Diagnostic accuracy of high-resolution T2-weighted MRI vs contrast-enhanced T1-weighted MRI to screen for cerebellopontine angle lesions in symptomatic patients

M.A. Hentschel | H.P.M. Kunst | M.M. Rovers | S.C.A. Steens

Objective: To evaluate diagnostic accuracy of high-resolution T2-weighted MRI (T2w) for detecting cerebellopontine angle (CPA) lesions compared to a combined protocol including gadolinium enhanced T1-weighted MRI (GdT1w).

Setting: Department of Radiology & Nuclear Medicine, Radboud University Medical Centre, Nijmegen, The Netherlands.

Participants: A random sample of MRIs from 350 patients (700 CPAs) with asymmetrical audiovestibular complaints was used, acquired between 2013 and 2016.

Main outcome measures: Sensitivity, specificity, positive and negative predictive values of T2w results compared to GdT1w and, in patients with any suggestion of CPA pathology, to the complete examination (T1w, GdT1w and T2w). Inter-rater agreement between an experienced neuroradiologist and a less experienced observer was calculated.

Results: Results of 678 CPAs in 340 patients were analysed. On T2w, the neuroradiologist identified all 27 lesions >2 mm in size out of a total of 30 CPA lesions (sensitivity: 90% [95% CI: 73.5%-97.9%]). Negative predictive value reached 99.5% (95% CI: 98.7-99.9). One missed lesion of 2 mm would have been detected in clinical practice, as this was one of 14 patients for which additional GdT1w would have been ordered based on T2w alone, increasing sensitivity to 93% (95% CI: 77.9%-99.2%) and negative predictive value to 99.7% (95% CI: 98.9%-100%). Inter-rater agreement for T2w was 98% (95% CI: 96.4-98.8).

Conclusion: T2w has a very high diagnostic accuracy for the presence of CPA lesions in patients with asymmetrical audiovestibular complaints. However, in a screening protocol with T2w only, smallest vestibular schwannomas as well as rare differential diagnoses that probably only would be detected on GdT1w may remain unnoticed.

1 INTRODUCTION

In a patient with asymmetrical hearing loss, unilateral tinnitus and/or vestibular symptoms, the otolaryngologist will order an MRI examination to evaluate the presence of a cerebellopontine angle (CPA) lesion. The most common CPA lesion is a vestibular schwannoma (VS). However, with an incidence of VS of around 1-3.3 per 100 000 people, the overall yield of these MRIs is 3%-4%. International guidelines discussing the optimal MRI protocol in these patients are lacking. Currently, MRI protocols to screen for CPA...
lesions in patients with asymmetrical audiovestibular complaints differ per hospital, either consisting of high-resolution T2-weighted MRI (T2w) alone or a combination with contrast-enhanced T1-weighted MRI (GdT1w). Including GdT1w increases scan time compared to T2w only. Moreover, an intravenous catheter and administration of a contrast agent are required, resulting in discomfort for patients, a risk of allergic reactions, and nephrogenic systemic fibrosis or accumulation in the brain of certain types of gadolinium contrast agents, and increased costs for society (e.g., Dotarem® (Gadoterate meglumine, Guerbet, Villepinte, France) has a list price (commercial price) of about €80 or approximately US$86 per 15 mL vial).6-8 Studies reporting on diagnostic accuracy of MRI protocols only consisting of T2w, on the other hand, are either outdated (lacking current state-of-the-art image quality), contain small patient samples and/or mainly positive MRI findings or are conducted in academic setting where specialised neuroradiologist assess images.9-13 The consequences of usage of a protocol consisting of T2w only in current clinical practice remain unclear. Our aim was to evaluate the diagnostic accuracy of T2w for the presence of CPA lesions in comparison with a combined protocol including GdT1w in a large cohort of patients with asymmetrical audiovestibular complaints, using standard MRI machines and observers with different levels of experience.

2 | MATERIALS AND METHODS

This study was performed alongside a diagnostic (cost-)effectiveness study in which we aim to optimise the diagnostic strategy, including imaging, in patients with asymmetrical audiovestibular complaints. The need for informed consent was waived by the medical ethics committee of our institution, because of the size of the study population and retrospective nature of the study.

2.1 | Population

In our tertiary hospital (Radboud University Medical Centre, Nijmegen, the Netherlands), it is policy to perform a screening MRI of the CPA region in patients with asymmetrical tinnitus, asymmetrical sensorineural hearing loss (confirmed by pure-tone audiometry) and/or vestibular symptoms (in conjunction with asymmetrical findings on electronystagmography). We used a random sample of 350 patients aged ≥16 years, for which an otorhinolaryngologist had ordered a "screening MRI CPA", that is 700 CPAs. All MRIs were acquired between January 2013 and April 2016. This recent time period was chosen to ascertain state-of-the-art quality of the included images, representative for current clinical practice.

2.2 | Data collection

Most MRI images were acquired using a Siemens Avanto (Siemens Healthcare GmbH, Erlangen, Germany) with a field strength of 1.5 Tesla. Eight patients were scanned using a Siemens TrioTim with 3 Tesla field strength. For each patient, both axial GdT1w of the CPA region (Avanto and TrioTim standard parameters: slice thickness 2 and 2 mm, spacing 2.2 and 2.2 mm, TR 400-500 and 700-795 ms, TE 17 and 11 ms, flip angle 90 and 120°, respectively) and 3D TSE T2w (Avanto and TrioTim standard parameters: slice thickness 0.5 and 0.5 mm, TR 1500 and 1500 ms, TE 296-297 and 301 ms, flip angle 170 and 170°, respectively) were obtained in the same session. The screening MRI of the CPA additionally includes a 5 mm T2w of the whole brain; however, abnormal findings with a location other than the CPA were outside the scope of this study. MRI images of the selected patients were pseudo-anonymised (coded) and imported in a specially developed survey environment (Cirrus, a scoring and viewing platform produced in-house, based on MEVISLAB (MeVis Medical Solutions AG, Bremen, Germany)).

Two observers, a radiologist specialised in neuro and head & neck radiology with 6 years of experience (SS), and a medical doctor without formal education in neuroradiology (MH) assessed all images independently of each other using a predefined form. The less experienced observer was instructed on CPA anatomy and pathology by the neuroradiologist before the onset of the study. Both observers were blinded to any patient characteristics, clinical information and original reports during data collection. The presence (yes or no) and most probable diagnosis of lesions located in the CPA (including internal auditory canal and/or vestibulocochlear system) were noted, first for all consecutive T2w, followed by all consecutive GdT1w images without access to T2w diagnoses and images, in separate sessions. In all patients in which one or both observers had reported a lesion, an equivocal finding or had expressed doubts about a diagnosis based on T2w and/or GdT1w, the same neuroradiologist additionally assessed the combination of T1w, GdT1w and T2w to establish a final diagnosis. In case, T2w and GdT1w were independently assessed as being normal by both observers, the chance of finding pathology on the combination of GdT1w, T2w and T1 was considered negligible. Following assessment of each T2w image, the neuroradiologist additionally registered whether he would have wanted the patient to be recalled for additional GdT1w, because of doubts about T2w diagnosis, if an imaging policy with T2w only would have been standard. This provides insight into the number and type of patients that would need to return for acquisition of GdT1w in a screening policy consisting of T2w only.

Keypoints

- T2w has a very high diagnostic accuracy for the presence of CPA lesions in patients with asymmetrical audiovestibular complaints.
- Vestibular schwannomas ≤2 mm as well as rare differential diagnoses might be missed on T2w only.
- Inter-rater agreement between an experienced and less experienced observer is high.
If quality of the images was judged insufficient to reliably assess one or both CPAs by one or both observers (eg, due to movement artefacts) this CPA was excluded. Maximal tumour diameter in any direction was measured for detected lesions (including internal auditory canal portion).

### 2.3 Analyses

All statistical analyses were performed in R version 3.2.3 (The R Foundation for Statistical Computing, Vienna, Austria, 2015), using the "epiR" and "rel" packages. The presence or absence of a CPA lesion was used as outcome, irrespective of the type of lesion. T2w findings (index test) were initially compared to GdT1w alone (reference test). In case of positive, equivocal or doubtful findings on T2w and/or GdT1w, the combination of T1w, GdT1w and T2w (reference test) was additionally assessed to confirm the diagnosis. We summarised this in 2 by 2 tables and calculated sensitivity, specificity and positive and negative predictive values. Moreover, we calculated the proportion of patients that would have been recalled by the neuroradiologist for additional GdT1w images if T2w only was standard imaging policy.

As CPA lesions are rare findings, even in symptomatic patients such as used in this study, we used Gwet’s AC1 as coefficient to evaluate inter-rater agreement for T2w. In contrary to intraclass correlation coefficient or Cohen’s Kappa, this outcome value is less affected by heterogeneity in the study population. Moreover, it adjusts for the fact that assessors may agree, even when giving random values as results.\(^1\)^ Gwet’s AC1 can range from 0 to 1; where 1 indicates perfect reliability and 0 no reliability at all.

### 3 RESULTS

Of the 700 CPAs in 350 patients, 22 CPAs in 12 patients were excluded: in 7 patients, the whole set of images was not available in the Cirrus system, and in 3 patients at least one of the observers reported insufficient quality of the images (the experienced observer reported insufficient quality of 1 T2w and 1 GdT1w sequence, and in 1 patient, both T2w and GdT1w were reported insufficient by both observers), resulting in exclusion of both CPAs, and in 2 patients, unilateral artefacts (identified by both observers) resulted in exclusion of one CPA. Results of 678 CPAs in 340 patients remained for further analysis.

### 3.1 Diagnoses

Based on the reference test, the neuroradiologist ultimately identified 30 CPA lesions (4.4% of CPAs) in 28 patients (8.2% of patients). Vestibular schwannoma (VS) as most probable diagnosis occurred most often, with 16 and 10 VSs diagnosed on the right and left side, respectively, of which 2 patients had a bilateral VS. There was 1 patient with a meningioma and 1 with an arachnoid cyst in the right and left CPA, respectively. One patient had a lesion of unknown origin on the left side, and 1 had an absent signal on T2w in the basal and 2nd turn of the right cochlea of which the origin could not be defined.

### 3.2 Diagnostic accuracy

A 2 by 2 table containing the results of the neuroradiologist, as well as sensitivity and specificity and positive and negative predictive values with corresponding 95% CIs, is displayed in Table 1. The neuroradiologist identified all 27 CPA lesions >2 mm (90%) correctly on T2w alone when compared to the 30 CPA lesions identified on the reference test.

There were 14 patients (4%) for which the neuroradiologist would have ordered additional GdT1w to confirm/exclude the presence of a CPA lesion with more certainty after assessment of T2w, that is, these patients would have been recalled in clinical practice with an imaging policy of T2w only. One of the 3 false negative observations on T2w would be additionally detected in clinical practice after being recalled for GdT1w (Table 1). Including GdT1w results in the index test in these 14 selected patients increased diagnostic accuracy: 1 false negative diagnosis was reclassified as true positive, and 1 false positive diagnosis was reclassified as true negative, finally resulting in 2 false negative and 2 false positive diagnoses. Hence, the number of correctly diagnosed CPA lesions (sensitivity) increased to 28 (93.3% [95% CI: 77.9%-99.2%]) and the number of correctly classified negative MRIs (specificity) to 646 (99.7% [95% CI: 98.9%-100.0%]), resulting in a positive and negative predictive value of 93.3% [95% CI: 77.9%-99.2%] and 99.7% [95% CI: 98.9%-100.0%], respectively. In the remaining 326 patients (95.9%), GdT1w was not deemed necessary, because the neuroradiologist indicated to be certain about diagnoses based on T2w alone. Inter-rater agreement (absence/presence of CPA lesion) on T2w between both observers, expressed as Gwet’s AC1 constant, reached 0.976 (95% CI: 0.964-0.988).

### 3.3 CPA lesions

Maximal lesion diameter varied from 2 to 23 mm (including internal auditory canal portion). All lesions >2 mm were correctly identified.

| TABLE 1 | Comparison of diagnoses made by a neuroradiologist based on T2w images versus GdT1w images, combined with T1w and T2w in selected patients |
|-------------|------------------------------------------|
|             | **Reference test (GdT1w, combined with T1w & T2w in selected patients)** | |
|             | CPA lesion (n [% of CPAs]) | No CPA lesion (n [% of CPAs]) |
| Index test  |                         |                             |
| T2w         | 27 (4.0)                 | 3 (0.4)                    |
| No CPA lesion | >3 (0.4)                | 645 (95.1)                |
| Total       | 30                       | 648                        |

Negative predictive value: 99.5% [95% CI: 98.7%-99.9%].
Positive predictive value: 90.0% [95% CI: 73.5%-97.9%].
Sensitivity: 90.0% [95% CI: 73.5%-97.9%].
Specificity: 99.5% [95% CI: 98.7%-99.9%].
CPA, Cerebellopontine angle; T2w, T2-weighted MRI; (Gd)T1w, (Contrast enhanced) T1-weighted MRI; CI, confidence interval.
on T2w alone by the neuroradiologist. The 3 lesions that were missed on T2w alone compared to the reference test were 2 mm and located distally in the internal auditory canal. The less experienced observer did not identify these 3 lesions either. T2w and GadT1w images of the 3 lesions are provided in Figure 1A,B. For the patient shown in Figure 1A, the neuroradiologist indicated T2w should be followed by additional GadT1w, that is, the patient would have been recalled. This lesion would have been detected on the combination of sequences and thus would not have been missed in clinical practice. Figure 1B displays the 2 lesions that were missed on T2w compared to the reference test. None of the latter 2 lesions are visible on T2w in retrospect. All 3 false positive lesions on T2w were located in the cochlea, of which an example is displayed in Figure 2. In one of these patients, following T2w assessment, the neuroradiologist indicated the patient should be recalled for additional GadT1w, that is, the presence of a lesion would eventually have been excluded on the combination of sequences. Another lesion in the CPA was correctly detected by both observers based on T2w (true positive), but was classified as a VS and appeared to be a meningioma on GadT1w (Figure S1).

4 | DISCUSSION

Our results show a very high negative predictive value for the presence of CPA lesions in patients with asymmetrical audiovestibular complaints using T2w alone, and a very high inter-rater agreement between an experienced and less experienced observer. A protocol consisting of T2w only would result in 2 (of 30) VSs being missed, having a maximal diameter of 2 mm.

4.1 | Previous studies

Our results are not completely in agreement with Fortnum et al16 who also compared diagnostic accuracy of high-resolution T2w to GadT1w in diagnosing VS. They pooled estimates of 11 papers published between 1996 and 2001 and reported sensitivity and specificity values of 98% and 96%, respectively. Specificity in the current study was higher with 99.5%, while sensitivity was lower with 90.0%. Possible explanations are the choice not to blind for clinical details9,10,13,17 usage of different sequences18,19 and field strength,10,19 and a different prevalence10,13,17-20 and size9,10,17 of CPA lesions in some of the studies included in the meta-analysis by Fortnum et al.16 In the current study, lesions not identified on T2w were 2 mm in size. In several studies within the meta-analysis, diameter of the smallest detected lesions was ≥3 mm.9,10,17 Possibly, lesions of 2 mm did not occur in these studies or were not detected.

The prevalence of CPA lesions in 8.2% of patients (including VSs in 7% of all patients) in our study was relatively high, which influences positive and negative predictive values.21 The higher incidence of CPA lesions in our study as compared to literature is probably caused by the fact that we selected our sample based on MRI coding. Due to the tertiary study setting, our sample might include some patients with a CPA lesion referred from another hospital, in which a new screening MRI was acquired in our institution.

4.2 | Strengths and limitations

We carefully chose the time frame to guarantee similar and state-of-the-art quality MRIs, which makes results representative for current clinical practice. The number of included CPAs was high. It is unlikely

![FIGURE 1](image1) A, Example of an initially false negative diagnosis of a left-sided intracanalicular vestibular schwannoma (VS) of 2 mm based on T2w (a) compared to GadT1w (b). Findings on T2w would have been a reason to request additional GadT1w, so this lesion would eventually have been diagnosed correctly. B, Example of two false negative diagnoses of left-sided intracanalicular VSs of 2 mm based on T2w (a and b) compared to GadT1w (c and d). Even in retrospect, these lesions could not be detected on T2w.

![FIGURE 2](image2) Example of a false positive finding in the left cochlea diagnosed as vestibular schwannoma (VS) based on T2w (A), while GadT1w revealed no enhancing structures (B). Findings on T2w would have been a reason for additional GadT1w, so the absence of a VS would ultimately have been correctly confirmed.
that insufficient GdT1w quality in few patients has introduced bias; the index test (T2w images) was first scored in a separate session and could not be linked to a particular GdT1w image during scoring. Only 1 patient was excluded, because of insufficient quality of T2w (assessed by experienced observer).

The current study was performed in a tertiary hospital, in which radiologists reporting on CPA screening studies are specialised in neuro and head & neck radiology. However, the majority of patients with asymmetrical audiovestibular complaints will be screened in a general hospital, and images will usually be assessed by general radiologists who have less exposure and experience. We have shown that an experienced and less experienced observer have high agreement with respect to T2w assessment. Agreement between a neuroradiologist and general radiologist is expected to be at least as sufficient and probably even higher. Moreover, we used Gwet’s AC1 to determine the agreement between assessors, because it is less affected by the prevalence of a disease, which is relatively low in case of CPA lesions.14

Some limitations should also be discussed. First, clinical information was not included in the analysis. In practice, such information will be provided and will focus the radiologist’s attention to one CPA in particular. This might have caused an underestimation of diagnostic accuracy and an overestimation of the simulated recall rate for additional GdT1w of 4%. It should be noted that a radiologist should always assess both CPAs, as incidentalomas are not uncommon in the CPA.22 Second, we have used the presence/absence of a CPA lesion as outcome, instead of the (most probable) type of lesion. Both observers misclassified one lesion for VS instead of menin-}

4.3 Clinical implications

Based on the neuroradiologists assessment of T2w alone, 14 of 340 patients would have been recalled for additional GdT1w. After including results of additional GdT1w examinations in the index test for the latter patients, as would occur in clinical practice, 2 lesions of 2 mm would have been missed. In other words, to prevent these 2 CPA lesions of 2 mm from being missed, 326 patients have to undergo GdT1w, with accessory costs (€26 080 or approximately US $27 929 when accounting for the official price of €80 per unit Dotarem®), discomfort and risks. In clinical practice, patients with lesions ≤2 mm are managed using a wait-and-scan policy, instead of invasive treatments such as radiotherapy or microsurgery.24 Of the VS patients in a wait-and-scan policy, no more than 40% require treatment at some point.25-28 Cisternal extension and a large tumour diameter at time of diagnosis have been mentioned as significant predictors for growth,26,29 which are not applicable to the small missed lesions in this study. On the contrary, at the moment there is no safety net for patients who have a small missed lesion that may require treatment once growth occurs later in life. As it appears that hearing loss deteriorates faster in case of growing intracanalicular tumours as compared to non-growing lesions and the contralateral ear,27,28 thorough patient instructions and a relatively simple test such as pure-tone audiometry which is already routinely acquired in these patients could possibly identify such patients at a later time and so may serve as a safety net. The general practitioner could potentially play a larger role in such a scenario. This should be further investigated (including analyses on cost-effectiveness) and translated into a guideline for usage in clinical practice.

Decisions about management also determine further steps regarding imaging. Given the results of this study and above named arguments, specifically the high negative predictive value of T2w alone for VSs >2 mm, one could argue to restrain from further action when T2w is normal. Whenever a CPA lesion is evident and the patient will be obtained in a wait-and-scan policy, additional GdT1w may not be required at all, especially when the lesion is typical for VS. Omitting GdT1w in follow-up of VSs was recently shown to be cost-effective and is policy in our hospital.30 MRI policies for post-surgical patients were outside the scope of the current study.

We have shown that T2w alone has a high sensitivity and specificity for the presence of CPA lesions. Although intracochlear VSs were not encountered in our study population, we know from experience that even small intracochlear VSs can be detected by scrutinising a high-quality T2w.21 When in doubt patients can be recalled for additional GdT1w. Another differential diagnosis that justifies additional GdT1w is labyrinthitis, which can be visualised as a filling defect on T2w.31 Intralabyrinthine haemorrhage can easily be diagnosed with aid of native T1w, which we would recommend to acquire in all patients.31

Diagnoses such as Lyme or tuberculosis cannot be established based on T2w alone, but are seldom, and symptoms are rarely restricted to audiovestibular complaints.31,32 GdT1w is also required to detect leptomeningeal metastases, usually prevalent in patients with a known history of malignancy, although these lesions are also seldom restricted to the CPA.11,31 One should note that we did not encounter any patients with granulomatous, inflammatory or other infectious pathology in our unselected study population, nor any patient with leptomeningeal metastases. A large series of GdT1w images of the CPA studied by Dawes et al6 only revealed 2 cases of labyrinthine inflammation out of 1139 scans (0.18%), which did not influence management. This indicates the rareness of differential diagnoses that cannot be seen on T2w. However, if one considers a policy of screening with T2w alone in patients with audiovestibular complaints, GdT1w should still be included when screening patients with a broader variety of symptoms and in those with a known history of inflammatory, infectious or malignant disorders.11 Preferably, differences in MRI protocols between hospitals are eliminated by
establishment of a guideline weighing benefits of improved diagnostic accuracy of GdT1w against its disadvantages of increased scan time, costs and potential harmful effects.

In conclusion, T2w alone has a high diagnostic accuracy for detection of CPA lesions >2 mm. Further research is needed focusing on a (clinical) safety net for the few patients with very small lesions being missed on T2w alone and patients with rare differential diagnoses. At least, GdT1w should always be considered in patients with a broader variety of symptoms, or a known history of inflammatory, infectious or malignant disorders.

ACKNOWLEDGEMENTS

This study was funded by a Health Care Efficiency Research grant by the Netherlands Organization for Health Research and development (ZonMw). The need for informed consent was waived by the medical ethics committee of our institution, because of the size of the study population and retrospective nature of the study. The authors thank Sven Lafebre for designing the Cirrus software.

CONFLICT OF INTEREST

None to declare.

ORCID

M.A. Hentschel http://orcid.org/0000-0001-6106-089X

REFERENCES

1. Kshettry VR, Hsieh JK, Ostrom QT, Kruchko C, Barnholtz-Sloan JS. Incidence of vestibular schwannomas in the United States. J Neurooncol. 2015;124:223-228.
2. Kleijwegt M, Ho V, Visser O, Godefroy W, van der Mey A. Real incidence of vestibular schwannoma? Estimations from a national registry. Otol Neurotol. 2016;37:1411-1417.
3. Stangerup SE, Tos M, Thomsen J, et al. True incidence of vestibular schwannoma? Neurosurgery. 2010;67:1335-1340.
4. Evans DG, Moran A, King A, Saeed S, Gurusinghe N, Ramsden R. Incidence of vestibular schwannoma and neurofibromatosis 2 in the North West of England over a 10-year period: higher incidence than previously thought. Otol Neurotol. 2005;26:93-97.
5. Dawes PJ, Mehta D, Arullendran P. Screening for vestibular schwannoma: magnetic resonance imaging findings and management. J Laryngol Otol. 2000;114:584-588.
6. Sadowski EA, Bennett LK, Chan MR, et al. Nephrogenic systemic fibrosis: risk factors and incidence estimation. Radiology. 2007;243:148-157.
7. Costello JR, Kalb B, Martin DR. Incidence and risk factors for gadolinium-based contrast agent immediate reactions. Top Magn Reson Imaging. 2015;26:257-263.
8. Kanda T, Fukusato T, Matsuda M, et al. Gadolinium-based contrast agent accumulates in the brain even in subjects without severe renal dysfunction: evaluation of autopsy brain specimens with inductively coupled plasma mass spectroscopy. Radiology. 2015;276:228-232.
9. Annesley-Williams DJ, Laitt RD, Jenkins JP, Ramsden RT, Gillespie JE. Magnetic resonance imaging in the investigation of sensorineural hearing loss: is contrast enhancement still necessary? J Laryngol Otol. 2001;115:14-21.
10. Zealley IA, Cooper RC, Clifford KM, et al. MRI screening for acoustic neuroma: a comparison of fast spin echo and contrast enhanced imaging in 1233 patients. Br J Radiol. 2000;73:242-247.
11. Abele TA, Besachio DA, Quigley EP, et al. Diagnostic accuracy of screening MR imaging using unenhanced axial CISS and coronal T2WI for detection of small internal auditory canal lesions. AJNR Am J Neuroradiol. 2014;35:2366-2370.
12. Maslan JT, Lack CM, Zapadka M, Gasser TG, Oliver E. High resolution T2 MRI in the diagnosis of cerebellopontine angle and internal auditory canal lesions. Clin Imaging. 2017;45:8-11.
13. Soulie D, Cordoliani YS, Vignaud J, Consnard G. MR imaging of acoustic neuroma with high resolution fast spin echo T2-weighted sequence. Eur J Radiol. 1997;24:61-65.
14. Wongpakaran N, Wongpakaran T, Wedding D, Gwet KL. A comparison of Cohen’s kappa and Gwet’s AC1 when calculating inter-rater reliability coefficients: a study conducted with personality disorder samples. BMC Med Res Methodol. 2013;13:61.
15. Ten Cate DF, Luime JJ, Hazes JM, Jacobs JW, Landewé R. Does the intraclass correlation coefficient always reliably express reliability? Comment on the article by Cheung et al. Arthritis Care Res (Hoboken). 2010;62:1357-1358, author reply 1358.
16. Fortnum H, O’Neill C, Taylor R, et al. The role of magnetic resonance imaging in the identification of suspected acoustic neuroma: a systematic review of clinical and cost effectiveness and natural history. Health Technol Assess. 2009;13:iii-iv, ix-xi, 1-154.
17. Marx SV, Langman AW, Crane RC. Accuracy of fast spin echo magnetic resonance imaging in the diagnosis of vestibular schwannoma. Am J Otolaryngol. 1999;20:211-216.
18. Stuckey SL, Harris AJ, Mannolini SM. Detection of acoustic schwannoma: use of constructive interference in the steady state three-dimensional MR. AJNR Am J Neuroradiol. 1996;17:1219-1225.
19. Hermans R, Van der Goten A, De Foer B, Baert AL. MRI screening for acoustic neuroma without gadolinium: value of 3DFT-CISS sequence. Neuroradiology. 1997;39:593-598.
20. Allen RW, Harnsberger HR, Shelton C, et al. Low-cost high-resolution fast spin-echo MR of acoustic schwannoma: an alternative to enhanced conventional spin-echo MR? AJNR Am J Neuroradiol. 1996;17:1205-1210.
21. Altman DG, Bland JM. Diagnostic tests. 1: sensitivity and specificity. BMJ. 1994;308:1552.
22. Lin D, Hegarty JL, Fischbein NJ, et al. The prevalence of “incidental” acoustic neuroma. Arch Otolaryngol Head Neck Surg. 2005;131:241-244.
23. Friedmann DR, Grobelny B, Golfinos JG, Roland JT Jr. Nonschwan- noma tumors of the cerebellopontine angle. Otolaryngol Clin North Am. 2015;48:461-475.
24. Hajiloff D, Raut VV, Walsh RM, et al. Conservative management of vestibular schwannomas: third review of a 10-year prospective study. Clin Otolaryngol. 2008;33:255-259.
25. Yoshimoto Y. Systematic review of the natural history of vestibular schwannoma. J Neurosurg. 2005;103:59-63.
26. Hunter JB, Francis DO, Ouellette R. Does the intraclass correlation coefficient always reliably express reliability? Comment on the article by Cheung et al. Arthritis Care Res (Hoboken). 2010;62:1357-1358, author reply 1358.
27. Hunter JB, Francis DO, Ouellette R. Does the intraclass correlation coefficient always reliably express reliability? Comment on the article by Cheung et al. Arthritis Care Res (Hoboken). 2010;62:1357-1358, author reply 1358.
28. van Linge A, Borsboom GJ, Wieringa MH, Goedegebure A. Hearing loss associated with meningioma: a comparison of patients with meningioma and patients with acoustic neuroma. Eur J Radiol. 2014;81:266-270.
29. Wolbers JG, Dallenga AH, van Linge A, et al. Identifying at diagnosis the vestibular schwannomas at low risk of growth in a long-term retrospective cohort. Clin Otolaryngol. 2016;41:788-792.
30. Coelho DH, Tang Y, Suddarth B, Mamdani M. MRI surveillance of vestibular schwannomas without contrast enhancement: clinical and economic evaluation. Laryngoscope. 2017;128:202-209.

31. Verbist BM. Imaging of sensorineural hearing loss: a pattern-based approach to diseases of the inner ear and cerebellopontine angle. Insights Imaging. 2012;3:139-153.

32. Espiney Amaro C, Montalvao P, Huins C, Saraiva J. Lyme disease: sudden hearing loss as the sole presentation. J Laryngol Otol. 2015;129:183-186.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Hentschel MA, Kunst HPM, Rovers MM, Steens SCA. Diagnostic accuracy of high-resolution T2-weighted MRI vs contrast-enhanced T1-weighted MRI to screen for cerebellopontine angle lesions in symptomatic patients. Clin Otolaryngol. 2018;43:805–811. https://doi.org/10.1111/coa.13051