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Evaluating vestibular schwannoma size and volume on magnetic resonance imaging: An inter- and intra-rater agreement study

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ABSTRACT

Objectives: In the management of patients with vestibular schwannoma it is essential to reliably assess tumor size. In respect to volumetric and linear measurements of these tumors we evaluated a) the inter-rater reliability, b) the intra-rater variability, c) the concordance of volume measurements derived from axial versus those from coronal MRI datasets, and d) the correlation of one-dimensional and volumetric measurements.
Patients and methods: We selected gadolinium-enhanced T1-weighted MRI datasets from 20 patients who had both axial and coronal datasets available with the same slice thickness in each of these orientations. Tumor volumes and diameters were independently determined by two investigators.
Results: The inter-rater reliability was determined based on the intra-class correlation coefficient, which was 0.998 for volumetric measurements and 0.950 for diameters. The relative smallest detectable difference between both raters was 21.2% for volumetric and 21.2% for linear measurements. Regarding the intra-rater variability we found a relative smallest detectable difference of 17.5% (rater 1) and 24.3% (rater 2) for volumetric measurements. The correlation between measurements on axial and those on coronal datasets was $\rho = 0.999$. In order to find a function that reliably predicts tumor volume from diameter, we fitted a series of equations based on linear and polynomial regression, with the highest regression coefficient being $r^2 = 0.79$.
Conclusion: The longitudinal use of semi-automated volumetric measurements has the potential to accurately inform vestibular schwannoma disease management. We have quantified the reliability of this technique. A strict MRI protocol for follow-up investigations should be adhered to in order to minimize measuring errors.

1. Introduction

In the management of patients with vestibular schwannoma (VS), especially those which are associated with neurofibromatosis type 2 (NF2), long-term radiological follow-up is essential. Exact assessment of tumor size is crucial in order to determine when therapeutic intervention is indicated and to assess the effectiveness of therapy.

A wide range of tools for three-dimensional measurements of VS on MRI or CT datasets are available and have been shown to produce more reliable results than linear measurements [1–3]. However, two-dimensional or linear size assessments are still commonly used in clinical practice [4], partly due to time efficiency, and partly because there is no generally accepted reporting system for volumetric measurements. There are established classifications for tumor expansion [5–7], which are either descriptive or based on linear measurements. Still, a standardized protocol for volumetric measurements, particularly with respect to follow-up measurements, is yet to be settled upon.

The aim of this study was to evaluate the accuracy, reproducibility and limitations of volumetric and linear measurements of sporadic or NF2-associated VS. To this end we evaluated a) the inter-rater reliability (IRR) of measurements; b) the intra-rater variability; c) the concordance of volume assessments derived from axial versus coronal MRI datasets; and

Abbreviations: CT, computed tomography; ICC, intra-class correlation coefficient; IRR, inter-rater reliability; MRI, magnetic resonance imaging; NF2, neurofibromatosis type 2; SDD, smallest detectable difference; SDD%, relative smallest detectable difference; ST, slice thickness; VS, vestibular schwannoma.

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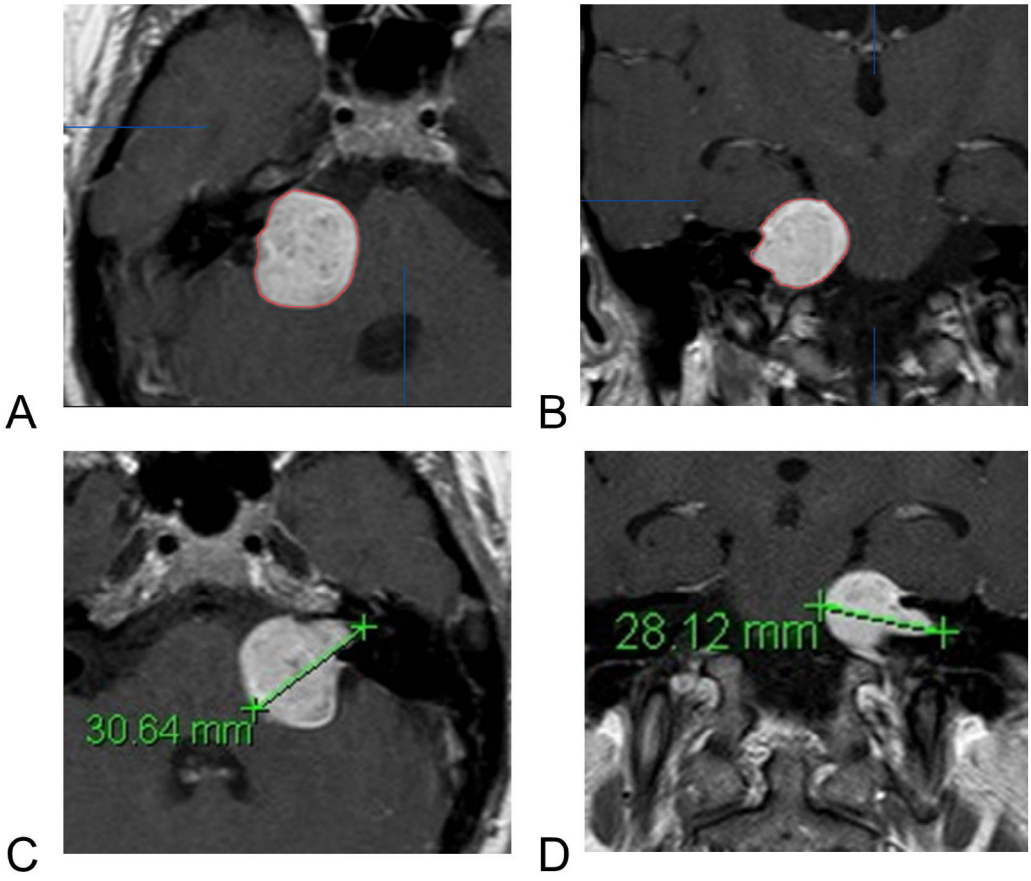

Fig. 1. Tumors were measured by semi-automated segmentation on axial (A) and coronal (B) slices, and the maximum diameter was measured on axial (C) and coronal (D) slices.

d) the correlation between linear and volumetric measurements.

2. Material and methods

We selected 40 datasets from 20 patients who had either sporadic or NF2-associated VS. All our datasets met the following inclusion criteria:

1. Individually obtained axial and coronal contrast-enhanced T1-weighted MRI datasets from the same day and with the same slice thickness (ST) and slice distance had to be available.
2. Datasets had to be individually recorded in both axial and coronal orientations. Reconstructions were excluded.

All scans were taken between July 2005 and October 2013 at our institution's radiology department, or in other units, according to varying MRI protocols. The model of MRI scanner used for cranial imaging at our institution was a GE Signa Excite 1.5T. Only one

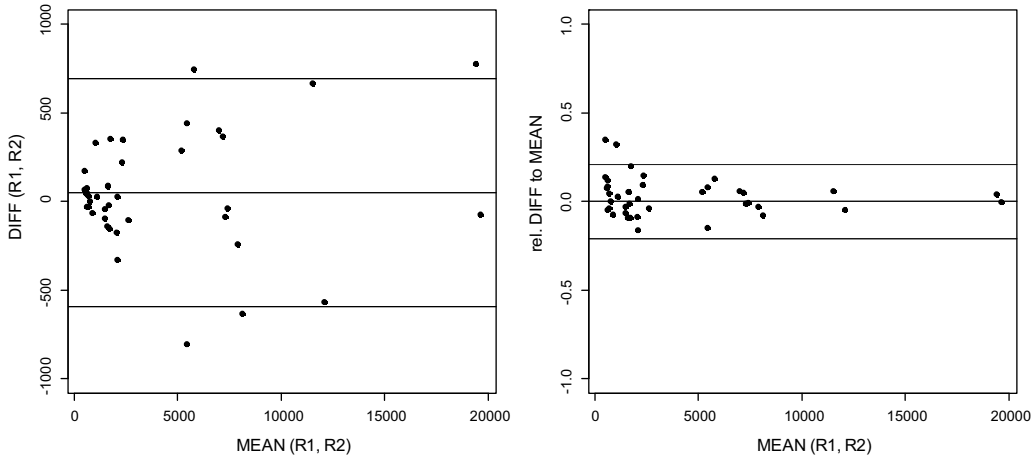

Fig. 2. Classical Bland-Altman plot (left) and plot of relative difference (right) between volumetric measurements by two independent raters. Horizontal lines indicate 1.96*SD (standard deviation). DIFF = difference, R1 = rater 1, R2 = rater 2, rel. = relative.