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HEAD, NECK AND DENTAL RADIOLOGY

MR dacryocystography: comparison with dacryoendoscopy in positional diagnosis of nasolacrimal duct obstruction

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Abstract
Purpose To compare the findings of MR dacryocystography with those of dacryoendoscopy and subsequent surgery in patients with nasolacrimal duct obstruction, and to determine the efficacy of MR dacryocystography in the positional diagnosis of nasolacrimal duct obstruction.
Materials and methods Thirty-one patients with clinically suspected nasolacrimal duct obstruction who underwent MR dacryocystography and dacryoendoscopy with subsequent surgical procedure were included. MR dacryocystography was performed by using heavily T2-weighted fast spin echo sequence in the coronal and axial planes after the topical administration of normal saline drops into the conjunctival sacs.
Results In MR dacryocystography, stenosis/obstruction at the canalicular level was correctly diagnosed in nine patients (100 %). Stenosis/obstruction at the lacrimal sac level was correctly diagnosed in 14 of 16 patients (87.5 %) in MR dacryocystography. Three patients with coexistent stenosis/obstruction at both the canalicular and the lacrimal sac level were misinterpreted as stenosis/obstruction at the canalicular level on MR dacryocystography. The overall accuracy of MR dacryocystography in depicting stenosis/obstruction was 84 %.
Conclusions MR dacryocystography after the topical administration of normal saline drops into the conjunctival sacs is a well-tolerated, minimally invasive imaging technique to identify the level of stenosis/obstruction in patients with nasolacrimal duct obstruction before dacryoendoscopy and subsequent surgery.

Keywords MR dacryocystography · Nasolacrimal duct obstruction · Heavily T2-weighted fast spin echo · Epiphora · Normal saline

Introduction

Nasolacrimal duct obstruction is a common ophthalmic problem, causing epiphora and eye discharge. Most primary acquired obstructions are due to idiopathic inflammation, fibrosis, and scarring of the nasolacrimal duct [1], and obstruction can occur at any level along the lacrimal drainage: punctum, canaliculus, sac, nasolacrimal duct, or nasal ostium. To select the proper surgical procedure, it is important to know the etiology and location (so called "positional diagnosis" [2]) of the obstruction. However, in the assessment of the nasolacrimal duct, it is often difficult to objectively determine the precise position and degree of stenosis/obstruction. Assessment of nasolacrimal duct obstruction had been primarily conducted by dacryocystography as the conventional radiographic imaging technique [3], and followingly conducted by CT dacryocystography with topical instillation of contrast material [4]. Recently, MR dacryocystography with or without diluted gadolinium contrast agents has been developed [3, 5]. Since MR dacryocystography does not require cannulation, ionizing radiation and chemical contrast media with high viscosity, some studies showed that MR dacryocystography was an easily and safely performed imaging technique to identify the presence or absence of obstruction and its level, compared with conventional dacryocystography and CT

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dacryocystography [3, 6–9]. More recently, dacryoendoscopy [2, 10–12] has been developed that allows direct visualization of the internal condition of the lacrimal passage, and has been reported to be a useful technique to directly diagnose the site of obstruction with accuracy in nasolacrimal duct obstruction. In this study, we aimed to compare the findings of MR dacryocystography with those of dacryoendoscopy and subsequent surgery in patients with nasolacrimal duct obstruction and to determine the efficacy of MR dacryocystography in the positional diagnosis of nasolacrimal duct obstruction.

Materials and methods

Study population

This retrospective study was approved by our institutional review board, and the requirement for informed consent was waived. From July 2004 to July 2008, 31 patients (13 men and 18 women; mean age 64.6 years; range 38–84 years) with clinically suspected nasolacrimal duct obstruction underwent MR dacryocystography, and were included in this study. After MR dacryocystography, dacryoendoscopy accompanied by subsequent surgical procedure was performed in all patients. Patients with nasolacrimal duct obstruction related to neoplasms and previous dacryocystorhinostomy were excluded from this study.

MR imaging technique

MR imaging was performed using a 1.5-T superconducting MR scanner (Signa Excite High speed; General Electric, Milwaukee, WI, USA). A body coil was used for signal excitation, with a 5-in diameter rounded surface coil for signal reception. Before the MR scanning, eyedrops using a sterile 0.9 % NaCl solution were applied into the conjunctival sac of both eyes of each patient (two drops/min per eye over a duration of 5 min) while the patient were in spine position. Immediately after final eye drop, MR dacryocystography was performed by heavily T2-weighted fast spin echo sequence in the coronal and axial planes using the following parameters; TR/TE = 8000/255–258 ms, band width (BW) = 20.83 kHz, signal averages = 3, field of view = 15 × 15 cm, slice thickness = 3 mm, interslice gap = 0.5 mm, matrix = 256 × 192. Additional MR imaging sequences included axial T1-weighted (TR/TE = 550/12.4 ms, BW = 15.53 kHz, signal averages = 2) and T2-weighted (TR/TE = 4000/102 ms, BW = 20.83 kHz, signal averages = 3) fast spin echo sequences (field of view = 15 × 15 cm, slice thickness = 3 mm, interslice gap = 0.5 mm, matrix = 256 × 192), and coronal T2-weighted half-Fourier single-shot fast spin echo sequence (TR/TE = 3139/1295 ms, BW = 20.83 kHz, signal averages = 3, field of view = 16 × 16 cm, slice thickness = 4 mm, interslice gap = gapless, matrix = 256 × 192). All images excluding T1-weighted images were performed with a fat saturation technique. Overall MR imaging time was less 25 min.

Image analysis

MR dacryocystography was reviewed independently by two radiologists who were blinded to any clinical information of the subjects, and was evaluated for the detection of obstructed points in the nasolacrimal drainage system according to three levels (canaliculus, lacrimal sac and nasolacrimal duct). The positional diagnosis of stenosis/obstruction was determined on the basis of the following MR dacryocystographic criteria. Stenosis or obstruction at the canalicular level was assumed, when fluid was not observed in the lacrimal sac and nasolacrimal duct (Fig. 1). Stenosis or obstruction at the level of the lacrimal sac was assumed when there was incomplete or complete filling of the sac with or without sac dilatation, with no filling of the nasolacrimal duct (Fig. 2). Stenosis or obstruction at the level of the nasolacrimal duct or nasal ostium was assumed when the dilated sac filled with fluid normally, and there was proximal or entire filling of the nasolacrimal duct (Fig. 3). Axial and coronal heavy T2-weighted MR images were complementary in interpretation. The findings of MR dacryocystography were compared with those of dacryoendoscopy and subsequent surgery for the positional diagnosis of nasolacrimal duct obstruction. Dacryoendoscopy with a probe diameter of 0.9 mm (RF-950; Fiber Tech Co. Ltd, Tokyo, Japan) using a charge couple device (CCD) imaging system (FT-201; Fiber Tech Co. Ltd, Tokyo, Japan) and subsequent surgery were performed by an experienced ophthalmologist, and the intraoperative findings were carefully recorded.

Statistical analysis

Interobserver agreement of obstructed points in the nasolacrimal drainage system between the two radiologists was also evaluated by using weighted κ statistics. κ values were interpreted as follows: less than 0.20 indicates poor agreement, 0.21–0.40 indicates fair agreement, 0.41–0.60 indicates moderate agreement, 0.61–0.80 indicates good agreement, and 0.80 or higher indicates excellent agreement. Statistical analyses were performed using SPSS for Windows version 22.0 software (SPSS, Chicago, IL). $P < 0.05$ was considered statistically significant.

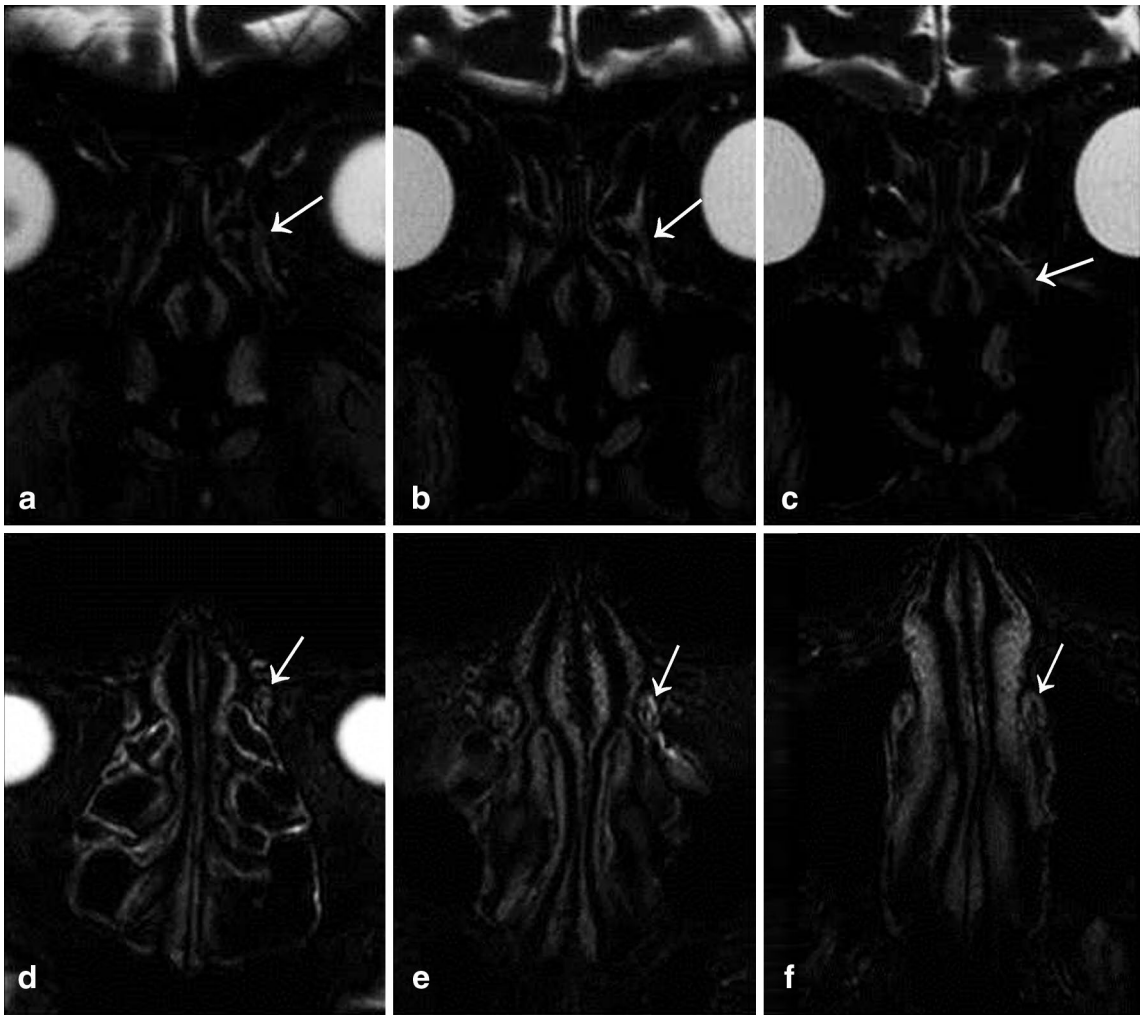

Fig. 1 Patient with obstruction at the left canalicular level confirmed by dacryoendoscopy and subsequent surgery. **a**–**c** Consecutive coronal MR dacryocystography. **d**–**f** Axial MR dacryocystography corresponding to the level indicated by *arrow* in **a**–**c**. Coronal and axial MR dacryocystography show no fluid in the lacrimal sac (*arrows* in **a**, **b**, **d** and **e**) and nasolacrimal duct (*arrows* in **c** and **f**). Dilatation of the lacrimal sac is not seen

Results

Stenosis/obstruction was confirmed on dacryoendoscopy in all 31 patients. Stenosis/obstruction involved at the canalicular level in 9 patients, at the lacrimal sac level in 16, at both the canalicular and the lacrimal sac level in 3, and at the nasolacrimal duct or nasal ostium level in 3 patients (Table 1). In MR examination, there were no complications during the study procedures in all patients. None of the subjects reported any discomfort due to the topical administration of drops of sterile saline solution. Analysis of inter-observer agreement between the two reviewers regarding the obstructed points in the nasolacrimal drainage system using MR dacryocystography demonstrated a κ value of 0.951, indicating excellent agreement. Hence, the results of the final MR images consensus review were used for data analysis. The results of comparison of positional diagnosis between MR dacryocystography and dacryoendoscopy are summarized in Table 2. In MR dacryocystography, stenosis/obstruction at the canalicular level was correctly diagnosed in nine patients (100 %) based on the finding of no fluid in the lacrimal sac and nasolacrimal duct. Regarding stenosis/obstruction at the lacrimal sac level, 14 (87.5 %) of 16 patients were correctly diagnosed in MR dacryocystography while there were discrepancies between MR dacryocystography and dacryoendoscopy in the assessment of stenosis/obstruction sites in the remaining two of 16 patients. In these two patients, stenosis/obstruction was assumed to be at the nasolacrimal duct or nasal ostium level on MR dacryocystography, whereas stenosis/obstruction was seen at the lacrimal sac level on dacryoendoscopy. In three patients with coexistent stenosis/obstruction at

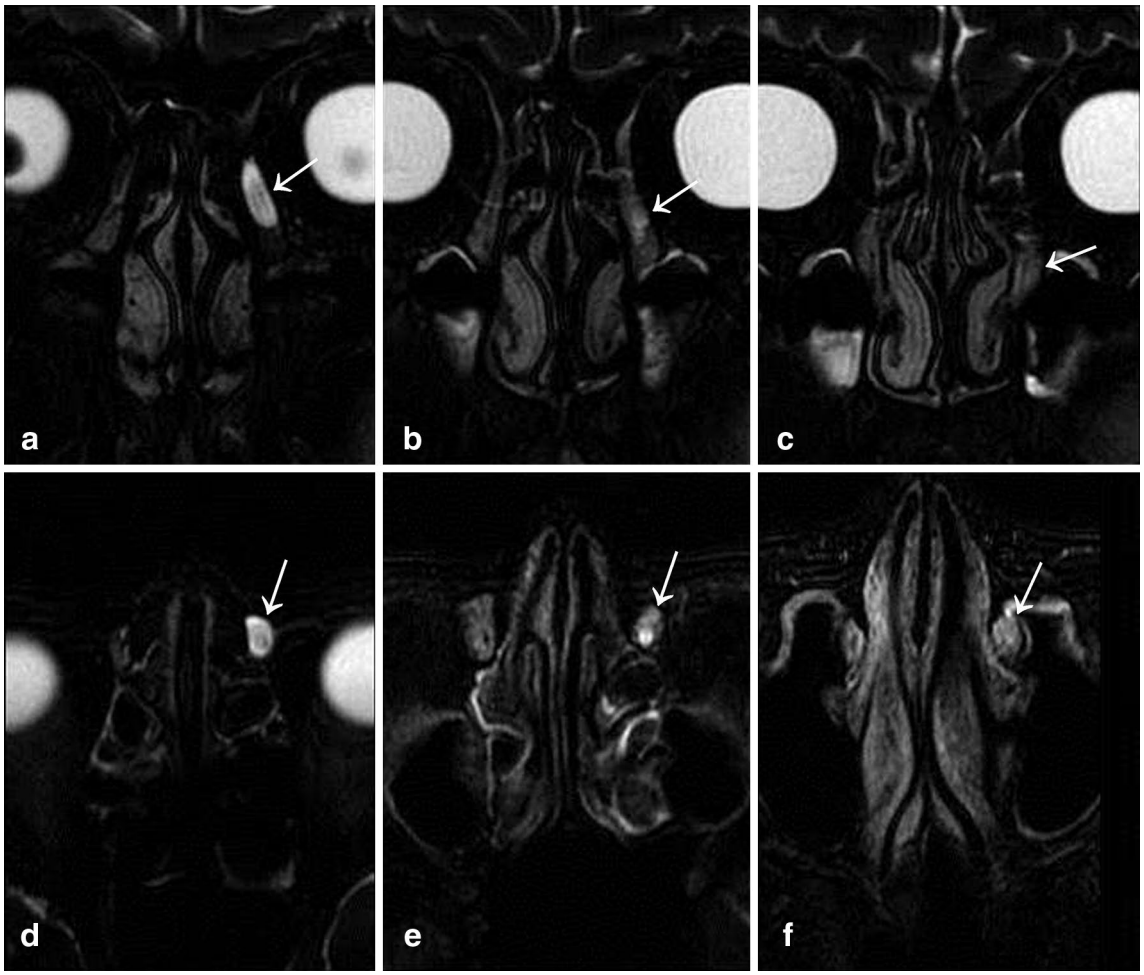

Fig. 2 Patient with obstruction at the level of the left lacrimal sac confirmed by dacryoendoscopy and subsequent surgery. **a**–**c** Consecutive coronal MR dacryocystography. **d**–**f** Axial MR dacryocystography corresponding to the level indicated by *arrow* in **a**–**c**. Coronal and axial MR dacryocystography show incomplete filling of fluid in the dilated sac (*arrows* in **a**, **b**, **d** and **e**), with no filling of the nasolacrimal duct (*arrows* in **c** and **f**). Thickened mucosa of the nasolacrimal duct with intermediate signal can be observed

both the canalicular and the lacrimal sac level on dacryoendoscopy, all three patients were misinterpreted as stenosis/obstruction at the canalicular level on MR dacryocystography. In these three patients, fluid was not observed in the lacrimal sac and nasolacrimal duct, probably due to coexistent stenosis/obstruction at the canalicular level proximal to the lacrimal sac. Stenosis/obstruction at the nasolacrimal duct or nasal ostium level was correctly diagnosed in three patients (100 %). The overall accuracy of MR dacryocystography in depicting the stenosis/obstruction in nasolacrimal system was 84 %.

Discussion

Dacryoendoscopy can directly visualize the lacrimal drainage system, and correctly diagnose the location of the obstruction preoperatively in patients with nasolacrimal duct obstruction, and therefore, can provide useful information for the subsequent endoscopy-guided surgical procedures [2, 10, 12–15]. However, before performing dacryoendoscopy, it would be more helpful if the positional diagnosis of nasolacrimal duct obstruction can be made by noninvasive imaging methods. Several studies have reported that MR dacryocystography provided detailed information about the nasolacrimal system without risks associated with cannulation, and could be a useful method for depicting nasolacrimal duct obstruction [5, 8, 9, 16]. However, there has been no report directly comparing the diagnostic performance in nasolacrimal duct obstruction between MR dacryocystography and dacryoendoscopy. In this study, MR dacryocystography can correctly depict the stenosis/obstruction in nasolacrimal system in 26 (84 %) of 31 patients who were confirmed by preoperative dacryoendoscopy. The combination use of axial and coronal MR

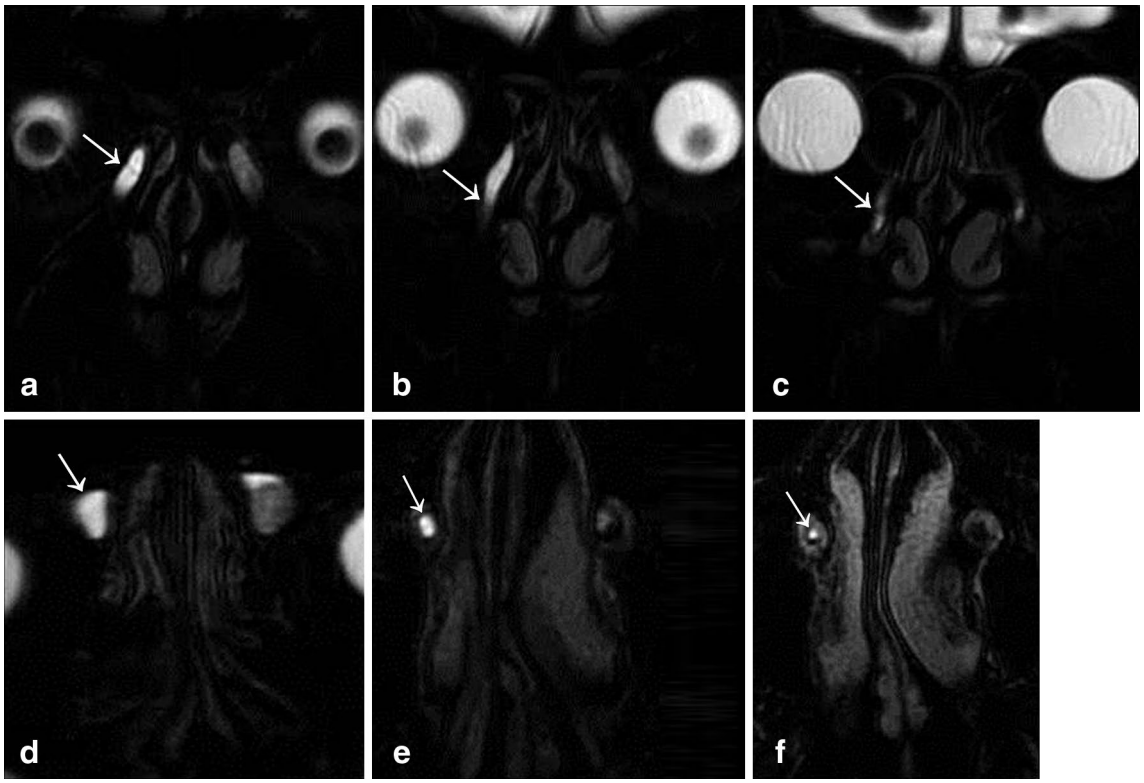

Fig. 3 Patient with obstruction at the level of the right nasal ostium confirmed by dacryoendoscopy and subsequent surgery. **a–c** Consecutive coronal MR dacryocystography. **d–f** Axial MR dacryocystography corresponding to the level indicated by *arrow* in **a–c**. Coronal and axial MR dacryocystography show the dilated sac filled with fluid normally (*arrows* in **a**, **d**), with the filling of the nasolacrimal duct (*arrows* in **b**, **c**, **e** and **f**)

Table 1 Stenosis/obstruction level of nasolacrimal duct obstruction on dacryoendoscopy in all 31 patients

Stenosis/obstruction level	Number of patients
Canalicular level	9
Lacrimal sac level	16
Both canalicular and lacrimal sac level	3
Nasolacrimal duct or nasal ostium level	3

dacryocystographic images allowed detailed assessment of luminal changes.

There are three locations of physiologic narrowing in the nasolacrimal duct system [8]. These included the junction between the common canaliculus and lacrimal sac, the neck of the sac, and the opening into the nasal cavity. Acute or chronic inflammation in the nasolacrimal duct persists in periductal tissue, and physiologically narrow regions of ducts have the possibility to adhere. Therefore, these regions are likely to cause severe stenosis or obstruction. In this study, dacryoendoscopy with subsequent surgery revealed that a total of 19 (61 %) of 31 patients with nasolacrimal duct obstruction had stenosis/obstruction at the level of the lacrimal sac (16 = lacrimal sac only, and 3 = both the canalicular and the lacminal sac), suggesting a common condition in nasolacrimal duct obstruction. In these 16 patients with stenosis/obstruction at the level of the lacrimal sac only, 14 patients were correctly diagnosed in MR dacryocystography, whereas, stenosis/obstruction was assumed to be at the level of the nasolacrimal duct or nasal ostium in the other two patients. This misinterpretation may be due to retained fluid collection of thickened mucus in the nasolacrimal duct. Otherwise, these two patients had stenosis at the level of the lacrimal sac, but did not have complete obstruction, showing administered saline fluids flowed into the nasolacrimal duct. Additionally, all three patients with coexistent stenosis/obstruction at both the canalicular and the lacrimal sac level were misinterpreted as stenosis/obstruction at the canalicular level on MR dacryocystography. Since stenosis/obstruction at the lacrimal sac level occurs most frequently, it will be important to consider that stenosis/obstruction in the lacrimal sac level may coexist when the obstruction in canalicular level was seen.

MR dacryocystography has some advantages over digital dacryocystography and CT dacryocystography. MR

Table 2 Comparison of stenosis/obstruction level of nasolacrimal duct obstruction between MR dacryocystography and dacryoendoscopy in all 31 patients

Patient	Fluid in lacrimal sac	Fluid in nasolacrimal duct	MR dacryocystography	Dacryoendoscopy	Concordance of both studies
1	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
2	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
3	Presence	Presence	Nasolacrimal duct	Nasolacrimal duct	Yes
4	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
5	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
6	Presence	Presence	Nasolacrimal duct	Nasolacrimal duct	Yes
7	Absence	Absence	Canaliculus	Both canalicular and lacrimal sac level	No
8	Absence	Absence	Canaliculus	Canaliculus	Yes
9	Absence	Absence	Canaliculus	Canaliculus	Yes
10	Absence	Absence	Canaliculus	Canaliculus	Yes
11	Absence	Absence	Canaliculus	Canaliculus	Yes
12	Absence	Absence	Canaliculus	Both canalicular and lacrimal sac level	No
13	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
14	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
15	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
16	Presence	Presence	Nasolacrimal duct	Lacrimal sac	No
17	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
18	Presence	Presence	Nasolacrimal duct	Lacrimal sac	No
19	Absence	Absence	Canaliculus	Canaliculus	Yes
20	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
21	Absence	Absence	Canaliculus	Canaliculus	Yes
22	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
23	Absence	Absence	Canaliculus	Canaliculus	Yes
24	Absence	Absence	Canaliculus	Canaliculus	Yes
25	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
26	Presence	Presence	Nasolacrimal duct	Nasolacrimal duct	Yes
27	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
28	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
29	Presence	Absence	Lacrimal sac	Lacrimal sac	Yes
30	Absence	Absence	Canaliculus	Canaliculus	Yes
31	Absence	Absence	Canaliculus	Both canalicular and lacrimal sac level	No

dacryocystography uses no ionizing radiation that focuses on the lenses of the eyes, and requires no local anesthesia, no cannulation of the punctum, and no injection of viscous contrast media, and has no risk of iatrogenic trauma on the punctum. In this study, MR dacryocystography was performed by using the topical administration of normal saline drops into the conjunctival sacs although some previous studies have performed MR dacryocystography with the use of diluted gadolinium contrast medium, which is an off-label use for MR dacryocystography [5, 7, 16–19]. We preferred saline solution because, as compared to gadolinium contrast medium, the saline solution has a lower viscosity, and therefore, causes less irritation in the mucosal structures. Different from gadolinium contrast medium, the saline solution has no risk of allergy. In this study, the topical administration of normal saline drops did not cause any local or systemic side effects and the patients did not report any discomfort. Additionally, topical administration of normal saline drops may allow a more physiologic examination, compared with the use of diluted gadolinium contrast medium with relatively high viscosity. Regarding image quality, one study has compared topical applications of saline solution and gadolinium solution [20], and reported that the images obtained after the application of the gadolinium solution had artifacts caused by the susceptibility effect, compared with those obtained after the application of the saline solution.

Furthermore, MR dacryocystography has some advantages over dacryoendoscopy. At first, the examination time in MR dacryocystography is shorter than that of dacryoendoscopy. Second, because MR dacryocystography requires no local anesthesia and no cannulation of the endoscopy, the patient discomfort is extremely low. Finally, MR dacryocystography needs experienced ophthalmologist and specific endoscopic device. Accordingly, for the positional diagnosis of nasolacrimal duct obstruction, MR dacryocystography may be replaced for dacryoendoscopy.

One limitation of this study was that it was retrospective in nature, and the number of patients was limited. Another limitation was that MR dacryocystography did not provide information concerning soft and bony tissue around the lacrimal sac and nasolacrimal duct. It is, therefore, crucial to obtain additional imaging sequences to demonstrate the surrounding soft tissues. When combined with T1- and T2-weighted fast spin echo sequences, MR allows anatomic imaging of extraductal soft tissues and neoplastic lesions within the lacrimal system although this evaluation was not pursued in this study. Final limitation was that MR dacryocystography before the topical administration of normal saline drops was not performed to reduce the total examination time in this study. It will be important to compare the images obtained before and after the administration of normal saline drops to differentiate the chronically retained fluid collection in the lacrimal duct system from administered saline solutions. Further studies comparing images before and after the administration of normal saline drops will be necessary to validate the diagnostic role of MR dacryocystography.

In conclusions, MR dacryocystography after the topical administration of normal saline drops into the conjunctival sacs is a well-tolerated, minimally invasive imaging technique to identify the level of stenosis/obstruction in patients with nasolacrimal duct obstruction, and could be used as a reliable preoperative method prior to dacryoendoscopy and subsequent surgery.

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Compliance with ethical standards

Conflict of interest Hiroki Higashi declares that he has no conflict of interest. Tsutomu Tamada declares that he has no conflict of interest. Kenichi Mizukawa declares that he has no conflict of interest. Katsuyoshi Ito declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent This retrospective study was approved by our institutional review board, and the requirement for informed consent was waived.

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