Role of Diffusion-Weighted Propeller Magnetic Resonance Imaging in Cholesteatoma Diagnosis

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Abstract

Background: Cholesteatoma is a pseudotumor with expansive growth that causes destruction of surrounding bone structures and thus damage of surrounding structures like facial nerve or inner ear. Early diagnosis and detection of any recurrence are essential. Radiological detection using Computed Tomography (CT) is the technique of choice due to its ability to detect bone destruction epically the destruction of ossicles which is characteristic. However, CT does not have high spatial resolution of tissue which is of particular necessary in congenital, recurrent, abnormal site or post-operative cholesteatoma. MRI overcomes the shortcomings of CT and can be useful in such cases.

Aim of Study: The aim of this study was to discuss the role of diffusion-weighted Propeller MRI in the diagnosis of cholesteatoma in non-operated and operated temporal bone.

Patients and Methods: A prospective study was performed on 37 patients. All the patients had undergone DW-MRI and CT temporal bone, 29 of them had undergone MRI examination with contrast. Clinical and surgical findings were correlated with diffusion-weighted Propeller MRI results.

Results: Sensitivity, specificity, positive and negative predictive values were 100%, 85.7%, 96.8% and 100%, respectively.

Conclusion: Diffusion-weighted Propellar MRI imaging is an effective technique in cholesteatoma diagnosis in operated and non operated patients.

Key Words: DWI diffusion-weighted imaging – DW-EPI diffusion-weighted echo-planar imaging – DWI-Propeller diffusion-weighted imaging with periodically rotated overlapping parallel lines with enhanced reconstruction – DW-non-EPI diffusion-weighted non-echo-planar imaging – EPI echo-planar imaging– NPV negative predictive value – PPV positive predictive value – T1WI T1-weighted imaging – T2WI T2-weighted imaging TM tympanic membrane – IAM Internal auditory meatus.

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Introduction

CHOLESTEATOMA is a pseudotumoural lesion composed of an active matrix which forms accumulations of keratinised, stratified epithelium in its interior and which grows in the form of concentric layers. This expansive growth entails the destruction of surrounding bone structures. If the disease progresses, it may affect the facial nerve and inner ear, and cause intracranial complications [1].

For this reason, early diagnosis and detection of recurrence in operated patients are essential for an adequate treatment of the disease [2].

Cholesteatomas can be classified as either congenital or acquired, though the origins are indistinguishable with histology and imaging. Only the location of the lesion, the clinical history of the patient, and the otologic status of the TM give some hints for differentiating these 2 types of cholesteatomas [3].

The diagnosis of cholesteatoma is based on clinical findings, in which otoscopy and otomicroscopy play a major role in conjunction with radiological findings. Computed Tomography (CT) is the technique of choice [2].

CT enables visualization of bone structures with high spatial resolution, detecting minimal erosions on the ossicles and walls of the tympanic cavity. Such findings are highly specific of cholesteatoma and lead to a correct diagnosis in most cases of acquired cholesteatoma. However, its lower tissue resolution compared with Magnetic Resonance Imaging (MRI) does not enable the nature of soft tissues to be identified (inflammatory, granulation or scar tissue and cholesteatoma) [4].

In cases of acquired cholesteatomas in atypical locations or those without clear bone erosion, congenital cholesteatomas and especially in ear surgery, where bone references are lost, a technique with a high capacity of tissue discrimination, such as MRI, acquires a high diagnostic value [2].

Until recently there were no imaging techniques which enabled the diagnosis of recurrent cholesteatomas in tympanoplasties, mainly in closed techniques which preserved the posterior wall of the external ear canal. Therefore, their diagnosis and treatment required a second surgical intervention known as "second-look". Some authors recommend the implementation of a second-look systematically, between 6 months and 1 year after undergoing closed tympanoplasty [5,6].

Diagnosis and monitoring of cholesteatoma have recently become possible, based on diffusion techniques capable of distinguishing small-sized lesions and establishing a differential diagnosis with inflammatory and scar-type lesions. These techniques also enable the detection of some lesions which are difficult to diagnose due to such lesions' location and, in the particular case of congenital cholesteatomas, lesions are found behind an intact tympanum [2].

The purpose of this study was to establish whether diffusion weighted Propellar MRI is effective for the diagnosis and monitoring of cholesteatoma, correlating clinical and surgical findings with radiological ones.

Material and Methods

This study was prospective study carried on 37 patients, 16 female and 21 male patients; mean age, 44 years; age range, 19-62 years, with suspected cholesteatoma over period of eighteen months June 2017 and December 2018 in Ain Shams University Hospital and private hospital (16 female and 21 male patients; mean age, 44 years; age range, 19-62 years).

Informed consent was obtained from all patients. Our study was approved by our institutional review board.

The number of studied patients were 37 of which 19 had been surgically intervened previously. The diagnosis was based on clinical history, otomicroscopic exploration and intraoperative findings.

Inclusion criteria was that all relevant data including histopathological results, otomicroscope, clinical and operative data were available. Patients were willing to undergo both CT temporal bone as well as MRI. Exclusionary criteria were; missing histopathology results, claustrophobia and unwillingness to undergo MRI exam.

All the patients had undergone DW-MRI and CT temporal bone, 29 of them had undergone MRI examination with contrast.

MR imaging technique:

Imaging was performed with a 1.5-T MR unit (GE Signa 1.5 T). IAM Protocol thin slices focused through the IAM region: Axial 3D FIESTA (T2 weighted), 18 FOV, slice thickness 0.8, frequency 320, Phase 256. Coronal 3D FIESTA (T2 weighted): 18 FOV, slice thickness 0.8, frequency 320, phase 256, if positive and lesion seen then we perform an Axial T1 pre contrast: 20 FOV, slice thickness 2.0, spacing 0.0, frequency 256, Phase 256. Axial T1 fat saturated post 10mls Dotarem contrast: 20 FOV, slice thickness 2.0, spacing 0.0, frequency 256, Phase 192, fat saturation. Coronal T1 fat saturated post 10mls Dotarem contrast: 20 FOV, slice thickness 2.5, spacing 0.0, frequency 256, Phase 256. Cholesteatoma DWI: This is a Propeller technique focused to just through the IAM area: Frequency 256, FOV 23, slice thickness 3.0, spacing 1.0.

Table (1):

Middle ear inflammatory conditions	T1	T1 delayed contrast	DEI	ADC
Cholesterol granuloma	Hyperintensity	Not assessable	May shine	No restriction
Cholesteatoma	Hypo/isointensity	No uptake	Intense shine	Restriction
Inflammatory tissue	Hypointensity	Uptake	No shine	No restriction
Purulent content	Hypointensity	No uptake	Intense shine	Marked restriction

The different MRI patterns for the differential diagnosis of middle ear inflammatory condition are described in (Table 1).

Cholesteatoma was diagnosed, as described in (Table 1), if the lesion had low signal intensity on unenhanced T1-weighted images, showed no

change in signal intensity on delayed contrast-enhanced T1-weighted images, and had high signal intensity on diffusion-weighted images obtained with a b factor of 1000sec/mm2.

The surgical findings were obtained from the surgical reports then compared with those at MR imaging.

Sensitivity, specificity, positive and negative predictive values were evaluated separately for diffusion-weighted fast SE images and compared with the findings from surgery. Using SAS software (Version 8.2), with a p-value of less than .01.

Results

In 31 patients, cholesteatoma was diagnosed at MR imaging. The lesion had low signal intensity on unenhanced T1-weighted images, showed no change in signal intensity on delayed contrast-enhanced T1-weighted images, and had high signal intensity on diffusion-weighted images and 30 of them was diagnosed at surgery (30 true-positive cases). The size and location of the cholesteatoma analyzed at MR imaging were in agreement with those found at surgery Figs. (1-3).

In 6 of 37 patients, no cholesteatoma was diagnosed at MR imaging: The middle ear lesion had low signal intensity on unenhanced T1-weighted images, showed enhancement on delayed contrast-enhanced T1-weighted images, and had low signal intensity on diffusion-weighted images obtained with a b factor of 1000sec/mm2. In these 6 patients, no cholesteatoma was found at surgery. As a result, the negative predictive value was 100%.

One false positive was found in this study as diffusion WI showed an intense brightness on the mastoid antrum. The surgery did not find cholesteatoma and was diagnosed as neurofibromatosis, so it was considered as a false positive result Fig. (4). Finally, the results with diffusion-weighted imaging were similar to those with delayed contrast-enhanced T1-weighted imaging. These data were used to calculate the sensitivity (100%), specificity (85.7%), positive predictive value (96.8%) and negative predictive value (100%) for the entire group.
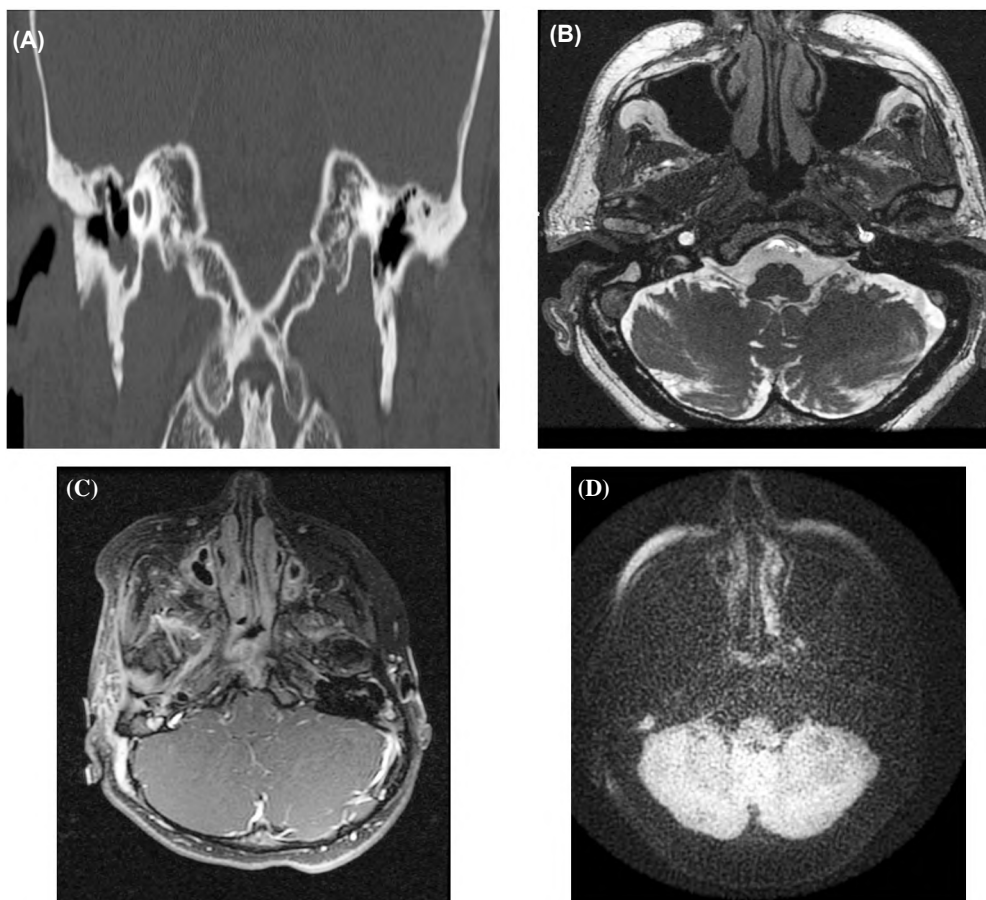

Fig. (1): Axial images of the right ear in a patient with cholesteatoma: (A) Is coronal CT image shows opacification of the middle ear cavity, (B) Is axial T2WI, (C) Is T1W post contrast, (D) Is DWI Propeller shows tissue with high signal intensity impressive of cholesteatoma.
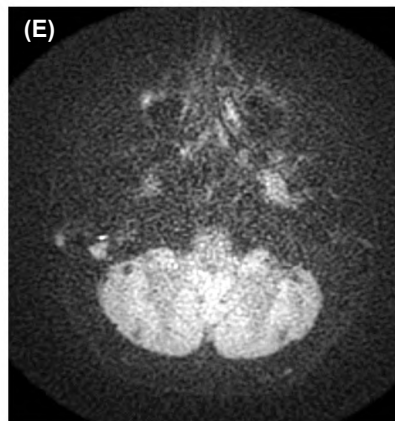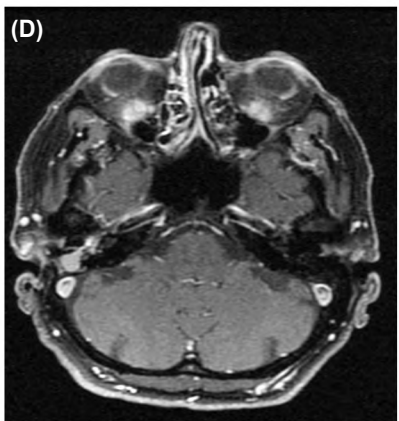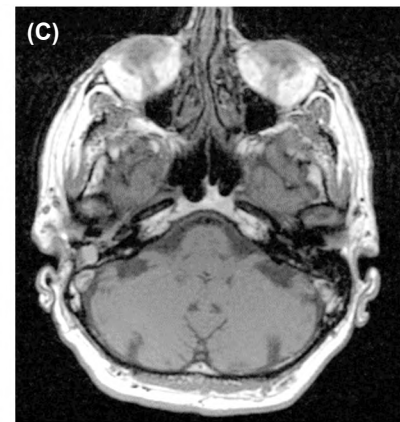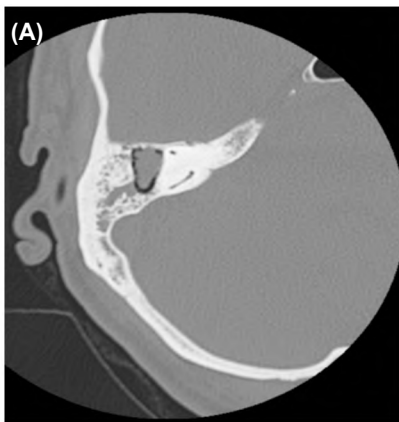
Fig. (2): Axial images of the right ear in a patient with cholesteatoma: (A) Axial CT image shows opacification of the middle ear cavity, (B) Axial T1WI, (C) Axial T2WI, (D) Axial T 1 W post contrast and (E) Propeller DWI shows tissue with high signal intensity.
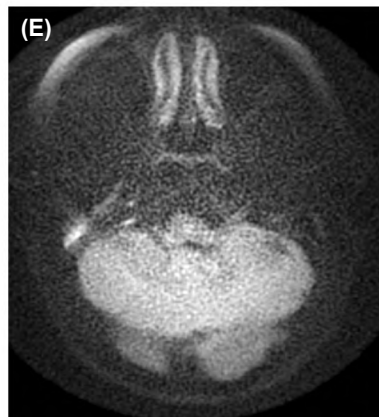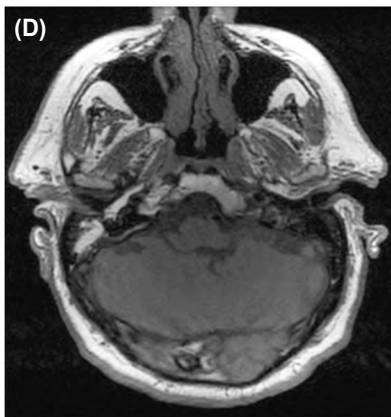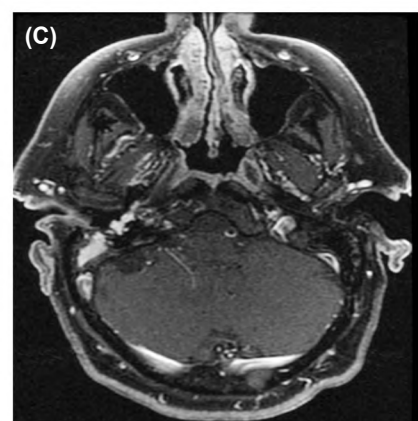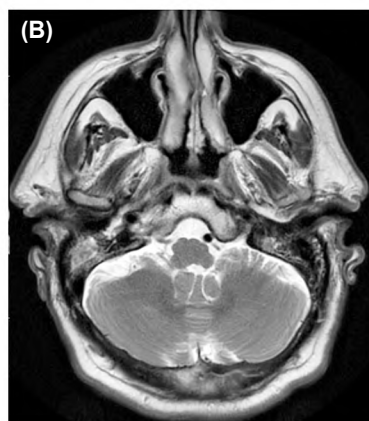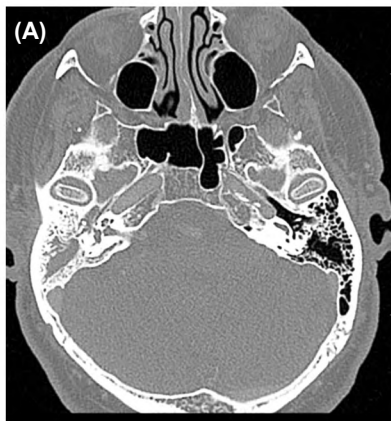

Fig. (3): Axial images of the right ear in a patient with cholesteatoma: (A) Is axial CT image shows opacification of the middle ear cavity, (B) Is axial T1WI, (C) Axial T2WI (D) Is T1W post contrast (E) Propeller DWI shows bright signal intensity lesion.
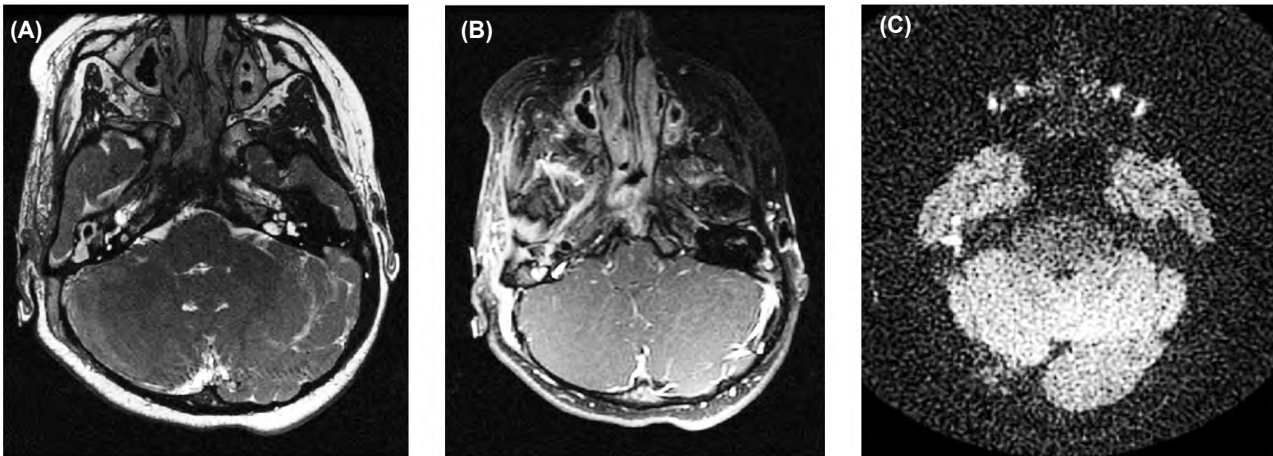
Fig. (4): Axial images of the right ear in a patient with cholesteatoma: (A) Is axial T1WI, (B) Is T1 W post contrast, (C) Is DWI shows high signal intensity lesion that was diagnosed in surgical report as neurofibromatosis (false positive case).

Discussion

For over 300 years Cholesteatoma has been a described in the medical literature; yet its precise detection with the use of imaging techniques remains a challenge. HRCT provides information about bony changes and intracranial complications; however it lacks precise characterization of any associate soft tissue mass. Recently, MRI has overcome this to enhance the sensitivity and specificity of diagnosis which is of particular value in recurrent cases and may prevent second-look surgeries [3].

MR imaging with its different pulse sequences provides better tissue differentiation. On imaging with MRI cholesteatoma usually appears as hypointense/isointense on T1WI and hyperintense on T2WI compared with brain tissue. Granulation or scar tissue in an post-operative ear and bloody serous or proteinaceous fluid also show hyperintense signal intensity on T2WI. Occasionally, it may show lower signal intensity on T2WI or on constructive interference in steady state/FIESTA images than the surrounding granulation tissue, however, they may also be indistinguishable on these sequences [3,4].

Before the use of diffusion, MRI was used with intravenous gadolinium to obtain delayed, T1 - enhanced images for the diagnosis of cholesteatoma. Both inflammatory tissue and scar tissue are vascularised and uptake contrast, as opposed to cholesteatoma, which is a collection of non-vascularised keratin and therefore shows no uptake in its interior. Hence, peripheral uptake can be observed in the surrounding inflamed mucosa, but not in the interior of the lesion. Since granulation tissue can be very fibrous and poorly vascularised,

the technique requires images to be obtained with a time delay (45-60min after intravenous administration of gadolinium) in order to be effective in differentiating cholesteatoma (avoiding false positives caused by lack of prompt uptake by scar tissue). Although some good results were reported at the time with these techniques even similar to those obtained subsequently with non-EPI diffusion techniques, the need for contrast and the time required for the study increased its cost. The administration of intravenous gadolinium involves risks and the interpretation of images is much more complex than with the diffusion technique. Given their speed, low cost and ease of interpretation, diffusion techniques have replaced delayed contrast techniques for the diagnosis of cholesteatoma. The use of the latter does not increase sensitivity or specificity (diagnostic efficacy) with respect to non-EPI techniques [8-10]. If non-EPI diffusion techniques are not available, then the use of MRI techniques with delayed contrast improves the sensitivity of EPI diffusion, enabling detection of lesions smaller than 5mm [8,11].

MRI diffusion techniques, whose use is now widespread in brain studies, were first used in the late 90s for the diagnosis of acute cerebral ischemia [12]. Subsequently, they showed high specificity in the diagnosis of pyogenic abscesses and intracranial epidermoid cysts. They are based on measuring molecular "Brownian motion", a random motion observed in some microscopic particles within a fluid medium [13]. The speed of movement of water molecular diffusion is markedly restricted under certain conditions, such as ischemia or acute pyogenic abscesses. This restriction is manifested as an intense brightness or shine in diffusion sequences, which can be quantified using image post-

processing techniques. These result in an Apparent Diffusion Coefficient (ADC) for each of the pixels which form the Diffraction-Enhanced Image (DEI), known as ADC maps. In addition to restricting diffusion, the residual T2 brightness of some lesions may result in DEI hyperintensity. Obtaining ADC maps enables the 2 causes of DEI hyperintensity to be differentiated. As described below, such differentiation is of great interest in the differential diagnosis between cholesteatoma (which restricts diffusion) and middle ear cholesterol granulomas (which do not show restriction of diffusion and, conversely, show a residual T2 brightness).

Cholesteatomas, like intracranial epidermoid cysts, are characterized by their intense brightness in diffusion sequences, which is therefore highly specific for these entities. There are multiple discussions on whether this hyperintensity is due to the restriction of molecular diffusion in the interior or to T2 residual brightness [14,15]. ADC values are clearly inferior to those of other entities, such as inflammatory granulation tissue or middle ear cholesterol granuloma, and this point indicates at least some degree of diffusion restriction. In any case, in the appropriate clinical context and location, this is a highly specific technique for the diagnosis of cholesteatoma or epidermoid cysts.

New, non-EPI diffusion techniques can diagnose cholesteatomas of up to 2mm in diameter, with specificity similar to EPI techniques, by minimizing the artifacts in the region of the temporal bone, thus obtaining greater spatial resolution. The name varies according to the different manufacturers, although, they have similar characteristics with minor variations. The most commonly used and referenced by most publications is the SS-TSE-DWI technique (HASTE-DWI, Siemens, Erlangen, Germany), which provides both axial and coronal planes. This technique has led to results with 100% specificity. Other, non-EPI diffusion sequences include the Propeller sequence (GE Healthcare, Milwaukee, WI, USA) and the BLADE-DWI (Siemens, Erlangen, Germany) [16-19].

In our study, performed with the propeller DWI technique and a 1.5T device, we obtained the following results. The sensitivity (100%), specificity (85.7%), positive predictive value (96.8%) and negative predictive value (100%) corresponded to the total patients studied.

The currently used radiological protocol includes T1 and T2 coronal images without contrast-useful for the spatial guidance of the lesion-and the diffusion sequence. After some initial cases,

we ceased to use delayed T1 images with contrast, thus reducing scan time and the potential adverse effects caused by the administration of gadolinium chelates, and also improving the cost-benefit efficiency.

As mentioned by other authors [18-21] using different diffusion techniques, MRI with non-EPI DEI, such as the PROPELLER sequence, is becoming established as a good diagnostic alternative to systematic surgical review of cholesteatoma.

The results of our study demonstrate the value of the Propeller diffusion-weighted imaging in the detection of recurrent cholesteatoma. In fact, the diffusion-weighted sequence and the delayed contrast-enhanced sequence showed the same results, and no false-negative case was found in our study. This means that when MR imaging showed no evidence of recurrent cholesteatoma, none was found at surgery. The negative predictive value was 100%.

There was one false-positive finding in our study. The false-positive finding occurred with both diffusion-weighted imaging and delayed contrast-enhanced T1-weighted imaging and at surgery appeared to be neurofibromatosis.

There were limitations in this study. First, only 37 patients were included in the study. Second, although we used an improved diffusion-weighted sequence to reduce the susceptibility artifacts, image distortions along the phase-encoding direction were unavoidable to some degree.

In conclusion, the results of this study show the reliability of diffusion-weighted Propeller MR imaging in the detection of cholesteatoma.

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دور تقنية التصوير بالرنين المغناطيسى غير الموزعة المستوى الموزع فى تشخيص الورم الكوليستيرولى

المقدمة: ورم الكوليسترول فى الآذن الوسطى هو مرض إلتهابى شائع مع حدوث ترقق العظم، مما يؤدى إلى مضاعفات موضعية داخل الجمجمة حيث يحدث تدمير لعظام الآذن الوسطى مع تآكل الجدار العظمى خاصة الجدار الجانبى والصفن.

والذى يمكن أن يؤدى إلى فقدان السمع وتشمل المضاعفات الآخرى النادرة لسرطان الكوليسترول التشنجات فى الأعصاب القحنية، الإمتداد داخل الجمجمة مع الخروج والدوار.

الهدف من البحث: تحديد دور تقنيات التصوير بالرنين المغناطيسى الموزع (DWI MRI) بما فى ذلك التصوير غير المرتبط بالإنتشار غير المرئى (EPI MRI) وEPI DWI (التصوير المرتقب لنشر الصدى المستوى) فى تشخيص الورم الكوليستيرولى الأولى أو المتكرر.

المرضى وطرق البحث: أجريت هذه الدراسة على ٣٧ من العيادات الخارجية أو قسم الأنف والآذن والحنجرة ٢٩ منهم خضعوا للرنين المغناطيسى (MRI) بما فى ذلك كل تقنيات (echo-planar DWI and non-echo-planar DWI sequences) قبل الجراحة المخطط لها . مع مقارنة النتائج الإشعاعية مع النتائج النسيجية المرضية بعد العملية التى كانت تعتبر الطريقة القياسية الذهبية دقيقة للتأكيد . حسبنا خصوصية وحساسية والقيم التنبؤية السلبية والإيجابية لكلا تقنيات DWI.

الإستنتاج: DWI MRI غير الصدى دقيق فى تشخيص ورم الكوليستيرولى فى الآذن الوسطى الآولى أو المتكرر.