The Journal of Laryngology & Otology (2011), ***125***, *10–12*.

doi:10.1017/S0022215110001805

MAIN ARTICLE

Cholesteatoma imaging using modified echo-planar diffusion-weighted magnetic resonance imaging

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Abstract

Introduction: Imaging of cholesteatomas can be useful especially in cases of recurrent disease. Computed tomography scans have been recommended before primary surgery, but cholesteatoma tissue looks similar to inflammatory tissue. Diffusion-weighted magnetic resonance imaging is both sensitive and specific in detecting cholesteatoma, which appears as a bright signal on a dark background. Non-echo-planar diffusion-weighted magnetic resonance imaging is superior to routine echo-planar diffusion-weighted magnetic resonance imaging as it minimises susceptibility artefacts; however, the addition of this facility involves expensive magnetic resonance scanner upgrading.

Method: To avoid the cost of such upgrading, we modified our echo-planar diffusion-weighted magnetic resonance imaging parameters and then scanned 15 consecutive cases of suspected cholesteatoma or suspected recurrent cholesteatoma.

Results: Imaging results correlated well with clinical and/or operative findings.

Conclusion: These results indicate that software adjustments can enable echo-planar diffusion-weighted magnetic resonance imaging to detect cholesteatomas reliably, and as effectively as non-echo-planar diffusion-weighted magnetic resonance imaging. This discovery has the potential to facilitate reliable delayed post-operative screening of canal wall up mastoidectomies, avoiding the need for a 'second look' procedure.

Key words: Magnetic Resonance Imaging; Diffusion Magnetic Resonance Imaging; Cholesteatoma

Introduction

Cholesteatoma imaging has gone through many stages of development, not only in the type of imaging used but also in the use of the scan by the otologist. Computed tomography (CT) scans can be used to identify bony structures such as ossicles, lateral semicircular canals and the facial nerve canal, and some otologists use these images before operating to familiarise themselves with any anatomical variation. However, CT differentiates poorly between different soft tissues and as such is less useful for cholesteatoma diagnosis. Granulation tissue, scar tissue, cholesterol granulomas and oedematous mucosa can all be mistaken for cholesteatoma on CT scanning, and vice versa. In CT images showing bony erosion apparently caused by a mass of soft tissue, the ability to predict cholesteatoma is of course improved. However, in cases with previous mastoid surgery the anatomy will have been altered at the initial operation, and the diagnosis is more difficult.

Non-enhanced magnetic resonance imaging (MRI) shows less detail of the temporal bone than CT. As regards temporal bone imaging, the first useful MRI technique was enhanced scanning using gadolinium contrast, which is slowly taken up by living tissue in the middle ear and mastoid.[1] Following a 45-minute delay between contrast administration and scanning, vascular middle-ear and mastoid structures give a hyperintense signal, whereas cholesteatoma, being avascular, does not enhance at all and can therefore be distinguished from other, vascular tissue. However, this is very time-consuming, and gadolinium is also known to occasionally cause side effects.

Echo-planar diffusion-weighted MRI scans are created with a 1.5 T superconductive unit scanner. Although not always available, such scanners are commonplace in neuroradiological departments and are used for brain scanning to detect small ischaemic cerebrovascular accidents.[2] Cholesteatoma is seen on echo-planar diffusion-weighted MRI as a hyperintense

Presented as a registrar paper at the North of England ENT Conference, 25th September 2009, Bradford, UK.
Accepted for publication 26 April 2010 First published online 10 September 2010

signal, distinguishing it from other middle-ear and mastoid structures. (See Figure 1) This imaging modality is therefore useful for the pre-operative diagnosis of primary or recurrent cholesteatoma when the clinical diagnosis is uncertain, and also for the post-operative detection of residual cholesteatoma following canal wall up mastoidectomy.

Unfortunately, when bone and air occur next to each other, a higher intensity MRI signal is produced, termed a susceptibility artefact. Where the temporal lobe lies next to the temporal bone and the mastoid air-space, a characteristic high intensity curvilinear artefact is often seen. As this is an area in which cholesteatomas can form, differentiation between susceptibility artefact and cholesteatoma can be difficult, making accurate diagnosis of small cholesteatomas problematic. There is also the risk of false positives, when the artefact is mistaken for cholesteatoma, and false negatives, when the cholesteatoma is hidden in the hyperintense artefact signal.

Non-echo-planar diffusion-weighted MRI uses a single shot fast (or turbo) spin echo diffusion-weighted image, which is a quicker sequence using a different magnet arrangement. Scans can take as little as 35 seconds, and images do not suffer from susceptibility artefacts. This means that small cholesteatomas of 3 or even 2 mm can be detected within the mastoid as a bright, hyperintense signal diagnostic of cholesteatoma.[3,4] Non-echo-planar diffusion-weighted MRI has been shown to be more sensitive and specific for small cholesteatomas than echo-planar diffusion-weighted MRI.[4,5] Non-echo-planar diffusion-weighted MRI is especially useful in detecting small residual pieces of cholesteatoma retained after canal wall up mastoidectomy, thereby avoiding the need for a 'second look' operation (often performed to check for residual cholesteatoma that would not be seen on otoscopy after a canal wall up mastoidectomy).

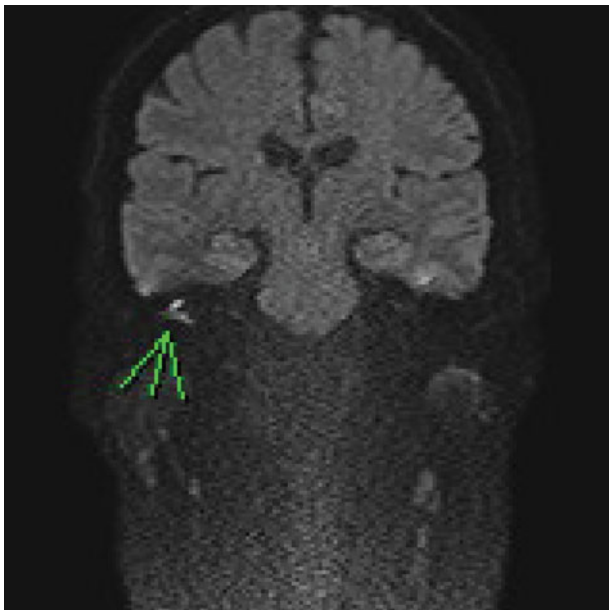

FIG. 1
Coronal modified echo-planar diffusion-weighted magnetic resonance imaging scan, showing primary right-sided cholesteatoma.

The equipment and systems needed to perform non-echo-planar diffusion-weighted MRI are in addition to those needed for standard echo-planar imaging. The main use for such equipment is for cholesteatoma detection; other clinical uses are limited. Therefore, the financial argument for purchasing such equipment may not be sufficiently strong in the current, stringent economic climate, especially in smaller departments where its use may be limited. As many departments already have echo-planar diffusion-weighted MRI units, it is logical to make the best use of these existing facilities in order to improve the quality and reliability of MR imaging.

In the out-patient clinic, the clinician often cannot be completely confident in diagnosing cholesteatoma, due to difficulty in visualising the deep canal in a discharging, infected and painful ear. It is our regular practice to undertake temporal bone imaging as a diagnostic investigation, and also to aid pre-operative planning by determining the extent of cholesteatoma.

Methods

By modifying the parameters of the MRI scanner, it is possible to dramatically reduce the susceptibility artefact and to obtain far clearer delineation of cholesteatomas. The radiology department of the Royal Albert Edward Infirmary, Wigan, uses a 1.5 T superconductive single shot spin echo-planar diffusion-weighted MRI scanner (Achieva; Philips, Amsterdam, The Netherlands) programmed with the following parameters: repetition time = 2850 ms; echo time = 89 ms; matrix = 160 (160) × 80 per cent; echo-planar factor = 35; number of signal averages = 2; 3 mm coronal slices using a Sense head coil (Philips, Amsterdam, The Netherlands); and scan time = 62 seconds. No contrast material is used.

- **Imaging for cholesteatoma can be useful, particularly in detecting recurrent disease**
- **Diffusion-weighted magnetic resonance imaging (MRI) is both sensitive and specific in detecting cholesteatoma, which appears as a bright signal on a dark background**
- **With software adjustments, echo-planar diffusion-weighted MRI can detect cholesteatoma as reliably and effectively as non-echo-planar diffusion-weighted MRI**

We used our modified 'cholesteatoma' settings to conduct echo-planar diffusion-weighted MRI scanning on 15 consecutive patients warranting investigation for chronic suppurative otitis media. All image reports were prepared by a single neuroradiologist. Seven patients were investigated for suspected primary

https://doi.org/10.1017/S0022215110001805 Published online by Cambridge University Press

cholesteatoma, and eight for suspected recurrent or residual cholesteatoma.

The alteration of echo-planar diffusion-weighted MRI parameters did not affect our patients in any way, as this imaging modality would have been used in any case as per our established imaging protocol. Adding a few extra seconds of scanning time did not require additional consent (as the radiologist may often request extra sequences while the patient is being scanned in order to clarify certain points, as per standard scanning procedure).

The review operations which took place during our imaging study were undertaken on clinical grounds only and were not part of our study; however, the surgical findings were included in the study dataset.

Results

Seven patients were investigated for primary cholesteatoma; four of these patients' scans showed cholesteatoma while three were negative for cholesteatoma (despite two of these patients having CT scans suggestive of cholesteatoma). Eight patients were investigated for recurrent or residual cholesteatoma; five of these patients' scans were positive for cholesteatoma while three were negative. All scan reports correlated with clinical or surgical findings. Notably, of the five cholesteatomas found in patients suspected of recurrent or residual cholesteatoma, two were keratin collections within the mastoid cavity and were successfully microsuctioned in the out-patient department to leave healthy cavities; such cholesteatomas are clinically unrelated residual cholesteatomas occurring medial to the tympanic membrane.

Conclusion

Our study used echo-planar diffusion-weighted MRI to detect cholesteatomas as small as 4 mm; the detection of smaller cholesteatomas may also be possible. Our findings represent an improvement on previously reported results for echo-planar diffusion-weighted MRI detection of cholesteatoma using standard neurological settings. In this study, we did not scan canal wall up cases to identify residual cholesteatoma; however, this imaging modality could readily be used in conjunction with exploratory second-look surgery for residual cholesteatoma.

Financial restraints may well prevent the upgrading of MRI machines to enable non-echo-planar diffusion-weighted MR imaging. However, if echo-planar diffusion-weighted MRI is available, adjustment of imaging parameters will produce reliable images which are useful for cholesteatoma diagnosis. We recommend that otologists discuss this topic with their local head and neck or neurological radiologist, in order to make the most of available resources.

Acknowledgements

We thank Stephanie Donaldson, Christies Hospital, Manchester, for her help in modifying the MRI sequence.

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Mr E Flook takes responsibility for the integrity of the content of the paper
Competing interests: None declared