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Postoperative diffusion weighted MRI and preoperative CT scan fusion for residual cholesteatoma localization

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ABSTRACT

Objective: To evaluate the ability of preoperative mastoid high resolution Computerized tomography (CT Scan) fusion with the postoperative diffusion weighted magnetic resonance imaging (Non-EPI DWI) to accurately localize the residual cholesteatoma thus sparing an unnecessary postoperative CT scan radiation.

Patients and methods: this is a prospective study performed in our tertiary care center. We followed up prospectively a consecutive group of patients presenting with middle ear cholesteatoma using preoperative mastoid CT scans, postoperative mastoid CT scan and mastoid diffusion weighted MRI (DWI) between 2012 and 2013. Postoperative DWI were fused to both: the preoperative and postoperative mastoid CT scans. Fused images were evaluated for their ability to detect accurately the location of residual cholesteatoma if any. Results were correlated to the surgical findings.

Results: Twenty-eight patients were included in this study. Ten patients showed middle ear opacity on the postoperative CT scans; the remaining negatively patients were excluded. DWI detected residual cholesteatoma in 3 out of the ten patients. Both CT scans; the pre and postoperative were able to precisely localize the residual cholesteatoma when fused to the postoperative DWI. Intra-operatively, three patients had a residual cholesteatoma that corresponded to the fused radiological images while a fourth patient presenting low signal intensity on the Non-EPI DWI had no cholesteatoma.

Conclusion: Diffusion weighted MRI/CT scan fusion combines the advantages of residual cholesteatoma detection and precise localization. Preoperative CT scans performed before the first surgery can be used for the fusion with the Non-EPI DWI in order to spare the patient an unnecessary another CT scan and thus decreasing radiation exposure.

1. Introduction

A *residual cholesteatoma* may develop if the initial surgery failed to completely remove the original cholesteatoma; residual cholesteatomas typically become evident within the first few years after the initial surgery.

A *recurrent cholesteatoma* is a new cholesteatoma that develops when the underlying causes of the initial cholesteatoma are still present leading to new formation of retraction pockets and keratin accumulation over the reconstructed tympanic membrane [1].

Residual cholesteatoma after Canal wall up (CWU) mastoidectomy is not uncommon [1]. Second look mastoidectomy is usually programmed in order to eliminate cholesteatoma remnants. In the recent years, MRI diffusion imaging has spared the majority of patients an unnecessary second look due to their ability to rule out residual cholesteatoma [2].

Computerized tomography (CT scan) is of great value in the assessment of the temporal bony structures such as the labyrinth, the tegmen and the facial nerve fallopian canal. Nowadays mastoid CT scan is mandatory before any cholesteatoma surgery. Magnetic resonance imaging (MRI) on the other hand is better for soft tissue assessment. Both imaging modalities are used for postoperative cholesteatoma follow-up in order to detect residual cholesteatoma [3].

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Fusion of a postoperative diffusion weighted images (DWI) MRI and postoperative high resolution CT scan has been described recently by other authors as an effective and promising technique for both, the precise localization of residual cholesteatoma and the surgical planning [4]. However, the inconvenience of this described technique is the exposure to a potentially harmful radiation, especially for pediatric patients by doing a second CT scan in the postoperative period.

In this study, we aim to evaluate the ability of the preoperative (before cholesteatoma excision) high resolution CT scan fusion to the postoperative Non-EPI (non-echo planar) diffusion weighted imaging MRI in the detection and localization of residual cholesteatoma before a second look surgery in order to prevent making a new postoperative CT Scan, therefore sparing a new radiation.

2. Methods

A group of consecutive patients were included in this prospective study between 2012 and 2013. All patients had preoperative and postoperative high-resolution mastoid CT scans. Postoperative non EPI DWI was performed only for patients with suspected opacity in the middle ear or mastoid cavity detected by postoperative CT scan. Inclusion criteria were: (1) patients age more than 18 years old, (2) operated middle ear cholesteatoma, (3) performed preoperative high resolution mastoid CT scan, (4) performed mastoid CT scan 12 months postoperatively and (5) performed non-EPI DWI at 12 months postoperatively. Patients were excluded if they were less than 18 years of age or had clear mastoid cavity on the postoperative CT scan. The study was approved by our Institutional Research Ethics Board and follows the standards of our Institutional Ethics Committee.

Radiological images were then fused using Osirix DICOM-viewer© version 5.9 32-bit as follow: (1) Preoperative mastoid CT scan with postoperative mastoid non-EPI DWI, (2) Postoperative mastoid CT scan with postoperative non-EPI DWI.

Images were evaluated for their accuracy in the localization of residual cholesteatoma. Positive cases of residual cholesteatoma on DWI were then programmed for a second look mastoidectomy and a correlation between the radiological and surgical findings were evaluated. Second look mastoidectomy was performed 8–12 months postoperatively.

2.1. Imaging techniques

2.1.1. High-resolution CT scan

Temporal bone CT protocol includes helically acquired 0.6-mm thick axial images on 16-row MDCT scanner from the arcuate eminence through the mastoid tip obtained without intravenous contrast. Images are routinely reconstructed in axial and coronal planes parallel and perpendicular to the lateral semicircular canal (LSCC) and in bone algorithm.

2.1.2. Magnetic resonance imaging

MRI was performed with a 1.5 T scanner (Symphony, Siemens) using a standard head coil. The following protocol was used: axial T1-weighted images (TR/TE, 450/15 ms; flip angle, 90°; slice thickness, 3 mm; distance factor, 0.10; matrix, 192 × 256; FOV, 180 mm), axial 3D-constructive interference in steady state [3D-CISS] (TR/TE, 12.25/5.9 ms; flip angle, 70°; one slab, slab thickness, 32 mm; effective thickness, 0.7 mm; number of partitions, 46; matrix, 230 × 512; FOV, 200 mm), axial and coronal diffusion weighted imaging with single-shot fast T2 half-Fourier acquisition single-shot turbo spin echo [HASTE] (TR/TE, 2700/132 ms; flip angle, 180°; slice thickness, 3 mm; intersection gap, 0 mm; b factor, 1000 s/mm^2; matrix, 256 × 256; FOV, 200 mm).

3. Results

Twenty-eight patients were included in the study; 18 patients had clear aerated mastoid and middle ear spaces in the postoperative CT-scan and they were excluded because there is no need for a second look and therefore no need for a DWI MRI. So, the remaining 10 patients had postoperative DWI and were evaluated for residual cholesteatoma. Three out of the 10 patients had high signal intensity on the DWI and one patient had low signal intensity.

Details of the radiological findings and fusion description of the four patients are demonstrated in Figs. 1–4. During the second look mastoidectomy, residual cholesteatoma was detected in patients #1, #2 and #3 as predicted by the radiological fusion and at the corresponding location, where the fused radiological images showed.

Patient #4 showed no residual cholesteatoma during the second look mastoidectomy. However, by reviewing the DWI, signal intensity/diffusion restriction was very small with a very low suspicion rate compared to the other three patients. Fig. 4.

4. Discussion

In the current study, preoperative CT-scan fusion to DWI was able to localize the residual cholesteatoma with an accuracy that resembles postoperative CT-scans.

CT-scan usage has increased up to 12 folds and 20 folds in the UK and US respectively, over two decades periods according to statistics published by Brenner et al in 2008 [5]. It is estimated that the lifetime risk of leukemia and brain tumors from one pediatric brain CT-scan is about 1 in 10000 and 1 in 2000, respectively [6,7]. Pearce et al. also concluded that 5 to 10 head CT-scans could deliver a cumulative ionizing radiation dose of 50 mGy to red bone marrow in children younger than 15 years, which could triple the risk of leukemia. Also, only 2 to 3 head CT-scans can deliver 60 mGy brain dose which almost triples the risk of brain tumors [7].

Residual cholesteatoma after CWU mastoidectomy varies in the literature between 10% and 40% [1,8,9]. The debate of whether a CWU or canal wall down (CWD) mastoidectomy is more effective in preventing this residual cholesteatoma is still present. Some surgeons believe that a CWD mastoidectomy is more effective [10]. However, although CWD might decrease the incidence of attic and mastoid cavity residual cholesteatoma, the incidence of mesotympanum residual cholesteatoma which is the most common site of residual cholesteatoma remains unaffected [9]. On the other hand, planned two-stage CWU mastoidectomy remains a commonly practiced approach in the management of cholesteatoma [11]. However, it is not realistic to schedule all patients for a two-stage mastoidectomy, knowing that at least about 60% of them will be negative for residual cholesteatoma.

Recent developments in the imaging techniques are of great value in the diagnosis and follow-up of cholesteatoma [12]. Two modalities of MRI have been described in the literature for the detection of residual cholesteatoma; Delayed post gadolinium injection and DWI [2]. Delayed post gadolinium MRI results in an enhancement of granulation tissue and scar tissue after a delay of 30–45 min while residual cholesteatoma does not show any enhancement [13,14]. This technique is able to detect cholesteatoma larger than 3 mm with 90% sensitivity and 100% specificity [15]. The other modality is DWI which is fast pulse sequence performed in about 1 min and does not require contrast injection [16–18]. High diffusion of water molecules results in low signal intensity enhancement in images. In granulation tissue, water diffuses easily, therefore, it has low intensity signal, while