Clinical Neurology and Neurosurgery 138 (2015) 72–77

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Review

Analysis of vestibular schwannoma size: A literature review on consistency with measurement techniques

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ARTICLE INFO

Article history:
Received 30 June 2015
Accepted 5 August 2015
Available online 7 August 2015

Keywords:
Vestibular schwannoma
Acoustic neuroma
Tumor size
Linear measurement
Volumetric measurement

ABSTRACT

Introduction: Vestibular schwannoma (VS) tumor size, a significant prognostic indicator, is closely analyzed in patients undergoing observation or treatment. It has historically been reported in terms of linear size; however, volumetric assessments can now be performed routinely. We examine the use of described measurement techniques in large published clinical series to assess their consistency.
Methods: Computerized searches of the MEDLINE database (Pubmed) from 1975 to August 2014 were conducted with the purpose of identifying large series describing the management of VSs. Articles that reported tumor size measurements were included if they described greater than 600 patients.
Results: 19 studies were found fitting the inclusion criteria, consisting of large retrospective studies with sample sizes ranging from 614 to 2991. A total of 17 studies reported linear measurements, while 2 studies reported volumetric assessments of tumor size. Significant variations were found regarding methods for linear measurement. Furthermore, several papers did not provide any details regarding the measurement technique. Inclusion of intracanalicular portions of the tumor was highly variable. Volume assessments were performed by segmented volume analysis.
Conclusions: Among the large published series on VSs, significant variation exists regarding the utilized measurement technique to assess size. Volumetric assessments have the greatest clinical utility, sensitivity and accuracy in measuring tumor size and growth. Standardization of volume assessments will provide the best method for producing consistent literature findings.

Published by Elsevier B.V.

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Abbreviations: VS, vestibular schwannoma; AN, acoustic neuroma; CPA, cerebellopontine angle; IAC, internal auditory canal; MLD, maximal linear diameter; AP, anteroposterior; CC, craniocaudal; ML, mediolateral; SVA, segmented volume analysis; IC, intracanalicular; MRI, magnetic resonance imaging; CT, computed tomography; ANCSRR, acoustic neuroma consensus on systems for reporting results.

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http://dx.doi.org/10.1016/j.clineuro.2015.08.003
0303-8467/Published by Elsevier B.V.

Table 1
Articles using linear measurements to describe VS size ($N > 600$).

Author	N	Measurement technique	IC portion included in measurement?
Ahmad et al. [1]	2400	Extrameatal tumor only. No description	No
Ben Ammar et al. [2]	1865	ANCSRR tumor classification MRI/CT	No
Bloch et al. [3]	624	MLD including IC portion	Yes
Chen [5]	614	MLD including IC portion on MRI only	Yes
Falcioni et al. [7]	1151	ANCSRR tumor classification on MRI only	No
Freeman et al. [9]	1037	No description	Unknown
Gjurić et al. [10]	735	Extrameatal largest diameter parallel to IAC on axial or coronal CT/MRI	No
Husseini et al. [6]	2500	No description	Unknown
Kaltoft et al. [11]	1378	ANCSRR tumor classification	No
Khrais et al. [13]	710	ANCSRR tumor classification	No
Samii and Matthies [21]	1000	Koos tumor classification on axial CT/MRI	Yes
Sampath et al. [22]	1006	No description	Unknown
Schüz et al. [23]	1087	Extrameatal tumor diameter No description	No
Stangerup et al. [25]	2283	ANCSRR tumor classification	No
Sughrue et al. [26]	700	MLD including IC portion on CT/MRI	Yes
Tan et al. [27]	835	MLD	Unknown
Van Gompel et al. [29]	1427	No description	Unknown

1. Introduction

Vestibular schwannomas (VS), or acoustic neuromas (AN), are benign neoplasms of Schwann cell origin. They occur most commonly on the vestibular division of cranial nerve VIII at the oligodendroglial/Schwann cell interface and reside within the cerebellopontine angle (CPA) and/or internal auditory canal (IAC). These neoplasms can occur as idiopathic, solitary lesions or as a part of a syndrome. These tumors are slow growing masses that may result in dizziness, ataxia, hearing loss, and facial paresthesias or weakness in patients. Newer imaging modalities have led to the detection of smaller VSs and subsequent neurosurgical advances in radiosurgery and microsurgery have widened the breadth of management approaches for tumors of all sizes.

Throughout many investigations, the size of VSs has been a major factor guiding management as well as an influential prognosticator of clinical outcome regarding hearing preservation and facial nerve function [3,7,27]. In addition, tumor size is routinely followed in patients, both those undergoing conservative management and in post-intervention patients with residual tumor. Tumor size dictates whether a conservatively managed patient may derive greater benefit from more aggressive management or if a post-treatment patient now has a recurrence that may need to be treated.

This review aims to evaluate the published literature with a focus on VS measurement techniques in order to determine an accurate and reproducible method for reporting on this clinically significant parameter.

2. Methods

A computerized search of the MEDLINE database (Pubmed) from 1963 until August 2014 was conducted using the search terms 'vestibular schwannoma', 'acoustic neuroma', 'size', 'radiosurgery', 'measurement', 'volumetric' and 'neurosurgery' with the purpose of identifying published articles on the management of VSs. Articles were included if they described a case series of $N > 600$. No review articles were included. The literature review consisted mostly of retrospective case series in single center as well as multi-center studies.

3. Results

The literature search yielded 19 case series meeting inclusion criteria, with sample sizes ranging from 614 to 2991. The literature review consisted mostly of retrospective case series in single or multi-center institutions.

Table 2
ANCSRR tumor size classification system [12].

0	Purely intracanalicular (mm)
I	1–10
II	11–20
III	21–30
IV	31–40
V	>40

Of these 19 articles, 17 case series quantified the size of VSs using linear measurements, with sample sizes of 614 to 2500 (Table 1). 5 Articles note using the Acoustic Neuroma Consensus on Systems for Reporting Results (ANCSRR) for measurement techniques. 4 articles provide no information regarding the measured value while another 4 articles measure maximum linear diameter (MLD) with or without the intracanalicular (IC) portion. 2 articles note that extrameatal tumor or tumor diameter was measured without additional details. 1 article utilized the Koos tumor classification system while another article used the extrameatal diameter parallel to the IAC. IC tumor was noted not to be included in the measurement technique in 8 studies and clearly included in the measurement of tumor size in 4 studies.

The remaining 2 articles discussed stereotactic radiosurgical treatment and used volumetric tumor size analysis with sample sizes of 829 and 2991 [16,18].

4. Discussion

Despite the bulk of literature on VS referencing tumor size as an influential factor in patient management, measurement techniques are variable and include linear and volumetric assessments. Various classification systems have been developed in an attempt toward standardization, such as the 2003 ANCSRR (Table 2) or 1993 Koos classification system (Table 3) with limited usage among the listed large series; in fact, the majority of the listed papers did not use such a classification system. These classification systems are based upon linear measurement techniques, correlating to MLD, which are most commonly referenced in the literature and by physicians. However, these linear measurements are highly variable due to a variety of factors, including inter-observer differences, presence or absence of intracanalicular (IC) tumor extension, and the measured MLD dimension. A smaller subset of radiosurgical papers cites volumetric measurements as a basis for tumor monitoring and