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ORIGINAL ARTICLE

Diagnostic imaging in chronic otitis media: does CT and MRI fusion aid therapeutic decision making? – a pilot study

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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ABSTRACT:

Introduction: Despite the recent advances in otosurgery diagnosis of cholesteatoma and qualification for surgery remains an issue in contemporary laryngology. In cases of cholesteatoma recidivism, it is of utmost importance to properly locate the pathology in the middle ear to plan surgical approach. Magnetic Resonance imaging in diffusion weighted non-echoplanar sequences (non-EPI DWI) enables cholesteatoma detection as small as 2 mm and could potentially prevent unnecessary second-look surgery. Computed Tomography of the temporal bone allows precise visualization of bony structures and topographical landmarks of the middle ear. A fusion of both imaging modalities combines the advantages of these techniques.

Material and methods: Five patients treated in the Department of Otolaryngology, Medical University of Lodz for probable cholesteatoma recidivism were included in this study. A high-resolution CT scan of the temporal bone and an MRI scan including non-EPI sequences was obtained in all patients. A fusion of CT and MRI studies was conducted using OsirixMD software. Fist, CT studies were fused with MRI BFFE sequences, then non-EPI sequences were added. Finally, if the patient qualified for surgical treatment histopathological diagnosis was compared with MRI results.

Results: CT scans were analyzed to establish the extent of previous surgical interventions and anatomical landmarks preservation. In all cases MRI results were suspicious of cholesteatoma recidivism. Four cases were confirmed in postoperative histopathological evaluation, there was one false positive case when intraoperatively scar tissue was identified, which was later confirmed as connective tissue upon histopathological evaluation.

Conclusions: CT and MRI fusion provides a helpful diagnostic tool in preparation for surgery in patients with suspected cholesteatoma recidivism.

KEYWORDS: magnetic resonance, computed tomography, cholesteatoma, canal wall-up surgery

EXPLANATION OF ABBREVIATIONS USED:

BFFE (Balance Fast Field Echo) – a sequence of steady-state free precession
T1W – T1 weighted image
T2W – T2 weighted image
non-EPI DWI – Non-echo-planar Diffusion Weighted Imaging
ADC – Apparent Diffusion Coefficient
CWD (Canal Wall Down) – open tympanoplasty
CWU (Canal Wall Up) – closed tympanoplasty

INTRODUCTION

Nowadays, imaging examinations in chronic otitis media (COM) constitute an indispensable element of diagnostics, complementing both clinical and audiological examination. Changes in the approach to surgical treatment of middle ear cholesteatoma aiming at minimally invasive surgery require precise information about the extent of lesions. Information about the aeration of temporal bone obtained from an analysis of imaging tests allows to answer the question whether conditions for performing closed tympanoplasty, exist thus making the procedure less invasive compared to the open technique. What is more, with the development of endoscopic techniques, many clinics are offering transcanal access without mastoidectomy in disease limited to the meso- or epitympanum[10].

High resolution computed tomography (CT) of the temporal bone (with a layer thickness below 1 mm) is an imaging examination of choice in the planning of surgical treatment of this area. Due to high spatial resolution and perfect visualization of bony structures, it allows to accurately reproduce the position of anatomical structures significant from a surgical point of view. Presence of cholesteatoma in the inflamed middle ear may be suspected only on the basis of indirect symptoms such as: erosion of the ossicles, semicircular canals and the tegmen or the presence of soft tissues within the middle-ear air space in a location typical for acquired cholesteatoma (Prussak space). CT has a high sensitivity in detection of middle ear disease reaching 88%; [9]however, the specificity of this imaging technique to recognize lesions caused by the presence of cholesteatoma is lower. Computed tomography does not allow to differentiate inflamed granulation tissue, scar tissue or cholesterol granulomas from middle ear cholesteatoma.

A valuable complement to information provided from indeterminate the CT study is sequences (MRI) using non-echoplanar diffusion weighted magnetic resonance imaging (non-EPI DWI MRI). The non-EPI DWI sequence does not require intravenous contrast, which makes the study quick and safe for the patient. It is characterized by high sensitivity (91%) and specificity (92%), therefore allowing to differentiate between scar tissue, inflamed granulation tissue and cholesteatoma [4]. This is particularly important in the group of patients with recidivism of disease after a middle ear surgery and in many centers is an alternative to second--look surgery. Diffusion restriction in the non-EPI DWI study is seen as a hyperintensive image with a low signal on the ADC map [3], which constitutes a graphical representation of the diffusion coefficient of water molecules and looks like a reverse image of the DWI sequence. The ADC map analysis is useful in interpreting images obtained from diffusion sequences and allows for differentiation of pathologies with similar signal intensity in DWI. The layer thickness is the lowest among the techniques used in detection of cholesteatoma, therefore it allows for detection of a lesion from the size of 2 mm[11]. Unfortunately, this is associated with a poorer spatial resolution than in the CT scan, whereas the MRI itself does not detect the osseous tissue, which impedes precise determination of the location of lesions.

The combination of advantages of both imaging techniques is provided by a computer fusion technique, known from positron emission tomography (PET-CT). In the world literature there are few reports from use of a similar technique in evaluation of the middle ear[1]. The study aim was to develop a method of fusion of non-EPI DWI MRI and high-resolution CT of the temporal bone using a commonly available radiological software and assessment of its effectiveness in diagnosis and localization of cholesteatoma recidivismm.

MATERIAL AND METHODS

Patients qualified for reoperation in whom otoendoscopy showed no direct signs of cholesteatoma recidivism were selected from patients referred to the Department of Otolaryngology, Laryngological Oncology, Audiology and Phoniatrics of the Medical University in Łódź due to chronic otitis media with cholesteatoma. Five patients (2 men, 3 women) aged 33.4 ± 28.04 were enrolled for surgical revision based on the outcome of MRI examination.

Firstly, all patients underwent a high-resolution temporal bone CT scanning without intravenous contrast. Research was conducted on a LightSpeed VCT (General Electric) multi-slice apparatus with a layer thickness of 0.625mm and a 512x512 matrix. Next, MRI was performed with a 16-channel Achiva 3.0 T (Philips Healthcare) using a 16-channel SENSE NeuroVascular voice coil with the use of standard T1W, T2W, BFFE, EPI DWI sequences and additionally non-EPI DWI, in which 2mm layer thickness, "b" equal to b=0 and b=1000 and a test matrix of 128x114 were determined.

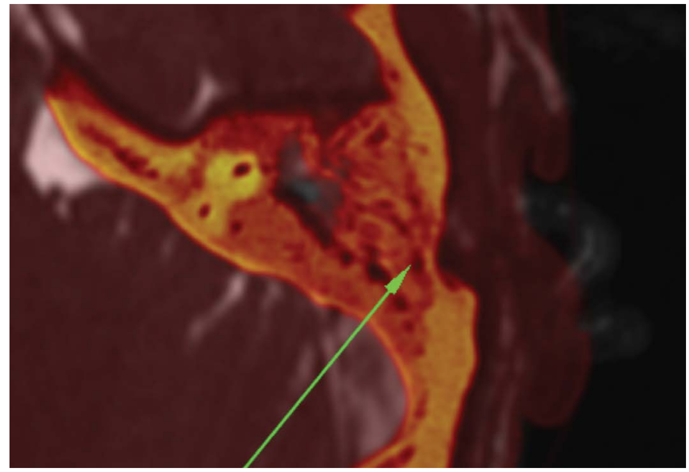

Fig. 1. An image of a fusion of CT and MRI in a patient with suspected cholesteatoma. The first stage of research fusion: imposition of BFFE RM and CT sequences. The arrow indicates the probable location of cholesteatoma determined based on non-EPI DWI image analysis, impossible to assess at this stage of fusion.

Computer fusion of research was carried out using the OsirixMD licensed software. Common reference points were determined for both imaging methods: internal auditory canal, eyeball contours, course of the optic nerve semicircular canals.

Due to the differences in patient positioning and different size of the acquisition matrix in both studies, the image obtained in computed tomography should be adjusted through multiplanar reconstructions in such a way that the common reference points mentioned above coincide with magnetic resonance imaging. The first stage of image fusion consisted superimposing of CT scan images and the RM 3D BFFE sequence (Fig. 1).

This allows for proper adjustment of soft tissue structures such as nerves, muscles and spaces filled with fluid in relation to the bones. Then, non-EPI DWI images b=0, b=1000 and ADC maps were used to determine the location of the lesion that could resemble to middle ear cholesteatoma (Fig. 2).

Because ADC maps represent cholesteatoma tissue as a hypointense image in relation to surrounding tissues, the ADC map image was not included in the fusion. It was decided to use images of b=1000, in which keratin has a high signal, thanks to which the lesion shows better contrast in the middle ear. Non-EPI DWI images b=1000 and the image from the fusion of CT and MRWI 3D BFFE obtained at the first stage were then superimposed, resulting in fusion of non-EPI DWI b=1000, 3D BFFE and CT sequences (Fig. 3).

In the final stage, the program automatically scaled the image (thickness of the layer's movement) to make it adequate in all projections. This process is illustrated in the diagram (Fig. 4). A DICOM file was generated allowing operators to open a fusion image in any DICOM browser. Images were evaluated by the otosurgical team and independently by two radiologists.

Patients were qualified for reoperation, during which surgeons independently performed intraoperative detection of lesion. After removing the tissue, it was sent for histopathological examination.

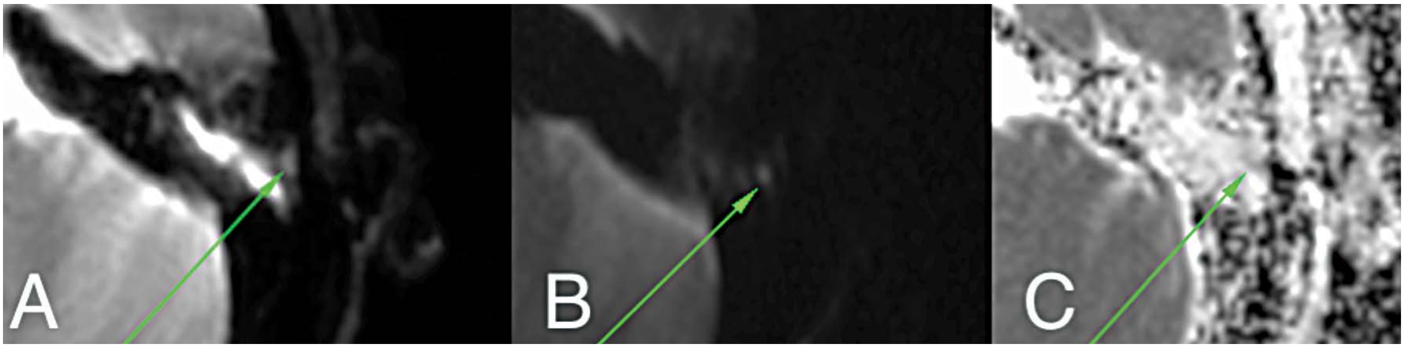

Fig. 2. An image of a non-EPI DWI sequence in a patient with a suspected cholesteatoma. Analysis of b=0, b=1000 and ADC images performed in the non-EPI DWI sequence. (A) – b=0 image, in which the lesion that may correspond to the cholesteatoma is hyperintensive. (B) – b=1000 image, in which the lesion that may correspond to a cholesteatoma is hyperintensive compared to the surrounding tissue. (C) – ADC image, on which the same lesion has a lower signal in relation to the environment. Analysis of these three images allows to suspect the presence of cholesteatoma with high probability.

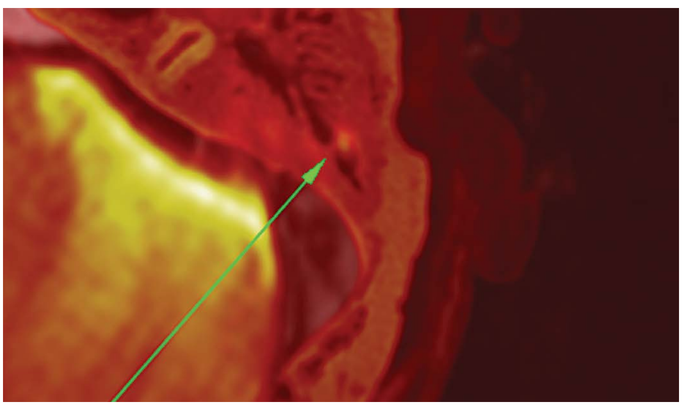

Fig. 3. The final fusion of BFFE, CT images and b=1000 non-EPI DWI images in a patient with chronic otitis media that allows to expose the cholesteatoma (marked with an arrow).

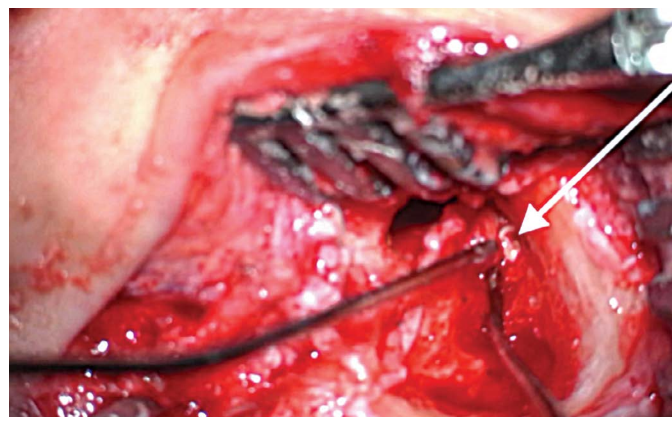

Fig. 5. Intraoperative image during open tympanoplasty in a patient M.W (age 21). A 2-mm diameter cholesteatoma was found (marked with an arrow).

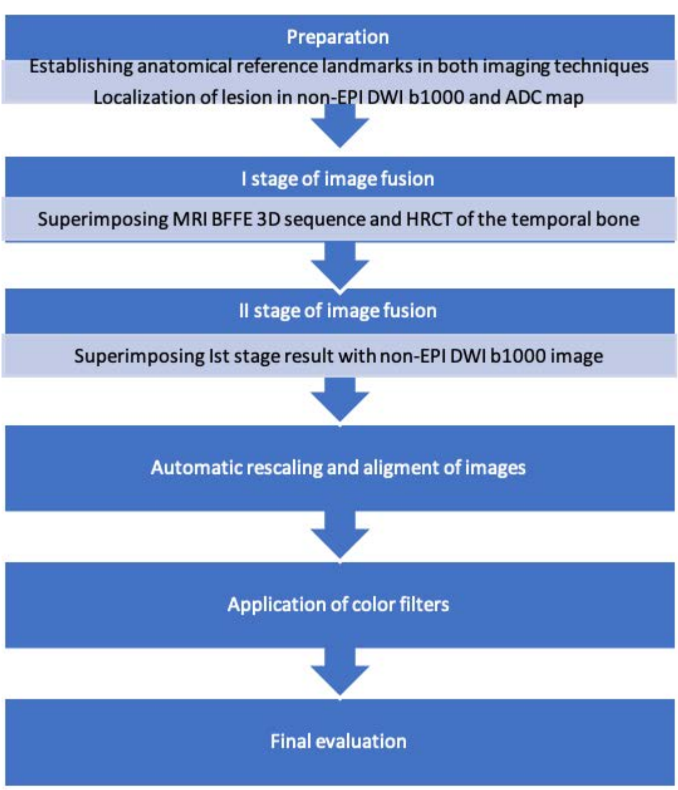

Fig. 4. A diagram illustrating the process of computer fusion of CT and MRI images.

RESULTS

After clinical diagnosis and fusion radiological imaging, all analyzed patients were qualified for reoperation. Four patients previously underwent canal wall up one patient underwent canal wall down surgery in another clinic. Among patients who underwent a CWU surgery, in one case it was decided to perform reoperation via CWD technique, in other cases a CWU was used. Characteristics of the study group and a summary of results of MRI examination, operation performed, as well as results of histopathological examination are summarized in Table I. In the MRI, cholesteatoma was identified as hyperintensive lesions in the T2W and non--DWI sequence in values of b0 and b1000, which had a low signal in ADC maps at 1.090 × 10-3 mm2/s ± 0.205 95%CI [0.123-0.590]. The location determined in the computer fusion was related to the surgeon's intraoperative observation.

In four cases, the MRI non-EPI DWI test result was classified as truly positive; histopathologic examination confirmed the presence of middle ear cholesteatoma with the smallest observed dimension of 2 mm (min. 2mm; max. 8mm). One case was classified as false positive; intraoperatively, the surgeon found presence of planar adhesions in the postsurgical cavity. Images obtained via computer fusion in each case correctly localized the lesion in the middle ear and in 80% of cases correlated with the presence of a cholesteatoma in the postsurgical cavity.

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Tab. I. List of the results of non-EPI DWI test, histopathological examination and procedure performed in patients qualified for reoperation due to suspected relapsing cholesteatoma.

PATIENT NUMBER AND INITIALS	SEX	AGE	TYPE OF PRIMARY OPERATION	TYPE OF REOPERATION	CLASSIFICATION OF NON-EPI DWI TEST RESULT	POSTOPERATIVE RESULT OF HISTOPATHOLOGICAL EXAMINATION	SIZE OF LESION
J.A	F	28	CWU	CWD	True positive	cholesteatoma	3 mm
D.P	M	18	CWU	CWU	True positive	cholesteatoma	3 mm
K.Z	F	30	CWU	CWU	True positive	cholesteatoma	7 mm
M.W	M	21	CWD	CWD	True positive	cholesteatoma	2 mm
A.K	F	70	CWU	CWU	False positive	Connective tissue	8 mm

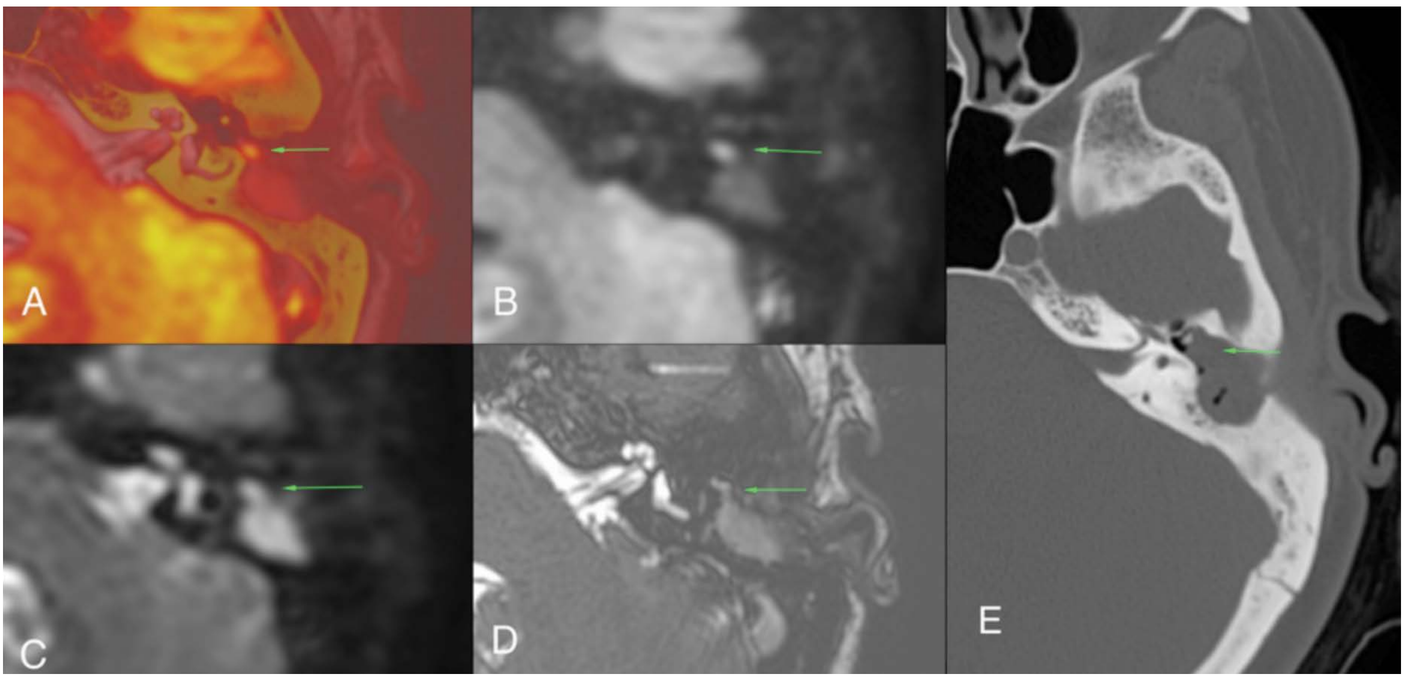

Fig. 6. Another example of a computer fusion of CT and non-EPI DWI MRI in a patient, J.A (age 28). The arrow indicates the location of the cholesteatoma. (A) Computer fusion of the BFFE, non-EPI DWI b1000 and CT sequence. Perfect visualization of bony structures; the overlaid graphic filter dyes the cholesteatoma to a bright pink-orange color. (B) non-EPI DWI b1000, the lesion is hyperintensive in relation to the surrounding Scar tissue. (C) non-EPI DWI b0, both the cholesteatoma and scar are hyperintensive. (D) the RM BFFE sequence perfectly exposes the nerves and inner ear cavities. The cholesteatoma is indistinguishable from the surrounding tissue. (E) Computed tomography, shaded post-operative cavity, cholesteatoma does not stand out from the surrounding soft tissues.

DISCUSSION

Computed tomography examination, due to high spatial resolution for bony structures, remains the method of choice in preoperative assessment of pathological lesions in chronic otitis media in previously unoperated patients. CT analysis allows to assess the extent of lesions within key areas unavailable in a examination trial: attic, antrum and mastoid process[7]. Sensitivity of CT examination in detection of middle ear cholesteatoma remains high in cases planned for primary surgery; unfortunately, in cases qualified for reoperation, reasoning based on indirect symptoms becomes difficult. The post-operative cavity is most often opacificated; it is not possible to differentiate between scar tissue, post-inflammatory granulation and the fluid space of cholesteatoma. Intensity of the gray scale measured in Hounsfield Unit [HU] cannot be used to distinguish cholesteatoma from other tissues.[8]

Non-EPI DWI MRI sequences have high sensitivity and specificity as well as high positive predictive value [2,4,5]. They allow for soft tissue differentiation based on the ADC parameter; it is significantly lower than the surrounding tissue for keratin within the middle ear. In our study, the average ADC for cholesteatoma was 1,090 × 10-3 mm2/s and in each case, it was hypointense in relation to the surrounding tissues.

The meta-analysis by Lingam et al. [4] compared sequence sensitivity (92% vs. 93%) and specificity (97% vs 91%) in preoperative cases and cases qualified for reoperation. Similarly, high sensitivity and specificity of non-EPI DWI in the diagnosis of cholesteatoma in patients qualified for primary surgery and reoperation was indicated. In another meta-analysis of 27 RM diffusion studies in the assessment of patients with suspected relapsing or persistent cholesteatoma, Muzaffar et al. [6] established sensitivity of the non-EPI DWI sequence at 89.79%±12.1% and specificity at 94.57%±5.8%. The advantage of non-EPI DWI was demonstrated when comparing echoplanar sequences to non-echoplanar sequences (sensitivity 71.82% vs. 89.79%, specificity 89.36% vs 94.57%).

Our study included one false positive case. The lesion described in the preoperative study was located within the post-operative cavity after CWD surgery. It is possible that the keratin deposits were sucked out when the ear was cleaned during the pre-operative visit, which is why the cholesteatoma was not detected intraoperatively. A similar case is described in the literature[1].

In a study by Campos et al. [1]regarding the fusion of DWI and non--EPI DWI as well as CT images of the middle ear in the evaluation of patients with chronic otitis media, the study was performed by an external clinic. In the protocol described in our study, the fusion was performed by a radiologist alone using a widely available software, which did not require involvement of additional resources. This enables wider use of fusion techniques in pre-operative evaluation. It should be emphasized, however, that performing a fusion of research is of clinical significance only by specifying the location of the lesion. It does not increase the sensitivity and specificity of imaging methods used.

CONCLUSIONS

The presented results constitute pilot studies. No similar research was found in the available Polish literature. The method of merging MRI and CT seems to be innovative and highly useful in the qualification of patients for surgical treatment, especially in suspected recurrence of cholesteatoma in a clinical trial. Both imaging methods provide mutually complementary information. The fusion of images combines the advantages of both techniques and helps the surgeon plan the operation.

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