

# Diagnostic Yield of MRI for Sensorineural Hearing Loss – An Audit

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**ABSTRACT:** *Purpose:* Contrast-enhanced magnetic resonance imaging (CEMRI) of the head is frequently employed in investigations of sensorineural hearing loss (SNHL). The yield of these studies is perceptibly low and seemingly at odds with the aims of wise resource allocation and risk reduction within the Canadian healthcare system. The purpose of our study was to audit the use and diagnostic yield of CEMRI for the clinical indication of SNHL in our institution and to identify characteristics that may be leveraged to improve yield and optimize resource utilization. *Materials and methods:* The charts of 500 consecutive patients who underwent CEMRI of internal auditory canal for SNHL were categorized as cases with relevant positive findings on CEMRI and those without relevant findings. Demographics, presenting symptoms, interventions and responses, ordering physicians, and investigations performed prior to CEMRI testing were recorded. Chi-squared test and *t*-test were used to compare proportions and means, respectively. *Results:* CEMRI studies revealed relevant findings in 20 (6.2%) of 324 subjects meeting the inclusion criteria. Pre-CEMRI testing beyond audiometry was conducted in 35% of those with relevant positive findings compared to 7.3% of those without ( $p < 0.001$ ). Auditory brainstem response/ vestibular-evoked myogenic potentials were abnormal in 35% of those with relevant CEMRI findings compared to 6.3% of those without ( $p < 0.001$ ). *Conclusion:* CEMRI is a valuable tool for assessing potential causes of SNHL, but small diagnostic yield at present needs justification for contrast injection for this indication. Our findings suggest preferred referral from otolaryngologists exclusively, and implementation of a non-contrast MRI for SNHL may be a better diagnostic tool.

**RÉSUMÉ :** **Rendement diagnostique des examens d'IRM dans le cas de pertes auditives neurosensorielles : une tentative de vérification.**

*Objectif:* On emploie fréquemment des examens d'IRM avec injection d'un agent de contraste (*contrast enhanced magnetic resonance imaging*) pour observer la tête et détecter des pertes auditives neurosensorielles (PANS). Les bénéfices de tels examens sont à première vue faibles et en porte-à-faux avec les objectifs, propres au système de santé canadien, d'une allocation judicieuse des ressources et d'une réduction des risques. Le but de notre étude a donc été d'évaluer dans notre établissement l'utilisation et le rendement diagnostique des examens d'IRM avec injection d'un agent de contraste dans le cas des PANS et d'identifier les aspects qui peuvent être mis à profit afin d'améliorer un tel rendement et d'optimiser l'utilisation des ressources. *Matériel et méthodes:* Les dossiers de 500 patients vus consécutivement et ayant subi des examens d'IRM avec injection d'un agent de contraste ciblant leur canal auditif interne ont été divisés en deux catégories : des cas pour lesquels des examens ont révélé des résultats positifs pertinents ; et d'autres cas pour lesquels aucun résultat pertinent n'a émergé. À cet égard, les aspects suivants ont été consignés dans le cadre de cette étude : les caractéristiques démographiques des patients, les symptômes qu'ils présentaient, les interventions effectuées et leurs réponses, les médecins prescripteurs et les examens effectués avant que les résultats d'IRM ne soient compilés. Enfin, des tests du  $\chi^2$  et de Student ont été utilisés afin de comparer respectivement les proportions et les moyennes. *Résultats:* Sur les 324 patients répondant à nos critères d'inclusion, des examens d'IRM avec injection d'un agent de contraste ont donné à voir des résultats pertinents chez 20 d'entre eux, soit 6,2 %. Des tests pré-IRM allant au-delà de l'audiométrie ont été effectués chez 35 % de ces 20 patients en comparaison avec 7,3 % chez ceux dont les résultats n'étaient pas pertinents ( $p < 0,001$ ). Les résultats aux tests de potentiels évoqués auditifs du tronc cérébral et de potentiels évoqués auditifs myogéniques étaient par ailleurs anormaux chez 35 % de ces 20 patients en comparaison avec 6,3 % chez les autres patients ( $p < 0,001$ ). *Conclusions:* Les examens d'IRM avec injection d'un agent de contraste constituent un outil intéressant si l'on veut évaluer les causes potentielles de PANS. Il est toutefois difficile de justifier leur utilisation pour ce problème médical étant donné leur faible rendement diagnostique. Nos observations suggèrent ainsi qu'un aiguillage à partir d'un otorhinolaryngologiste seulement et l'utilisation d'examen d'IRM sans ajout d'agent de contraste sont peut-être de meilleures avenues diagnostiques dans le cas des PANS.

**Keywords:** Sudden hearing loss, sensorineural hearing loss, MRI

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## INTRODUCTION

Hearing loss is a common ailment that affects all age groups.<sup>1</sup> Hearing loss if left uncorrected has a negative impact on health-related quality of life especially with respect to social and emotional aspects of communication.<sup>2,3</sup> Hearing loss is

also linked to cognitive decline and decrease in work productivity. It impairs language development if present in early childhood.<sup>4,5</sup> The mechanism of loss may be conductive, sensorineural, or mixed. Conductive hearing loss stems mostly from benign processes such as cerumen impaction, otitis

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media, cholesteatoma, and otosclerosis. Sensorineural hearing loss (SNHL), in contrast, has a broader range of etiologies including neoplasms and viruses. Due to the possibility of these etiologies, clinicians pursue further investigations beyond the acute phase of SNHL, particularly when symptoms are asymmetric.

Investigations for SNHL often culminate in contrast-enhanced magnetic resonance imaging (CEMRI). Studies have suggested MRI as a preferred imaging modality for the investigation of both sudden and asymmetrical SNHL.<sup>6–8</sup> Gadolinium-enhanced MRI of the whole brain including the auditory pathway can give valuable information and can confirm the underlying cause for SNHL.<sup>9,10</sup> CEMRI has been suggested to be the gold standard for the investigation of asymmetrical SNHL with 100% sensitivity and specificity.<sup>11</sup> Unfortunately, MRI cost and access are perennial problems within any healthcare system including that of Canada. The average waiting time for non-urgent MRI studies was 10.6 weeks in 2018.<sup>12</sup> The typical cost of such a study is reported to be several thousands of dollars.<sup>13</sup> The investigation itself, with the use of gadolinium, is not without risk to the patient.<sup>14</sup> These risks may not outweigh the benefits given that the majority of investigations are negative. Thus, the aforementioned factors suggest that current practice requires further examination to determine whether MRI is being deployed appropriately for SNHL and whether study yield can be increased.

Vestibular schwannomas are a rare cause of asymmetrical SNHL and have an estimated prevalence of 0.1–7.0 per 10,000 people when detected by MRI.<sup>15</sup> Although the actual prevalence of this condition is very low in patients with SNHL, visualization of vestibular schwannomas can be facilitated by administration of IV contrast during an MRI examination.<sup>16</sup> According to American College of Radiology Appropriateness Criteria for hearing loss and/or vertigo,<sup>16</sup> there is insufficient evidence to prove incremental benefit of contrast administration beyond an MRI internal auditory canal (IAC) protocol performed without IV contrast in patients presenting with SNHL. In a recent survey,<sup>17</sup> approximately 95% of American neurotologists reported that they ordered an MRI in patients with asymmetrical SNHL and sudden deafness, despite the awareness of a high prevalence of negative test results. About 40% of these otologists stated that medicolegal concerns were a significant factor in their decision to pursue imaging.<sup>17</sup> Many studies<sup>18–21</sup> have suggested a non-contrast MRI with a dedicated IAC protocol to be used as an initial screening test for patients with SNHL. Sequences like T2-weighted imaging and a steady-state free precession (brand names “FIESTA,” “TrueFISP,” and balanced FFE) provide higher spatial resolution and clearer depiction of tiny intracranial structures. These sequences are more cost-effective than CEMRI and provide excellent spatial resolution of the cerebellopontine angle structures including the cisterns, the lower cranial nerves tracts, as well as the composition of the IAC and cochlea.

In recent years with campaigns such as “Choosing Wisely,” there has been a huge shift in the medical community to rethink the inappropriate overuse of medical tests and treatments that provide patients with little added value.<sup>22,23</sup> The purpose of our study was to audit the use and diagnostic yield of CEMRI for the clinical indication of SNHL in our institution and to identify characteristics that may be leveraged to improve yield and optimize resource utilization.

## MATERIALS AND METHODS

The study was approved by our Institutional Research Ethics Board (REB #: 1021597). This was a single-center retrospective chart review of consecutive patients who had undergone CEMRI of head with IAC protocol for investigation of asymmetric SNHL between August 2011 and July 2016. Patients were excluded if they (1) were followed for known acoustic neuroma, (2) were being investigated for trigeminal neuralgia or multiple sclerosis, (3) had previously undergone stereotactic therapy or other intervention, (4) had no specified indications on the requisition, and (5) refused contrast or did not receive contrast due to known allergies to gadolinium contrast agent. Additional information was also collected on the clinical presentation, any other neurological deficits, and the specialty of referring physicians or other healthcare professionals. When applicable, we also recorded data on the symptomatic response to a short course of prednisone in treated patients.

Data were compiled and analyzed in Excel (Microsoft, Redmond, WA, USA). Patients were categorized as those with relevant positive findings or those without findings on CEMRI, and different characteristics were compared between them. Chi-squared and two-sample *t*-test analyses were used to compare proportions and means, respectively, between the two groups. A *p*-value of <0.05 was considered significant.

## RESULTS

A total of 500 consecutive patients were reviewed. Of these, 176 met our exclusion criteria and the remaining 324 patients were included in our final analysis. The demographic details, referral pattern, and clinical characteristics are summarized in Table 1. The mean age of study patients was 56.2 years (range 18–86) and more than half were males (55%). The majority (92%) of referrals for CEMRI came from the otolaryngologists. The most common indication cited for CEMRI was asymmetric SNHL. All patients who had relevant positive findings on CEMRI were referred from otolaryngologists. Twenty out of 301 patients (6.6%) referred from otolaryngologists had relevant positive findings on CEMRI.

Of 324 study participants meeting the inclusion criteria, 20 (6.2%) had relevant positive findings on CEMRI (Table 2). Vestibular schwannomas accounted for 19 of the 20 (95%) patients with positive relevant findings. All other findings on CEMRI were irrelevant or negative.

In comparing patients with relevant positive findings on CEMRI to those without, several significant differences were found between the two groups. A greater proportion of participants with relevant positive CEMRI findings (35%) had abnormal auditory brainstem response (ABR)/vestibular-evoked myogenic potential (VEMP) tests than those without (6.3%) ( $p < 0.001$ ). Vestibular symptoms ( $p = 0.03$ ) and tinnitus ( $p = 0.07$ ) were more prominent in those with relevant positive CEMRI findings. Duration of symptoms was longer (3.84 years) in those with relevant positive findings on CEMRI compared to those without (2.48 years) but was not statistically significant ( $p = 0.20$ ).

Majority (92.8%) of those without relevant positive findings on CEMRI did not have any other tests beyond a standard audiometry compared to 65% of those with relevant positive findings on CEMRI ( $p < 0.001$ ). Abnormal ABR/VEMP test

**Table 1: Demographics and clinical findings by CEMRI findings (N = 324)**

	Relevant CEMRI findings (N = 20)	Non-relevant CEMRI findings (N = 304)	P-values
Sex, n (%)			
Male	13 (65%)	164 (54%)	0.34
Female	7 (35%)	140 (46%)	0.34
Age, years			
Mean	54	56	0.44
Range	28–79	18–86	
Medical referral			
Otolaryngology	20 (100%)	281 (92.4%)	0.20
Neurology	0 (0%)	5 (1.6%)	
General practitioner	0 (0%)	5 (1.6%)	
Internal medicine	0 (0%)	4 (1.3%)	
General surgery	0 (0%)	1 (0.3%)	
PMR	0 (0%)	1 (0.3%)	
Ophthalmology	0 (0%)	1 (0.3%)	
Orthopedic surgery	0 (0%)	1 (0.3%)	
Neurosurgery	0 (0%)	1 (0.3%)	
Anesthesiology	0 (0%)	1 (0.3%)	
Psychiatry	0 (0%)	1 (0.3%)	
Emergency medicine	0 (0%)	1 (0.3%)	
Nurse practitioner	0 (0%)	1 (0.3%)	
ABR/VEMP test results, n (%)			
Abnormal	7 (35%)	19 (6.3%)	<0.001
Normal	0 (0%)	3 (1%)	
Not tested/unspecified	13 (65%)	282 (92.8%)	<0.001
Presenting symptoms, n (%)			
Vestibular (disequilibrium, vertigo)	8 (40%)	60 (19.7%)	0.03
Tinnitus	8 (40%)	68 (22.4%)	0.07
Neurological deficits (aphasia, weakness, auditory verbal hallucinations)	1 (5%)	6 (2%)	0.37
Pain (otalgia, headache)	2 (10%)	9 (3%)	0.10
Average duration of symptoms, years	3.84	2.48	0.20
Treatment			
Symptom resolution with prednisone	1 (5%)	12 (4%)	0.82
No symptom resolution with prednisone	1 (5%)	8 (2.6%)	0.52
None or unspecified	18 (90%)	284 (93.4%)	0.96

PMR=physical medicine and rehabilitation; ABR=auditory brainstem response; VEMP=vestibular-evoked myogenic potential; CEMRI: contrast-enhanced magnetic resonance imaging.

results were found in 35% of those with relevant positive findings on CEMRI compared to in 6.3% of those without ( $p \leq 0.001$ ).

## DISCUSSION

This study examined the patterns of referral, presenting symptoms, and imaging results in patients who underwent CEMRI at our institution for asymmetrical SNHL, over the course of 5 years. Relevant positive findings were seen on CEMRI in 6.2% of these patients. Similar studies have been

conducted with smaller sample sizes, but none were performed in the context of the Canadian healthcare system.<sup>24–29</sup> Among the aforementioned studies, relevant intracranial abnormality along the acoustic pathway in patients was reported to range from 3.7%<sup>28</sup> to 31%.<sup>27</sup> This warrants an assessment of our selection criteria for CEMRI for SNHL at our institution. Although clinical practice guidelines are available regarding the diagnosis and workup for SNHL,<sup>30</sup> these guidelines do not specify indications for CEMRI in these patients. Our findings suggested that a

**Table 2: Summary of findings on CEMRI**

Diagnosis	Total patients (N = 324)
Relevant positive findings	20 (6.2%)
Acoustic neuroma/vestibular schwannoma	19 (95%)
Linear enhancement in fundus of IAC consistent with Ramsey hunt syndrome	1 (5%)
Incidental findings	7 (2.2%)
Chiari I malformation	1 (14.3%)
Labyrinthitis	1 (14.3%)
Gliosis	1 (14.3%)
Neuritis	1 (14.3%)
Meningioma	1 (14.3%)
Pituitary adenoma	2 (28.6%)
Negative findings	297 (91.7%)

CEMRI=contrast-enhanced magnetic resonance imaging.

request for CEMRI in patients with SNHL is expected to yield relevant positive CEMRI findings when requested by otolaryngologists in patients presenting with vestibular symptoms with abnormal ABR or VEMP.

Tests used prior to MRI referral include pure tone audiometry, ABR, and VEMP.<sup>30</sup> Pure tone audiometry is a subjective test that relies on the patient's response to given stimuli across a range of frequencies. It is often the first step of investigation. It tests thresholds and allows distinction between conductive hearing loss and SNHL. ABR is a clinical test for the auditory pathway, including the cochlear nerve, often used to test the entire pathway in patients who may not be able to comply with audiometry. It provides an objective and passive measurement of evoked potential in the brainstem in response to loud clicks. Given the recent improvement in resolution and reduction in cost of MRI, appropriateness of ABR as the primary test used to screen for SNHL is debatable.<sup>31</sup> ABR has a low sensitivity and specificity in the evaluation of patients with an asymmetrical SNHL.<sup>11</sup> VEMP testing detects myogenic potentials in the sternocleidomastoid evoked by monaural clicks. These potentials are believed to originate in the inferior vestibular nerve region and have been demonstrated to be an effective means of testing the vestibular nerve.<sup>32</sup> It provides additional information for the tumor, effected nerve division in the IAC, and hence helps in the pre-surgical planning.<sup>33</sup>

It is important to note that over 90% of our patients did not undergo any testing beyond an audiogram prior to CEMRI referral. The low utilization rate of inexpensive and non-invasive adjunct tests could stem from factors such as lack of familiarity, lack of specialized equipment, or from the perception that these investigations do not impact management. Although these tests are not a diagnostic replacement for MRI in patients with vestibular schwannomas, they serve to provide an additional source of information.

Based on a cost-effectiveness model, some studies suggest a diagnostic algorithm that deploys non-contrast MRI as an initial imaging screen in the investigation is less costly than and likely to be as effective as available contrast MRI.<sup>18,21,34</sup> Although our

study does not provide a definitive solution to our current radiological practice for CEMRI for SNHL at our institution, we highlight the small yield of this test for this indication. A non-contrast MRI with high-resolution imaging of the IAC for this indication is likely a better screening test. Our study may help modify the imaging protocol in other centers where CEMRI is used for screening of SNHL.

#### LIMITATIONS TO STUDY

The current study is limited by the biases associated with studies involving retrospective chart review and by the small number of cases with positive findings. Twenty patients had findings related to the SNHL. The small number limits the ability to develop a decision tree, and only simple exploratory statistics were performed. However, this low diagnostic yield with current practices highlighted the reasoning behind this study and brings to focus the potential areas to improve upon.

#### CONCLUSION

CEMRI is a valuable tool for assessing potential causes of SNHL, but small diagnostic yield at present needs justification for contrast injection for this indication. Our findings suggest preferred referral from otolaryngologists exclusively, and implementation of a non-contrast MRI for SNHL may be a better diagnostic tool.

#### CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

#### INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

#### STATEMENT OF AUTHORSHIP

HW – data acquisition and manuscript preparation; YAT – design of study, data acquisition, and final approval; KF – draft and revise the manuscript and final approval; JJSS – conceptualized the project, supervision, design of study, data analysis and interpretation, revision of manuscript, and final approval.

#### ETHICAL APPROVAL

All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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