d 200-550 days, and 7 with a slow growth rate, T_d 3 years or more (Figs. 1, 2). Tumours showing no observable growth were included in the latter category.

Of the 6 men in our series, 3 had tumours with a slow volume growth rate, compared with only 3 of the 15 women. No other clinical, radiological or histological feature predicted either moderate or slow growth rate. The duration of clinical symptoms - mainly loss of hearing - did not correlate with primary tumour volume V_1 or with tumour doubling time, T_d. Tumour calcifications (3 tumours) or cysts (3 tumours) or the primary tumour volume, V_1, did not correlate with any type of T_d, nor did any histological detail in the routine reports.

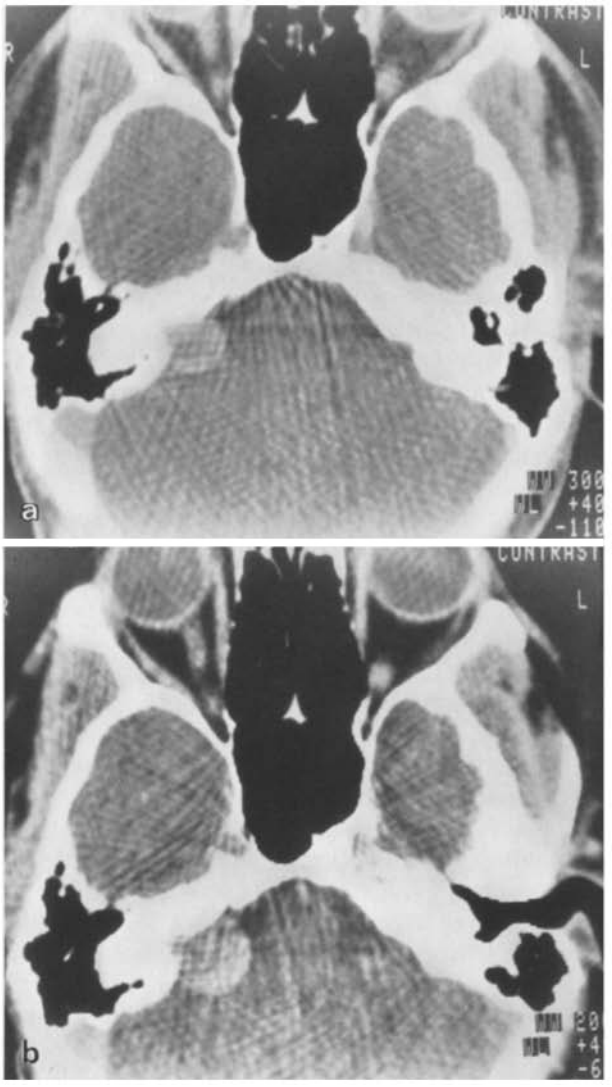

Fig. 1 a, and b. (Patient 8, M 43). A right-sided acoustic neurinoma that doubled in volume between the two CT investigations

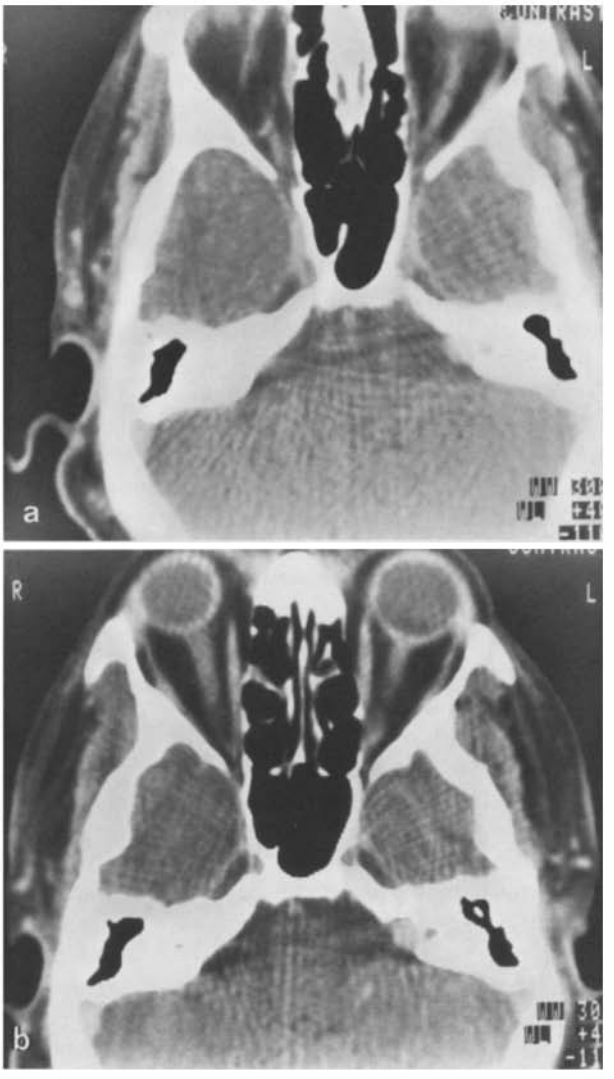

Fig. 2 a, and b. (Patient 21, M 44). No visible growth in a left-sided acoustic neurinoma between the two CT investigations during an interval of 6 months

Bilateral tumours and central neurofibromatosis were diagnosed in 7 patients. A moderate growth rate was found in 6 of these 7. The 2 patients with unoperated bilateral neurinomas (patients 2 and 17) had a T_d of 220 and 295 days, and 1130 and 1395 days, respectively, the difference between the sides being 25% and 20%.

In patient 2, the growth rates were initially 220 days on the left and 315 days on the right, the difference between the sides being 30%. This patient then received stereotactic radiation therapy to her left acoustic neurinoma in the Department of Neurosurgery, Karolinska Hospital, Stockholm, Sweden. No change in the volume growth rate of this tumour was seen during the 7 months following radiotherapy. The growth rates were 215 days on the left and 265 on the right (difference 19%).

Discussion

A matter of ethics should be broached immediately: why were these patients not operated on when the tumour was initially diagnosed? The general reasons are given in "Patients and methods". In addition, all tumours except 6, 12, 15, and 20 were small (Table 1) and none of the operations for a small tumour was considered urgent. Patients 6 and 20 were elderly and in a poor general condition; both patients had a shunt and were later readmitted for a new CT scan

and clinical assessment, but were still considered too unfit. Patient 15 had a pulmonary condition precluding any major operation, and as there were no signs of increased intracranial pressure, no shunt was inserted. Patient 12 had bilateral tumours; the second tumour was left until the facial nerve recovered after the removal of the first tumour.

A systematic error is difficult to quantify in a method based on logarithms. We must accept that the error may well be ±25%, especially in small tumours [25]. The slice thickness used in CT scan is the critical limit. If the tumour radius is less than the slice thickness, tumour volume analysis is very uncertain [26], as are the chances of even diagnosing the tumour. Overlapping slices do not help much. Volume measurement on the basis of the three diameters of the tumour seems a relatively good approximation, and the error of this method probably does not differ much from direct volumetry. However, the calculated volumes based only on the thickness of the tumour (patients 7, 18 and 20) must be regarded as highly uncertain.

A third factor may contribute to the uncertainty of volume growth analysis, especially if the time between the two CT scans is long: over long periods the tumour growth rate is probably not linear, as assumed here, but more like the ∫-curve of a normal distribution sample [27, 28]. It is also well known that some tumours in patients with neurofibromatosis suddenly grow fast, while others may remain dormant; puberty appears to start off a good many [29-31] and so may pregnancy; the effect of the menopause on these tumours is not known. Our series is also biased, with more bilateral and small tumours than a "normal" acoustic neurinoma series (cf. [16, 17, 32]).

Reports on brain tumour volume growth rate concern mainly malignant tumours [22, 23] with tumour doubling times as short as 20 days [33]. Benign tumours have a different time scale for their growth, so we preferred the terms "moderate" and "slow" growth rate [34].

Why do these tumours fall into two categories, moderate and slow, as regards growth rate? There is no straightforward answer, and we do not even know whether this division is real. However, three conclusions can be drawn.

1. If there is a strong suspicion of acoustic neurinoma on audiological grounds, but the primary CT is negative, a CT check by the same method may reveal the tumour at the earliest after 1 year, and it may be preferable to let 2 years pass; a decision to do an air CT cisternogram will depend on local availability and experience.
2. If an acoustic neurinoma is very small, e.g. its thickness is at the most 6 mm, an observation time of 1 year will mean at most a 3-mm increase in thickness (=2 volume doublings, each leading to a 25% increase in the thickness of the tumour).
3. After an apparently radical removal of an acoustic neurinoma, it will take at least 3 years before a recurrence might be visible in a CT scan - so no "routine" checks should be done before at least this time has elapsed.

As an example, let us examine the figures of patient 5. Her tumour recurred and had a volume of 2.00 cm^3 77 months after the primary operation; at 67 months after the operation the volume of the tumour had been 0.88 cm^3, i.e. a tumour doubling time of 250 days = 8.2 months. By extrapolation her tumour volume would have been about 0.06 cm^3 at 36 months after the primary operation. A tumour with a volume of 1 cm^3 has a diameter of 13 mm [1]; a hemispherical tumour of 0.06 cm^3 has a diameter of 6 mm and a thickness of 3 mm - just visible in a CT slice with a thickness of 3 mm [8].

So far, we have not been able to draw any far-reaching conclusions with regard to the clinical management of patients with acoustic neurinoma. When a small acoustic neurinoma is diagnosed radiologically, the first concern is the patient's hearing; if this has been fading, there seems a good chance that it will continue to do so, and the best course may well be to suggest early operation, with an attempt at preservation of what there is left of hearing in the ear. However, if operation is deferred for some reason, we strongly suggest a follow-up CT scan in 1 year; it may then be possible to give a well-founded prognosis, and the more CT scans there are available for comparison, the more accurate the prognosis will be.

References

1. Möller A, Hatam A, Olivecrona H (1978) Diagnosis of acoustic neuroma with computed tomography. Neuroradiology 17: 25-30
2. Palva T, Jauhiainen T, Sjöblom C-J, Ylikoski J (1978) Diagnosis and surgery of acoustic tumours. Acta Otolaryngol 86: 233-240
3. Servo A, Porras M, Jääskinen J (1981) Metrizamide cisternography in the diagnosis of acoustic neurinomas. Neuroradiology 21: 37-41
4. Sortland O (1979) Computed tomography combined with gas cisternography for the diagnosis of expanding lesions in the cerebellopontine angle. Neuroradiology 18: 19-22
5. Wende S (1980) Die kombinierte Anwendung von Computertomographie und Luftzisternographie bei Kleinhirnbrückenwinkeltumoren. Fortschr Röntgenstr 132: 666-667
6. Mödder U, Neumann G, Prömper C (1982) Wandel der Röntgendiagnostik bei Neurinomen des VIII. Hirnnerven. Fortschr Röntgenstr 136: 432-434

7. Young IR, Bydder GM, Hall AS, Steiner RE, Worthington BS, Hawkes RC, Holland GN, Moore WS (1983) The role of NMR imaging in the diagnosis and management of acoustic neuroma. Am J Neuroradiol 4: 223–224
8. Valavanis A, Dabir K, Hamdi R, Oguz M, Wellauer J (1982) The current state of the radiological diagnosis of acoustic neuroma. Neuroradiology 23: 7–13
9. Pinto RS, Kricheff II, Bergeron RT, Cohen N (1982) Small acoustic neuromas: detection by high resolution gas CT cisternography. Am J Neuroradiol 3: 283–286
10. Johnson DW (1984) Air cisternography of the cerebellopontine angle using high-resolution computed tomography. Radiology 151: 401–403
11. Palva T, Troupp H, Jauhiainen T (1985) Hearing preservation in acoustic neurinoma surgery (in press)
12. Buchheit WA, Gastaldo JA (1977) The posterior fossa approach to acoustic tumors preservation of hearing. In: Silverstein H, Norrell H (eds) Neurological surgery of the ear, vol 1. Aesculapius, Birmingham, Ala, pp 263–266
13. Kaseff LG, Perkins R, Hambley WH (1981) Radiological techniques for small acoustic tumors – a re-evaluation. Laryngoscope 91: 63–70
14. Palva T, Troupp H, Jauhiainen T (1981) Team surgery for acoustic neurinomas and the preservation of hearing. Acta Otolaryngol 91: 37–45
15. Smyth GDL, Gordon DS, Campbell R, Kerr AG (1982) The facial nerve in acoustic neuroma surgery. J Laryngol Otol 96: 335–346
16. Mathew GD, Facer GW, Suh KW, Houser OW, O'Brien PC (1978) Symptoms, findings and methods of diagnosis in patients with acoustic neuroma. Laryngoscope 68: 1893–1903
17. Kasantikul V, Netsky MG, Glasscock ME, Hays JW (1980) Acoustic neurilemmoma. Clinicoanatomical study of 103 patients. J Neurosurg 52: 28–35
18. Hatam A, Bergström M, Möller A, Olivecrona H (1978) Early contrast enhancement of acoustic neuroma. Neuroradiology 17: 31–33
19. Lange S, Steinhoff H, Aviles C, Kazner E, Grumme T (1979) Kontrastmittelkinetik in zerebralen Tumoren. Fortschr Röntgenstr 130: 666–669
20. Breiman RS, Beck JW, Korobkin M, Glenny R, Akwari OE, Heaston DK, Moore AV, Ram PC (1982) Volume determinations using computed tomography. Am J Roentgenol 138: 329–333
21. Ericson K, Håkansson S (1981) Computed tomography of epidural hematomas. Association with intracranial lesions and clinical correlation. Acta Radiol Diagn 22: 513–519
22. McCullough DC, Huang HK, DeMichelle D, Manz HJ, Sinks LF (1979) Correlation between volumetric CT imaging and autopsy measurements of glioblastoma size. Comput Tomogr 3: 133–141
23. Kretschmar K, Schicketanz KH (1982) Measurements of the volume and density of intracerebral tumors by CT following therapy. Neuroradiology 23: 175–184
24. Petersen OF, Espersen JO (1984) Extradural hematomas: Measurement of size by volume summation on CT scanning. Neuroradiology 26: 363–367
25. Pearlman AW (1976) Breast cancer – influence of growth rate on prognosis and treatment evaluation. A study based on mastectomy scar recurrences. Cancer 38: 1826–1833
26. Goodenough D, Weaver K, Davis D, LaFalce S (1981) Volume averaging limitations of computed tomography. Am J Neuroradiol 2: 585–588
27. Hoshino T, Wilson CB (1975) Review of basic concepts of cell kinetics as applied to brain tumours. J Neurosurg 42: 123–131
28. v Fournier D, Weber E, Hoeffken W, Bauer M, Kubli F, Barth V (1980) Growth rate of 147 mammary carcinomas. Cancer 45: 2198–2207
29. Eldridge R (1981) Central neurofibromatosis with bilateral acoustic neuroma. In: Riccardi VM, Mulvihill JJ, Wade WM (eds) Advances in neurology, vol 29: Neurofibromatosis (von Recklinghausen Disease). Genetics, cell biology and biochemistry. Raven Press, New York, pp 57–65
30. Riccardi VM (1981) Von Recklinghausen neurofibromatosis. N Engl J Med 305: 1617–1627
31. Zanella FE, Mödder U, Benz-Bohm G, Thun F (1984) Die Neurofibromatose im Kindesalter. Computertomographische Befunde im Schädel- und Halsbereich. Fortschr Röntgenstr 141: 498–504
32. Gardeur D, Palmieri A, Mashaly R (1983) Cranial computed tomography in the phakomatoses. Neuroradiology 25: 293–304
33. Yamashita T, Kuwabara T (1983) Estimation of rate of growth of malignant brain tumors by computed tomography scanning. Surg Neurol 20: 464–470
34. Jääskeläinen J, Haltia M, Laasonen E, Wahlström T, Valtonen S (1985) The growth rate of intracranial meningioma and its relation to histology: an analysis of 43 patients. Surg Neurol 24: 165–172

Received: 29 January 1985

E. M. Laasonen, MD
Töölö Hospital
Topeliuksenkatu 5
SF-00260 Helsinki
Finland