

## Topical Contrast-enhanced Magnetic Resonance Dacryocystography

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**Purpose:** To evaluate the usefulness of magnetic resonance dacryocystography (MRD) with topical administration of normal saline solution and diluted Gd-DTPA solution for the assessment of lacrimal outflow disorders.

**Materials and Methods:** Two T2-weighted sequences and two T1-weighted sequences were evaluated in this study. The 1:100 diluted Gd solution was prepared by diluting Gd-DTPA (Magnevist®) with normal saline solution. A phantom study using tube phantoms of various diameters filled with normal saline solution and 1:100 diluted Gd solution was performed. A preliminary study was performed in ten normal volunteers. Eighteen patients with lacrimal outflow disorders underwent clinical MRD, and 14 also underwent conventional dacryocystography (CDG). MRD images were evaluated and compared with clinical symptoms and CDG images.

**Results:** In all sequences, MRD could visualize the full length of 0.7 to 1.7 mm diameter tube phantoms and could show all of the normal lacrimal sacs and nasolacrimal ducts. In the clinical study, MRD findings were compatible with the symptoms in 14 patients but were not compatible with CDG findings in half of the cases.

**Conclusion:** Topical contrast-enhanced MRD provided a simple, non-invasive means of obtaining detailed morphological and functional information on the lacrimal drainage apparatus.

**Key words:** magnetic resonance imaging, lacrimal apparatus diseases, gadolinium-DTPA, sodium chloride, topical administration

### INTRODUCTION

MANY PATIENTS complain of epiphora caused by obstruction or stenosis of the lacrimal sacs and/or the nasolacrimal ducts. Most of these patients have primary acquired nasolacrimal duct obstruction.<sup>1</sup>

Conventional cannulation dacryocystography (CDG) using X-ray systems and contrast media is the most common means of visualizing disorders of lacrimal drainage systems. This technique is considered relatively invasive, with the risk of iatrogenic trauma or scarring, and needs skilled operators. It has been hoped that modern technology would provide safer and more straightforward methods. Recently, contrast-enhanced magnetic resonance dacryocystography (MRD) with topical administration of diluted gadolinium-DTPA

solution has been found to be useful for patients with lacrimal outflow disorders, and MRD with topical administration of normal saline solution has been found to be useful for visualization of the normal lacrimal apparatus.<sup>2-6</sup> However, MRD with topical administration of normal saline solution, which is less invasive, less expensive, and less complicated, has not been clinically evaluated. In addition, projected images with topical administration of diluted gadolinium-DTPA solution, which present images similar to CDG images, have not been previously described.

The purpose of this study was to evaluate topical contrast-enhanced MRD, including transverse images and projected images, with topical administration of normal saline solution and subsequent topical administration of gadolinium-DTPA (Gd) solution diluted with saline solution in normal volunteers and patients with lacrimal outflow disorders.

### MATERIALS AND METHODS

#### *MR imaging*

MR studies were performed with a 1.5 Tesla

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**Table 1. Sequences and timing parameters**

	T2WPI	T2-weighted FSE	T1-weighted FFE	T1-weighted SE
Slice section plane	coronal	transverse	transverse	transverse
Topical solution	saline solution	saline solution	Gd	Gd
TR (ms)	12000	4500	31	550
TE (ms)	2000	100	2.6	15
Flip angle (°)	90	90	30	90
Field of view (mm)	180	200	110	200
Matrix	256×196	256×196	256×256	256×196
Number of slices	1	20	60	20
Slice thickness	80	3	1	3
Acquisitions	6	2	2	2
Echo train length	256	9		
Fat suppression	Yes	Yes	Yes	Yes
Acquisition time (min)	1:21	3:00	8:04	4:30
Number of MIP images			12	

T2WPI: T2-weighted projected image, FSE: fast spin echo, SE: spin echo, FFE: fast field echo, Gd: diluted Gd-DTPA solution.

superconducting imaging system (Gyrosan NT, Philips Medical Systems, Best, The Netherlands). A body coil was used for transmission and an 11-cm diameter rounded surface coil was used for reception. The MR protocol included a T1-weighted spin echo sequence with transverse thin slice sections, a T2-weighted fast spin echo sequence with transverse thin slice sections, a T2-weighted fast spin echo sequence with long echo time and a coronal thick slice section (T2-weighted projected image, T2WPI), and a 3D-T1-weighted fast field echo (FFE) sequence with thin transverse sections. In addition, images projected in the anterior-posterior direction were reconstructed from transverse images of a 3D-FFE sequence using maximum intensity projection (MIP) processing. The parameters for each sequence are shown in Table 1.

#### *Phantom study*

Phantom studies using 0.7, 0.9, 1.1, 1.4, and 1.7 mm diameter tube phantoms filled with saline solution and 1:100-diluted Gd solution were performed. The tube phantoms filled with saline solution were used for evaluation of two T2-weighted sequences and the ones filled with diluted Gd solution were used for evaluation of two T1-weighted sequences. We recorded whether each phantom was visualized or not. We also recorded phantom sizes on each image. The 1:100 diluted Gd solution was prepared by diluting Gd-DTPA (Magnevist®, Nippon Schering, Osaka, Japan) with normal saline solution.

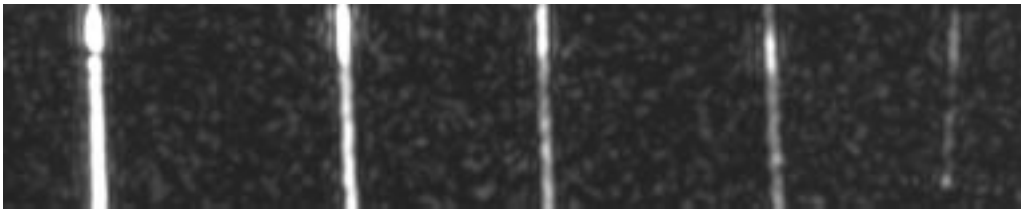
#### *Preliminary study*

Ten normal volunteers (eight men, two women) aged 25 to 38 years (mean age, 30.5 years) underwent MRD using the above-mentioned four sequences in the supine position. For each of the volunteers, we first obtained T2-weighted images of one side of the lacrimal drainage systems using two T2-weighted sequences just after topical administration of saline solution. Subsequently we obtained T1-weighted images of the other side using two T1-weighted sequences just after topical administration of 1:100-diluted Gd-solution. Saline solution and diluted Gd-solution were administered just before each scan. About 3 ml of contrast medium was administered five times before each scan.

#### *Clinical study*

Eighteen patients (four men, 14 women) aged 46 to 81 years (median age, 66.2 years) that had complained of epiphora underwent bilateral MRD using the above-mentioned four sequences in the supine position. Thus, a total of 36 lacrimal drainage systems were examined. Four of the patients had previously undergone unilateral dacryocystorhinostomy (DCR). Fourteen of the patients also underwent conventional dacryocystography (CDG) within 4 weeks of MRD. In these patients, a total of 17 lacrimal drainage systems were examined by CDG.

For all patients, we first obtained T2-weighted images using two T2-weighted sequences just after bilateral topical administration of saline solution. We subsequently obtained T1-weighted images using two T1-weighted sequences just after bilateral topical administration of 1:100 diluted Gd-solution. CDG



**Fig. 1.** T2-weighted projected image of tube phantoms filled with saline solution. All tube phantoms are shown in this figure (left to right, 0.7, 0.9, 1.1, 1.4, and 1.7 mm in diameter).

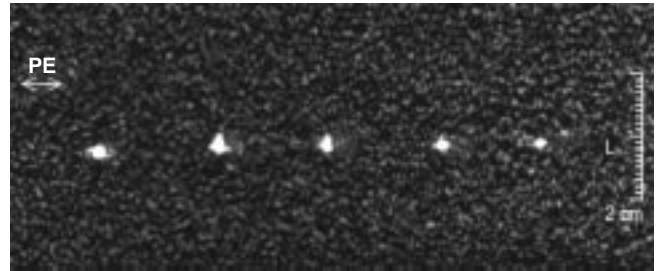
images were obtained just after pressure-injection of iodized oil (Lipiodol Ultra-Fluide®, Guerbet, Villepinte, France) by a cannulation technique.

#### *Image interpretation and evaluation*

On projected MRD images, the cranio-caudal level of the caudal end of the lacrimal sac was defined at the caudal end of the upper quarter of the distance between the lacrimal lake and bottom of the inferior nasal meatus. The cranio-caudal level of the caudal end of the nasolacrimal duct was defined at the cranial end of the lower quarter of the distance between the lacrimal lake and bottom of the inferior nasal meatus.

In the preliminary study, we recorded whether or not each portion of the lacrimal drainage system was completely visualized. In the clinical study, we estimated each projected MRD image as follows. Stenosis or obstruction at the canaliculus was assumed if the lacrimal sac and nasolacrimal duct were not visible. Stenosis or obstruction at the lacrimal sac was assumed if there was incomplete filling of the sac, without filling of the nasolacrimal duct. Stenosis or obstruction at the nasolacrimal duct was assumed when the sac was visualized normally, but there was no filling of the nasolacrimal duct. Stenosis was assumed if the caudal portion of the narrowed site was seen on a projected image and the residual lumen of the narrowed site was seen on at least one transverse image.

MRD images were evaluated by two radiologists and a consensus opinion was obtained in both the preliminary study and clinical study. In the clinical study, diagnoses of MRDs were determined by combining the assessments of the saline solution-enhanced T2-weighted images and the Gd solution-enhanced T1-weighted images, including both projected and transverse images. If a discrepancy was noted between the findings of T2WPI and FFE-MIP images, the narrowed site was determined by the findings of the Gd-enhanced FFE-MIP image. Transverse images were used to confirm the diagnosis on projected images. Other findings including volume of the residual lumen and situation of the mucosa, information contributing to



**Fig. 2.** FFE source image of tube phantoms filled with 1:100 diluted Gd-DTPA solution. All tube phantoms are visible, but artifacts caused by the susceptibility effect are seen (left to right, 0.7, 0.9, 1.1, 1.4, and 1.7 mm diameter phantoms). PE: phase encoding direction.

therapy, was recorded for each image. Diagnoses of MRDs were compared with clinical symptoms and the findings of CDGs.

## RESULTS

#### *Phantom study*

MRD could visualize the full length of 0.7 to 1.7 mm diameter tube phantoms filled with saline solution in exactly the actual size using two T2-weighted sequences (Fig. 1). MRD could visualize the full length of 0.7 to 1.7 mm diameter tube phantoms filled with Gd-solution in 5-89% larger sizes than the actual size using two T1-weighted sequences. FFE transverse and MIP images were less accurate than spin echo images for measuring phantom size, and had artifacts caused by the susceptibility effect (Fig. 2).

#### *Preliminary study*

Lacrimal sacs were well visualized in all 10 normal volunteers in all sequences. The cranial portions of the nasolacrimal ducts were well visualized in all 10 normal volunteers in all sequences, but the caudal portions were visualized in only four cases on T2WPIs, five cases on FFE-MIP images and T2-weighted transverse images, and six cases on T1-weighted transverse images. Canaliculi were visualized in five cases on T2-weighted

transverse images and T1-weighted transverse images, and in seven cases on FFE-transverse images.

### *Clinical study*

The results are shown in Tables 2 and 3. MRDs were performed without difficulty in all patients. In two cases of postoperative deformities of the nasal cavity or orbital cavity, MRD could be performed without difficulty. No patients complained of discomfort during the examinations.

Seven obstructions or stenoses of canaliculi, five obstructions or stenoses of lacrimal sacs, eight obstructions or stenoses of nasolacrimal ducts, and one post-DCR stenosis were detected on MRDs, and MRD diagnoses were compatible with symptoms except for four drainage systems in four patients. Residual sac lumens were more frequently seen on T2WPIs and T2-weighted transverse images in seven cases than on all T1-weighted images. Mucosal thickenings were seen in two cases on T2-weighted transverse images. In 11 drainage systems of 10 cases, the findings of T2WPIs were not consistent with those of the FFE-MIP images. And T2WPIs tended to show the caudal portion of the site of obstruction or stenosis and reveal false-negative findings. In cases 1 and 11 with visualized residual caudal lumen of the obstructed or narrowed site, simple irrigation therapy improved the symptoms. FFE-MIP images were helpful in diagnosing the obstructed or narrowed site because they were similar to the CDG images. The CDG findings were consistent with the MRD findings of eight drainage systems in eight of the 14 patients who underwent CDG, but they were not consistent with the MRD findings of nine drainage systems in seven patients. In addition, the T2WPI findings were not consistent with the CDG findings of 14 drainage systems in 12 patients. The CDG findings were consistent with symptoms for 15 drainage systems in 13 patients. Slight stenoses of the long segment appeared as obstructions on MRD in two cases (cases 6 and 8). The MRD findings of three typical cases are shown in Figs. 3, 4, and 5. A typical case of lacrimal sac stenosis (case 5) is shown in Fig. 3, a typical case of long segmental stenosis due to mucosal thickening (case 6) in Fig. 4, and a typical case of false-negative finding (case 11) on T2WPI in Fig. 5.

### DISCUSSION

Therapies for epiphora caused by obstruction or stenosis of the lacrimal drainage system include dacryocystorhinostomy, dacryocystoplasty, nasolacrimal stenting, and simple irrigation with antibiotic drugs.<sup>7-9</sup> Information on the site and nature of

the stenosis or obstruction is important for decision making. Many imaging modalities have been used for diagnosis. CDG is the simplest, most widely performed, and most well-established of these methods, but it is not only relatively invasive but also provides only limited morphological information about the surrounding structures and limited functional information about the lacrimal drainage apparatus. For example, it does not provide much information concerning the condition of the mucosa and is unable to detect slight narrowing of the drainage system or dysfunction of the canalicular muscle pump. In addition, this method irradiates the lens. In a standard examination, this method irradiates the lens of the eye with a dose in the range 0.04-0.2 mSv.<sup>10,11</sup> Topical contrast-enhanced CT dacryocystography has been reported to be useful for evaluating the lacrimal drainage apparatus.<sup>4,6</sup> However, this method requires the use of iodinated contrast material, which is irritative to conjunctiva, and the dose absorbed by the lens in CT has been reported to be 1.8-2.6 mSv.<sup>12</sup> Dacryoscintigraphy, while providing functional information, offers little morphological information. In addition, the radiation absorbed by the lens is about 0.038 mGy/MBq <sup>99m</sup>Tc in normal subjects and about 1.09 mGy/MBq <sup>99m</sup>Tc in patients with complete obstruction of the lacrimal drainage system.<sup>13</sup>

MRD with conjunctival administration of diluted Gd-DTPA has been described previously.<sup>2-5</sup> It has an advantage over non-invasive simultaneous bilateral visualization, while CDG is generally performed for a unilateral side because it is thought to be an invasive preoperative examination by most ophthalmologists. MRD also provides relatively high-resolution images as well as functional information. However, only raw transverse or coronal images, which are not familiar to most ophthalmologists, were evaluated in these reports. Further, MRD with conjunctival administration of normal saline solution has been reported only in normal volunteers.<sup>6</sup> Therefore, we evaluated the usefulness of projected images of Gd-enhanced MRD and saline solution-enhanced MRD in normal volunteers and patients.

In this study, T2WPIs had a calculated spatial resolution of 0.70×0.92 mm, and FFE-MIP images had a calculated spatial resolution of 0.43×0.43×1.00 mm. We found in our phantom study that all the sequences we used could visualize equal to or smaller than 0.7-mm diameter ducts filled with contrast material. In our preliminary study, we could visualize normal sacs and nasolacrimal ducts in all the sequences, but we were unable to visualize the caudal portions of normal nasolacrimal ducts in about half of the normal volunteers. This is thought to be due to the relatively fast flow in

**Table 2. Patient list and results**

Case	Age (yr), sex	Previous therapy	Epiphora	T2WPI	FFE-MIP	MRD diagnosis	Other MRD findings	CDG diagnosis
1*	54, M	Lt. DCR	Rt.	Rt. LS stenosis	Rt. LS stenosis	Rt. LS stenosis		(not done)
2	63, F	Rt. DCR	Rt.	No stenosis	Rt. NLD obstruction	Rt. NLD obstruction Post-DCR stenosis	Residual Rt. sac lumen	Rt. NLD obstruction Post-post-DCR stenosis (Rt.: not done)
3	74, F		Lt.	No stenosis	Lt. CL obstruction	Lt. CL obstruction	Residual Lt. sac lumen	Lt. CL obstruction (Rt.: not done)
4	46, F		Lt.	Lt. CL obstruction	Lt. LS obstruction	Lt. LS obstruction	Residual Lt. sac lumen	Lt. LS obstruction (Rt.: not done)
5	74, F		Lt.	Lt. LS obstruction Rt. NLD obstruction	Lt. LS obstruction Rt. NLD obstruction	Lt. LS obstruction Rt. NLD obstruction	Residual Lt. sac lumen	Lt. LS obstruction (Rt.: not done)
6	66, F		Bilat.	Lt. NLD obstruction	Lt. NLD obstruction	Lt. NLD obstruction	Thickening of mucosa	No stenosis
7	78, F	Rt. SI	Rt.	Rt. CL obstruction	Rt. NLD obstruction	Rt. NLD obstruction	Thickening of mucosa	Rt. LS stenosis (Lt.: not done)
8	81, M		Bilat.	Bilat. CL obstruction	Bilat. CL obstruction	Bilat. CL obstruction		Bilat. LS/NLD stenosis
9	60, F		Lt.	No stenosis	Lt. CL obstruction	Lt. CL obstruction	Lt. CL dilatation	Lt. LS obstruction (Rt.: not done)
10	61, F		Rt.	No stenosis	Rt. LS obstruction Lt. NLD obstruction	Rt. LS obstruction Lt. NLD obstruction		Rt. NLD stenosis (Lt.: not done)
11	72, M		Lt.	No stenosis	Lt. NLD obstruction	Lt. NLD obstruction		(not done)
12	64, F		Rt.	Rt. CL obstruction	Rt. CL obstruction	Rt. CL obstruction		Rt. NLD obstruction (Lt.: not done)
13	66, F		Rt.	Bilat. CL obstruction	Bilat. CL obstruction	Bilat. CL obstruction	Residual bilat. sac lumen on transverse images	Rt. LS obstruction (Lt.: not done)
14	52, F		Rt.	Rt. LS stenosis	Rt. CL obstruction	Rt. CL obstruction	Rt. LS cyst	Rt. CL obstruction (Lt.: not done)
15	73, F	Rt. DCR	Lt. (mild)	No stenosis	No stenosis	No stenosis		(not done)
16	56, F	Lt. DCR	Rt.	Rt. CL obstruction	Rt. CL obstruction	Rt. CL obstruction	Residual Rt. sac lumen	Rt. CL obstruction (Lt.: not done)
17	73, F		Bilat.	Rt. LS stenosis Lt. CL obstruction	Bilat. NLD slight stenosis	Bilat. NLD slight stenosis		(not done)
18*	79, M		Bilat.	Bilat. NLD obstruction	Rt. NLD obstruction Lt. CL obstruction	Rt. NLD obstruction Lt. CL obstruction	Residual bilat. sac lumen	Bilat. LS obstruction

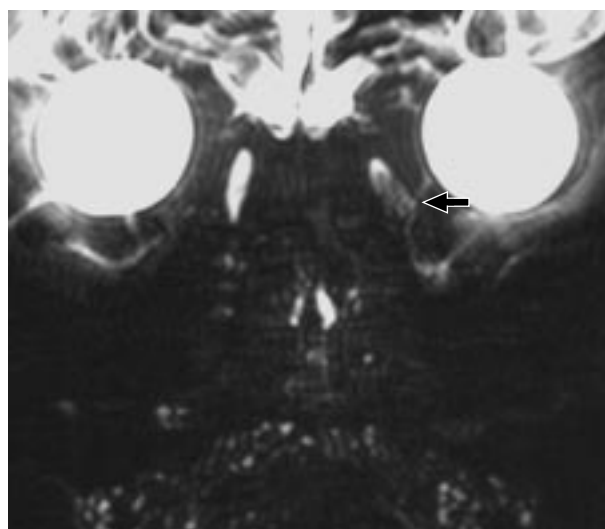
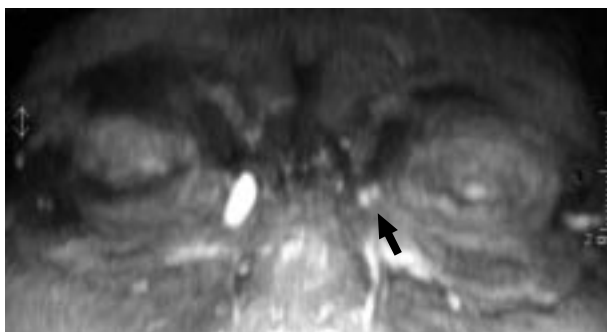
\*: with postoperative deformities of the nasal cavity or orbital cavity, DCR: dacryocystorhinostomy, SI: silicone intubation, LS: lacrimal sac, NLD: nasolacrimal duct, CL: canaliculus, CDG: conventional cannulation dacryocystography, MRD: magnetic resonance dacryocystography, T2WPI: T2-weighted projected image, FFE-MIP: maximum intensity projection image of 3D T1-weighted fast field echo sequence.

the narrower lumen of the caudal nasolacrimal duct or to be caused by an increase in the viscosity of intraluminal fluid.<sup>14</sup>

In our clinical study, the sites of obstructions or

**Table 3. Results of clinical study (symptom vs. MRD findings or CDG findings)**

	MRD	CDG
Symptom	32/36 systems	15/17 systems
(epiphora)	14/18 patients	13/14 patients



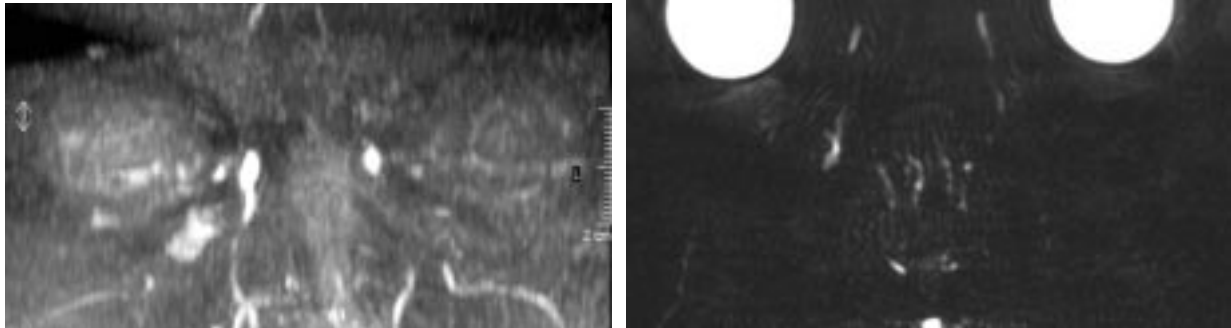
a	b
c	

**Fig. 3.** Case 5. A 74-year-old woman with left epiphora.  
**a:** FFE-MIP image with topical administration of the diluted Gd-DTPA solution showing obstruction of the left lacrimal sac (arrow).  
**b:** T2-weighted projected image with topical administration of the saline solution showing obstruction of the left lacrimal sac (arrow).  
**c:** Conventional dacryocystogram of the left lacrimal drainage system. The findings are similar to those of the FFE-MIP image.



**Fig. 4.** Case 6. A 66-year-old woman with bilateral epiphora.  
**a:** Conventional dacryocystogram showing long segment stenosis of the bilateral lacrimal drainage system.  
**b:** T2-weighted transverse image with topical administration of saline solution showing bilateral mucosal thickening with low signal intensity (arrows). These findings suggest mucosal fibrous thickenings.

a	b
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**Fig. 5.** Case 11. A 72-year-old man with left epiphora.

**a:** FFE-MIP image with topical administration of the diluted Gd-DTPA solution showing obstruction of the left lacrimal sac. **a** | **b**

**b:** T2-weighted projected image showing no obvious stenosis.

His symptoms disappeared after several irrigation therapies. This suggests that visualization of the residual caudal lumen on T2-weighted projected images may predict the effectiveness of conservative therapies.

stenoses of lacrimal sacs and nasolacrimal ducts were more clearly determined on Gd solution-enhanced FFE-MIP images than on saline solution-enhanced T2WPIs when compared with the CDG findings. However, saline solution-enhanced T2WPIs and thin slice transverse T2-weighted images can be a less invasive, less expensive screening test for slight and functional stenoses. They can also provide information useful for therapy, such as the condition of the mucosa, lumen, collected fluid, volume of residual sac, and anatomical relationship to surrounding tissues without topical or intravenous administration of contrast medium. MRD using intravenous administration of contrast medium has been reported to provide useful information on the mucosa.<sup>5</sup> In this study, we found that T2-weighted transverse images provide enough information on the mucosa for patient management without the need for costly intravenous administration of contrast medium. Moreover, the ability to visualize the residual caudal lumen of an obstructed or narrowed site may make it possible to predict the effectiveness of conservative therapies, such as irrigation therapy, as seen in our cases 1 and 11. Therefore, we recommend a combination of topical Gd solution-enhanced MRD and saline solution-enhanced MRD to obtain detailed information on the lacrimal drainage apparatus.

One disadvantage of saline solution-enhanced T2WPIs is that the high viscosity of intraluminal fluid can interfere with visualization of the lumen.<sup>14</sup> This

phenomenon is caused by the long echo time of this sequence. In diagnosing MRD images, the discrepancy of findings on T2WPIs and FFE-MIP images suggests the occurrence of this phenomenon. In making an analysis, the patient's symptoms and history must be considered, and the echo time may need to be adjusted for each patient's condition. Another problem is that this hydrographic technique visualizes the administered saline solution as well as tears and collecting fluid. In some cases, both topical Gd solution-enhanced MRD and saline solution-enhanced MRD are needed to obtain precise information because the former method visualizes only the administered contrast medium. A problem of the Gd-enhanced FFE-MIP images is their sensitivity to inhomogeneity in the magnetic field, which is a characteristic of gradient echo sequences. Severe deformity of the structures surrounding the lacrimal drainage apparatus may damage image quality. Additional T1-weighted spin echo sequences may help in such cases.

The MRD findings were consistent with the CDG findings for only eight drainage systems in seven of the 14 patients. MRD can be performed under physiological conditions without any pressure caused by injection of contrast material. This adds MRD functional information. However, MRD has a lower spatial resolution than CDG. The limited spatial resolution of MRD and the absence of pressure can result in the overexpression of stenosis and make the findings on

MRD images different from those on CDG images. For example, stenosis of the long segment could appear as an obstruction on MRD. In one clinical case, severe long-segment stenosis of the lacrimal sac extending to the nasolacrimal duct (case 8) was mistaken for an obstruction of the canaliculus. This overestimation of stenosis is not so serious when using conventional methods such as DCR to care for a patient. However, when precise information including the length of stenosis and degree of narrowing is necessary in order to plan for dacryocystoplasty or nasolacrimal stenting, a topical contrast-enhanced MRD diagnosis by itself may not be sufficient. Canulation MRD using saline solution or contrast material may resolve this problem.

In conclusion, topical contrast-enhanced MRD provided a simple, non-invasive means of obtaining detailed morphological and functional information on the lacrimal drainage apparatus, and it could be an examination of first choice for patients with lacrimal outflow disorders.

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