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Cost Analysis of Contrast Enhancement in Magnetic Resonance Imaging for Screening Retrocochlear Pathologies in Asymmetric Hearing Loss

Abstract

Objective: Contrast-enhanced temporal magnetic resonance imaging (MRI) is the gold standard for differential diagnosis of retrocochlear pathologies. Nowadays, with the improvement of MRI devices and new imaging modalities, we have very detailed images of the cerebellopontine angle. In this study, we calculated the additional cost of contrast-enhanced MRI and questioned that if contrast-enhanced imaging is still necessary for diagnosis.

Methods: Temporal bone MRIs of 1145 patients admitted to our clinic with unilateral asymmetric sensorineural hearing loss were evaluated retrospectively. The factors that affect the cost of the imaging, including serum creatinine test, establishing vascular access, and contrast material were analyzed, both for the cost and the time consumed.

Results: Of the 1145 patients, 31 were diagnosed with vestibular schwannoma (VS). Re-examination of the images of the patients with VS revealed that the tumor could be seen on the images with and without contrast in 30 cases. Only one patient had a tiny VS that was difficult to identify on noncontrast imaging. The total additional time and cost for contrast-enhanced imaging were calculated as 18,320 minutes and 37,888 USD. The sensitivity and specificity of the noncontrast 3D FIESTA technique have been determined as 96.8% and 99.9%, respectively.

Conclusion: We recommend the noncontrast MRI 3D FIESTA modality for screening because of its high sensitivity and specificity when the cost and time spent for contrast enhancement are taken into account. It will also reduce the expenses of the health system, increase hospital income, and shorten waiting lists of patients.

Keywords: Hearing loss, magnetic resonance imaging, vestibular schwannoma

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Introduction

Unilateral (asymmetric) hearing loss is a common symptom encountered in otorhinolaryngology practice. A survey-based study reported the prevalence of unilateral hearing loss as 7.6% in the United States.[1] Niskar et al.[2] screened school-aged children and reported that 3% of them had unilateral hearing loss. We can assume that approximately 5% of the population is admitted to hospitals in their lifetime for unilateral hearing loss. The differential diagnosis of these patients is an important workload for doctors and a significant burden on the healthcare system.

The most frequent retrocochlear pathology is vestibular schwannoma (VS), the incidence of which was reported as 1.09 per 100,000 of the population in the United States.[3] Fujita et al.[4] have retrospectively evaluated the MRI scans of 499 patients with sudden sensorineural hearing loss and reported that 15 (3%) had VS. Computerized tomography (CT), auditory evoked brainstem responses (AEBR), and magnetic resonance imaging (MRI) can be used in the differential diagnosis of retrocochlear disorders, with MRI being the gold standard.[5, 6] Usually, T1-weighted spin-echo MRI with contrast is the preferred imaging method; however, getting an MRI scan is expensive in most countries. AEBR is a good alternative and is a more convenient and cheaper test in some countries. However, its sensitivity is low for tumors smaller than 1 cm.[5] The cost of a noncontrast MRI is very close to a diagnostic AEBR in our setting.

We need a cost-effective and sensitive method for screening retrocochlear diseases. With new technologies entering the imaging market, we have improved MRI devices and new

image modalities. For example, high-resolution fast spin-echo T2-weighted MRI and T2* weighted three-dimensional Fourier transformation - constructive interference in steady-state (3DFT-CISS) have been shown to have similar success rates as T1 with contrast.[7] The use of contrast in MRI increases costs, both by increasing the scanning time and adding the cost of the contrast agent. Therefore, omitting the contrast agent will reduce healthcare cost for screening as well as eliminate the side effects of the contrast material.

Gadolinium is commonly used as a contrast agent for tumor imaging in MRI, at the region of the cerebellopontine angle. It contains paramagnetic metallic ions and is usually harmless. Patients may have mild nausea, vomiting, itching, rash, headache, and paresthesia. However, it can cause serious nephrogenic systemic fibrosis if used in a patient with renal or hepatorenal disease.[8]

In this study, we aimed to investigate the factors that affected the cost of temporal MRI with contrast and calculate its burden on the healthcare system. We evaluated if contrast use was necessary for screening for unilateral sensorineural hearing loss.

Methods

A total of 1145 patients admitted to our clinic with unilateral (asymmetric) sensorineural hearing loss and who had temporal bone MRI with contrast between July 2009 and May 2018 were included in this retrospective study. This study was performed with the permission of the Ethics Committee of Pamukkale University (60116787-020/35525). The patients who were referred from other clinics with different symptoms (neurosurgery, neurology) and ordered an MRI scan were excluded. Thus, we only evaluated patients with a complaint of unilateral asymmetric sensorineural hearing loss.

The cost of an MRI scan is reimbursed by general health insurance. The standard cost for an MRI scan is 11.43 USD. Additional expenses like contrast agent and laboratory tests are added as a separate item to the bill. Sometimes, AEBR is proposed as an alternative strategy. For comparison, the cost of a diagnostic AEBR at a tertiary care center is 14.9 USD.

Prior to the MRI, all the patients were screened for renal disease with serum creatinine levels. Venous access was established in all the patients on the day of the appointment prior to imaging. The MRI protocol was first employed without administering the contrast, followed by contrast administration, and T1AG axial and coronal images were obtained.

The contrast agents used were either 0.2 mL/kg gadobenat dimeglumin (Multihance, Bracco S.p.A, Italy) or 0.2 mL/kg gadodiamide (Omniscan, Amersham Health, Ireland), and both were administered intravenously. The cost of an Omniscan (20 mL vial) was 23.77 USD and that of Multihance (20 mL vial) was 39.66 USD. The mean cost of the two contrast agents, 31.72 USD, was used for calculations.

The factors that were determined to affect the cost of the MRI scan, including serum creatinine test, vascular access, and contrast agent were analyzed for both cost and the time consumed.

Temporal bone MRI was done with a 1.5 Tesla MRI device (GE Signa Excite HD, GE Medical Systems, Milwaukee, Wisc., USA). The following imaging protocols were used:

- T1W (TR, 500 ms; TE, 15.7 ms; slice thickness 3 mm; interslice gap 0.5 mm; FOV 20 × 20 cm; matrix 320 × 224; NEX 3).
- T2W (TR 3000 ms; TE 104.8 ms; slice thickness 3 mm; interslice gap 0.5 mm; FOV 22 × 22 cm; matrix 320 × 224; NEX 3). T2W images were obtained with FSE sequences.
- 3D FIESTA (fast imaging employing steady-state acquisition) (TR 4.8 ms; TE 1.4 ms; slice thickness 0.5 mm; FOV 18 × 18 cm; matrix 352 × 192; NEX 4).

The MRI images were re-examined in 31 patients out of 1145 who were reported to have a VS by a radiologist. The expected outcome was to preserve the diagnostic power of the MRI even with the noncontrast technique. T1 and T2 weighted scans with and without contrast and 3D FIESTA protocols were compared.

The prices and currency conversion was fixed to date, April 29, 2019 (1 USD = 5.94 TL) (USD: United States Dollars, TL: Turkish Lira).

Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences version 21.0 (IBM Corp., Armonk, NY, USA) package program. Continuous variables were expressed as mean values and categorical variables as numbers and percentages. A receiver operating characteristic (ROC) analysis was used, and the area under the curve (AUC) was calculated. In addition, the sensitivity and specificity values were obtained by two-by-two table analysis. We considered $P < .05$ as statistically significant.

Results

All 1145 patients had audiological tests and were diagnosed with asymmetrical sensorineural hearing loss. MRI was performed for screening for retrocochlear pathologies. There was a positive result in 31 (2.7%) patients. Thirty patients had unilateral VS, and one had bilateral VS. The patient with bilateral VS had been followed up with the prediagnosis of neurofibromatosis type 2 (NF2).

Among patients with VS, there were 18 women and 13 men with a mean age of 51.7 years. Re-examination of the images of the patients with VS revealed that the tumor could be easily seen on the images with and without contrast in 30 cases (Figure 1). However, the tumor was hardly seen on the images without contrast in one patient. The size of the tumors ranged between 2.5 and 25 mm. When we investigated the value of the 3D FIESTA MRI technique for diagnosing acoustic neuromas, the area under the ROC curve was found 0.984 ($P < .01$). The sensitivity and specificity of the noncontrast 3D FIESTA modality were calculated as 96.8% and 99.9%, respectively (Table 1). The false-negative rate was calculated as 3.2%.

The cost of a standard MRI scan is 11.43 USD. There are some additional items on the bill for contrast-enhanced imaging. Table 2 shows the factors that affect the cost and the extra time spend for an MRI scan with contrast. They were serum creatinine test, vascular access (one for creatinine test, one for contrast), and contrast agent. A total of 1145 contrast agent vials were used.

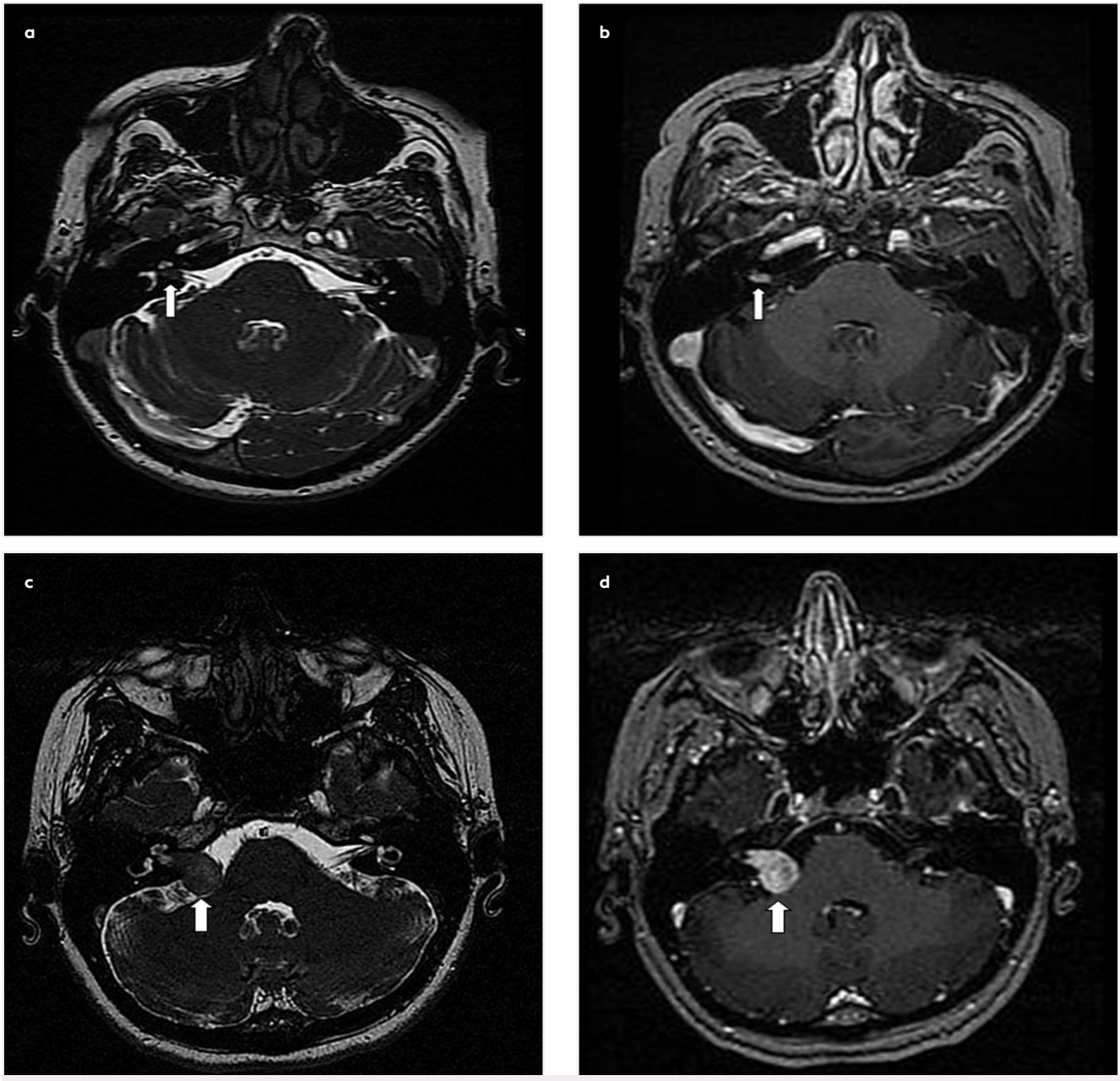

Figure 1. a-d. (a) Axial 3D FIESTA scan of temporal bone MRI showing a soft tissue filling defect in the right internal acoustic canal replacing the normal high-intensity perilymphatic fluid. (b) Postcontrast axial T1-weighted MRI in the same patient showing enhancement of this vestibular schwannoma (~ 8 × 5 mm) (white arrows). (c) Axial 3D FIESTA and (d) postcontrast axial T1-weighted scan of temporal bone MRI in another patient show vestibular schwannoma (~18 × 13 mm) extending from the right cerebellopontine angle through the internal acoustic canal (white arrows).

The total cost of the contrast agent was 37,888 USD. All additional costs are shown in Table 2.

A standard noncontrast temporal bone MRI takes 20 minutes inside the MRI device. Patients spend an additional 5 minutes inside the MRI for contrast imaging. When we consider the preparation period, the extra time needed for scanning with contrast was calculated as 17 minutes for every patient. A total of 18,320 minutes more was spent on 1145 patients. A frequent side effect of contrast is nausea and vomiting. If the patient has nausea and vomiting, it takes an additional 30 minutes to clean the room.

Discussion

Progressive sensorineural hearing loss involving high frequencies is the most common pathological finding in patients with VS. Some patients may present with sudden hearing loss.[9] MRI with contrast is accepted as the ideal imaging method for the diagno-

Table 1. Two-by-two Table Analysis

		Contrast Agent +		
		VS +	VS -	Total
Contrast Agent -	VS +	30	0	30
	VS -	1	1114	1115
	Total	31	1114	1145

The sensitivity and specificity of noncontrast 3D FIESTA technique have been determined as 96.8% and 99.9%, respectively.
VS: vestibular schwannoma.

Table 2. Additional Costs for a Contrast-enhanced MRI Scan

Parameters	Cost per procedure (USD)	Time needed per procedure (min)
Serum creatinine test	0.77	5
Vascular access	0.6	4
Contrast agent*	31.72	2
MRI scan	No extra cost	5
Subtotal (1 patient)	33.09	16
Total (1145 patients)	37,888	18,320

USD: United States of America Dollars, min: minutes, *mean price of two companies.

sis of VS. We found 31 patients with VS in a sample of 1145 patients with unilateral hearing loss. Only one of them was suspicious in noncontrast MRI (3D FIESTA). Therefore, the contrast agent was used unnecessarily in the remaining 1144 patients. When we look from the reimbursement point of view, the system spent 37,888 USD more for 1145 contrast-enhanced MRI scans. When we consider the hospital budget, every patient spends 5 minutes more on the MRI device. Taking 1145 patients into account, we lost 286 extra noncontrast MRIs and 3,268 USD (286×11.43 USD) possible extra income for the hospital, which is only a rough calculation. We have to also consider the cost of purchasing, financing, and storing the contrast agent for the hospital. There is not much profit in reselling the contrast agent. It is also impossible to calculate the income potential of the time spent on the preparation of every patient (11 min/patient). From the view of patients, an additional 286 MRI means at least 11.9 days shortened appointment time in an 8-hour working day system. This situation is a significant burden on the healthcare system when all the patients in our country are taken into account.

T1- weighted spin-echo MRI with contrast has been regarded as the standard technique for the diagnosis of VS. It can reveal very small tumors in the internal acoustic canal prior to the development of hearing loss.[10] Kwan et al.[11] retrospectively demonstrated that T2*-weighted 3DFT-CISS imaging using a slice thickness of 1.2 mm was able to reveal every VS. Nadol et al.[10] have confirmed that result with high-definition fast spin-echo T2-weighted MRI. Stuckey et al.[8] have compared T2-weighted noncontrast (three-dimensional Fourier transformation-constructive interference in steady-state) (3DFT-CISS) MRI method with postcontrast T1-weighted MRI with two observers and found sensitivity and specificity as 94%-100% and 94%-98%, respectively. In a comprehensive review, Fortnum et al.[5] reported the sensitivities of high-resolution noncontrast T2-weighted (T2W) and T2*weighted (T2*W) imaging modalities as 98% and 96%, respectively, when compared with T1-weighted MRI with contrast (GdT1W). The specificities of those modalities ranged between 90%-100% (T2W) and 86%-99% (T2*W).[5] In this study, the sensitivity and specificity of noncontrast 3D FIESTA modality were calculated as 96.8% and 99.9%, respectively.

Held et al.[12] have reported that 3DFT-CISS was a very sensitive method for screening for VS, and it was able to show small meatal tumors and even the tumors within the labyrinth. FSE T2W MRI with ≤2 mm slices is recommended as a screening tool if the physician and patient are aware of small VS, labyrinthine VS, and inflammatory disorders that can be missed.[13] Hatipoğlu et al.[14] have compared 3D FIESTA with FSE T2W sequences for evaluation of cranial nerves, and they found that they were equally effective; however, 3D FIESTA was better in the imaging of cranial nerves in the cisternal part of the posterior fossa.

A consensus committee from the United Kingdom proposed that "MRI screening on patients with ≥10 dB of interaural difference at two or more contiguous frequencies or ≥15 dB at one frequency be pursued to minimize the incidence of undiagnosed VS."[6] They also concluded that noncontrast MRI for VS is cost-effective.

One of the main limitations of this study is that we had only one radiologist evaluating the MRI scans; whereas, a another radiologist with a different experience level may have had different results. We calculated all the expenses in our country settings. The time and money may be different in other countries. In our country, materials and devices are expensive, but labor is cheap.

We believe that 3D FIESTA is sufficient in the differential diagnosis of unilateral sensorineural hearing loss because of its high sensitivity. It has to be a preferred screening method when the cost of healthcare is taken into account. Noncontrast MRI is cheaper than diagnostic AEBR. The contrast might be useful in VS follow-up, undiagnosed progressive unilateral hearing loss, or suspicion of inflammatory disease. Using 3D FIESTA protocol without contrast will save time and money of screening without any risk to the patients. Although our cost calculations are related to our health system, the time consumed is equal for every country. It is especially crucial for countries with low health expenditure per capita. Similar studies in different health systems will yield more constructive results.

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