MRI Evaluation of Lacrimal Drainage After External and Endonasal Dacryocystorhinostomy

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Purpose: External and endonasal dacryocystorhinostomy (EX-DCR and EN-DCR, respectively) affect the tear drainage mechanism. This study evaluates the preservation of "lacrimal pump" function in both procedures.

Methods: Cases of successful EN-DCR (4 patients) and EX-DCR (4 patients) were included. All patients underwent MRI of the rhinostomy areas, at least 6 months postoperatively. The vertical diameter of rhinostomy (both osseous and soft-tissue apertures) was measured in T_1-oriented images, whereas the signal intensity levels were examined for 3 regions of interest (ROIs) in T_2-oriented (true fast imaging steady state pulse) images with instillation of normal saline to the conjunctival fornices, both before and after blinking (activation of the "lacrimal pump"). ROI 1 corresponded to the globe (control), ROI 2 corresponded to the inferior conjunctival fornix, and ROI 3 corresponded to the rhinostomy site.

Results: Signal intensity in ROI 3 (rhinostomy) was significantly increased after blinking in both EX-DCR and EN-DCR cases. The increase was significantly higher in the latter. Signal intensity changes in ROI 3 were significantly correlated with rhinostomy size in both groups, whereas the respective correlations with the postoperative interval were not statistically significant.

Conclusions: Findings imply that the "lacrimal pump" is active following DCR and may be better preserved in the EN-DCR than in the EX-DCR group. Persistent epiphora after patent DCR may thus be attributed to a defective "pump" function and treated accordingly.

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Lacrimal drainage relies on several factors, including gravity, capillary attraction forces, and the "lacrimal pump."[1,2] Various mechanisms have been proposed for the latter, including the action of the deep part of orbicularis oculi (Horner) muscle on the lacrimal sac, which causes expansion of the sac and creation of negative pressure or the elastic expansion of the lacrimal papillae on opening of the eyelids.[1–3] Patients with defective "pump" mechanisms may show decreased tear flow even after successful dacryocystorhinostomy (DCR).[4] DCR aims at establishing a direct communication between the upper part of the lacrimal drainage apparatus (lacrimal sac) and the nasal cavity, thus transforming the tricompartmental route of lacrimal drainage (conjunctival fornices and lacrimal canaliculi, lacrimal sac, nasal cavity) into a bicompartmental one (conjunctival fornices and lacrimal canaliculi, unified space of lacrimal sac and nasal cavity).[5] Previous studies have shown that DCR-induced changes affect the mechanism of tear drainage.[4] The fact that the external approach, in contrast to the endonasal one, potentially affects the medial canthal tendon area and includes incision of the orbicularis oculi fibers locally implies that the action of the "lacrimal pump" may differ postoperatively between the 2 techniques.[6]

MRI is a noninvasive technique extensively used in the study of ocular and orbital tissues.[7,8] Previous studies have used MRI to examine lacrimal flow dynamics in the nasolacrimal duct.[3] This study uses MRI for the evaluation of lacrimal flow after successful external DCR (EX-DCR) or endonasal DCR (EN-DCR). Results could prove useful in understanding the role of the "lacrimal pump" after DCR and associated differences between the external and the endonasal approaches.

METHODS

This is a retrospective, nonrandomized case series. Eight adult patients who suffered in the past from postsaccal-acquired nasolacrimal duct obstruction without canalicular stenosis and who had undergone successful EX-DCR (4 cases) or successful EN-DCR (4 cases) were included. Success was defined as the subjective discontinuation of both mucopurulent and watery discharge and patency on irrigation. Patients were recruited from the Department of Ophthalmology (external cases) and the Department of Ear, Nose, and Throat (ENT) Surgery (endonasal cases) of the University Hospital of Heraklion, Crete, Greece. All patients had undergone surgery at least 6 months before recruitment to allow for complete resolution of postoperative inflammation. The demographic and clinical information of patients studied, including age, gender, postoperative interval, and technique, are presented in Table 1. None of the patients of either the EX-DCR or EN-DCR group had been diagnosed with eyelid disorders potentially resulting in epiphora, such as eyelid laxity, ectropion, or entropion. All patients signed a written informed consent form in accordance with the tenets of the Declaration of Helsinki.

All procedures had been performed under general anesthesia and following pack of the ipsilateral nasal mucosa with xylometazoline and tetracaine. The EX-DCR procedure included an oblique incision of skin and orbicularis 1 cm medial to the medial canthus, identification and detachment of the superficial part of the medial canthal tendon, incision of the periosteum along the anterior lacrimal crest and lateral displacement of the lacrimal sac, removal of the anterior lacrimal crest (with an electric saw), H-shaped incision at the nasal mucosa and lacrimal sac, and suturing of posterior and anterior flaps between the lacrimal sac and nasal mucosa over silicone stents. The superficial part

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TABLE 1. Demographic and clinical information of patients studied

Patient	Age (years)	Gender	Technique	Postoperative interval (months)
1	75	Female	EX-DCR	6
2	62	Female	EN-DCR	24
3	54	Female	EN-DCR	17
4	64	Male	EN-DCR	8
5	27	Female	EX-DCR	31
6	56	Male	EX-DCR	19
7	76	Male	EN-DCR	15
8	74	Female	EX-DCR	9

EN-DCR, endonasal dacryocystorhinostomy; EX-DCR, external dacryocystorhinostomy.

of the medial canthal tendon was reattached by sutures before skin closure. For EN-DCR, an incision of the nasal mucosa at the middle meatus was followed by punch-assisted osteotomy and removal of the medial wall of the lacrimal sac. Lacrimal stents were then inserted through the lacrimal canaliculi and ostium. In both EX-DCR and EN-DCR, stents were removed 3 months postoperatively. The age of patients included was 58.0 ± 22.4 years (range, 27–75 years) in the EX-DCR group and 64.0 ± 9.0 years (range, 54–76 years) in the EN-DCR group.

Each patient underwent high-resolution, T_1- and T_2-weighted MRI using a 1.5-T scanner (SonataVision, Siemens Medical Solutions, Erlangen, Germany) following the instillation of normal saline in the conjunctival fornix (every minute for 5 minutes prior to imaging). The osseous rhinostomy aperture was first identified in T_1-oriented coronal images, in which bones are presented with a low-intensity (dark) signal (Fig. 1). The soft-tissue rhinostomy aperture was also identified in T_1-oriented images as a low-intensity (dark) band (corresponding to the aperture) surrounded by higher-intensity (lighter) tissues, corresponding to soft-tissue development (Fig. 1). Lacrimal flow was then assessed with a true fast imaging steady-state pulse[9,10] sequence. Coronal images through the anastomotic site were examined, both before and after repeated opening and closing of the eyelids for 1 minute to activate the "lacrimal pump." Images were obtained at 2-mm thickness using a 512 × 448 matrix over a 10 × 11.6-cm field of view. Digital Imaging and Communications in Medicine images were analyzed with the eFilm workstation (eFilm Medical Inc, Toronto, Ontario, Canada) and the EvoRAd RIS-PACS workstation (EvoRAd Medical Information Systems, Heraklion, Crete, Greece). In cases of images with motion or other artifacts, scans were repeated until images free from degradation and eligible for quantitative assessment were obtained for all patients.

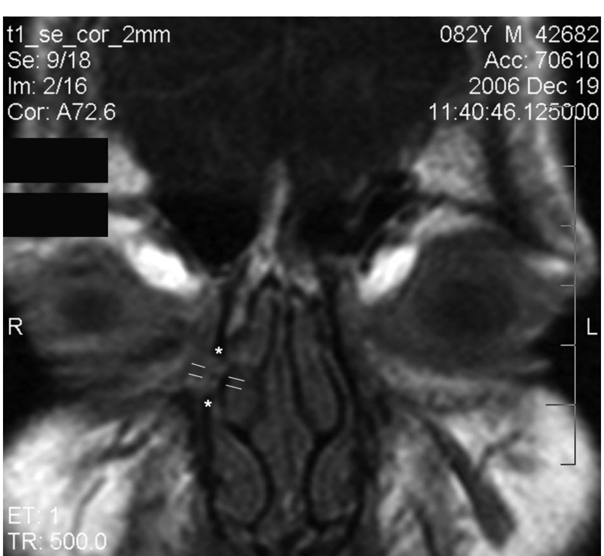

FIG. 1. T_1-oriented coronal image through the rhinostomy site of a patient after external dacryocystorhinostomy. The borders of osteotomy (osseous aperture) are marked with "*." The patent part of the rhinostomy (soft-tissue aperture) is marked with white parallel lines on each side of the nasal bone.

The vertical diameter of both osseous and soft-tissue apertures was measured in T_1-oriented coronal images (Fig. 1). Signal intensity at 3 regions of interest (ROIs) was measured in coronal true fast imaging steady-state pulse images corresponding to the rhinostomy before and after repeated blinking for 1 minute (Figs. 2 and 3). The first ROI (ROI 1) included the visible portion of the globe and was used as a control. The second ROI (ROI 2) was a rectangle of 15 × 15 mm with its superior side tangential to the inferior edge of the globe and its medial side adjacent to the medial edge of the globe (corresponding to the inferomedial conjunctival fornix), whereas the third ROI (ROI 3) was a rectangle of 15 × 15 mm with its lateral side adjacent to the medial side of ROI 2 (corresponding to the canaliculi and anastomotic region). In all cases, the borders of each ROI were manually delineated (at coronal images corresponding to the rhinostomy site) using the ellipse and polygonal measurement tools of the EvoRAd RIS-PACS workstation. Signal intensity was recorded in each ROI using raw data (EvoRAd Medical Information Systems). Differences in signal intensity at all ROIs between preblinking and postblinking intervals were examined (paired-samples t-test) and correlated with the surgical method used (EN-DCR or EX-DCR). Furthermore, correlations between the rhinostomy size or the patients' age and the difference in signal intensity between preblinking and postblinking intervals were also examined (Pearson bivariate correlation coefficient). Statistical analysis of the findings was performed using SPSS 8.0 (SPSS, Chicago, IL, U.S.A.). Statistical significance was set at 0.05.

RESULTS

The vertical diameter of the osseous aperture of rhinostomy (mean ± SD, range) was 1.1 ± 0.2 (0.3–1.2) cm in the EX-DCR group and 1.0 ± 0.3 (0.2–1.1) cm in the EN-DCR group. The respective soft-tissue aperture diameter was 0.7 ± 0.4 (0.4–0.9) cm in the

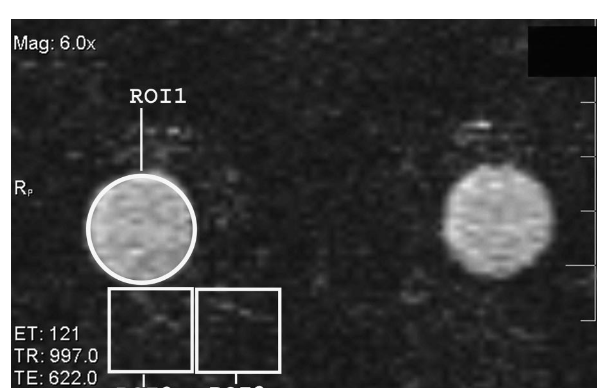

FIG. 2. True fast imaging steady-state pulse (TruFISP) coronal image through the rhinostomy site of a patient following endonasal dacryocystorhinostomy, showing the 3 regions of interest (ROIs) examined (ROI 1 corresponds to the visible part of the globe, ROI 2 is a square of 15 × 15 mm corresponding to the inferior conjunctival fornix, ROI 3 is a square of 15 × 15 mm corresponding to the rhinostomy site and respective middle nasal meatus).

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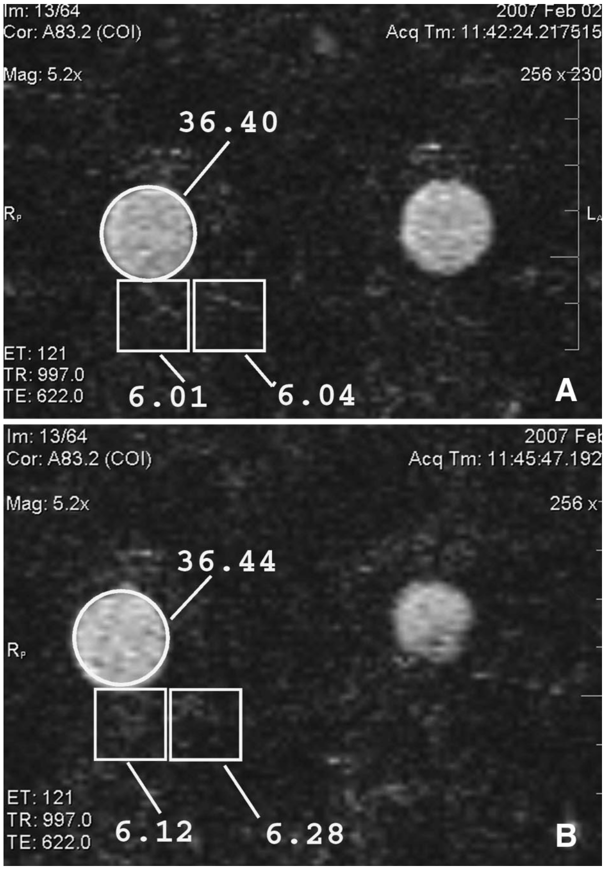

FIG. 3. True fast imaging steady state pulse (TruFISP) coronal images of the same anatomical level (rhinostomy site) of a patient after endonasal dacryocystorhinostomy, before (**A**) and after (**B**) repeated blinking. The mean signal intensity values of the 3 regions of interest (ROIs) examined are shown. Signal intensity at ROI 3 (rhinostomy site and respective middle nasal meatus) is increased following blinking, whereas respective changes at ROIs 1 and 2 are less pronounced.

EX-DCR group and 0.6 ± 0.3 (0.3–0.9) cm in the EN-DCR group. Differences between EN-DCR and EX-DCR were not statistically significant with regard to both osseous and soft-tissue apertures. Signal intensity of ROI 3 increased significantly after blinking in both EX-DCR and EN-DCR cases, whereas respective differences for signal intensity of ROIs 1 and 2 were not statistically significant. Mean signal intensity values of the ROIs examined for external and transnasal cases before and after repeated blinking and statistical significance of the respective differences (paired-samples t-test) are presented in Tables 2 and 3, respectively. The difference in signal intensity of ROI 3 between the preblinking and postblinking intervals was higher in the EN-DCR group (1.09 ± 0.19) than in the EX-DCR group (0.84 ± 0.22). The difference was statistically significant (independent-samples t-test = 3.18, $p = 0.03$). In both groups, the difference in signal intensity of ROI 3 between preblinking and postblinking intervals was significantly correlated with the osseous rhinostomy size (Pearson bivariate correlation coefficient = 0.94, $p = 0.01$ and Pearson bivariate correlation coefficient = 0.96, $p = 0.01$, in EN-DCR and EX-DCR groups, respectively), whereas respective correlations for ROIs 1 and 2 were not statistically significant in both EN-DCR and EX-DCR groups. Furthermore, correlations between changes in signal intensity in all ROIs and the postoperative interval were not statistically significant in both EN-DCR and EX-DCR groups. An inverse correlation between patients' age and the difference in signal intensity of ROI-3 between preblinking and postblinking intervals was also noted in both EN-DCR and EX-DCR groups, although it did not reach statistical significance (Pearson bivariate correlation coefficient). Respective correlations for ROI 1 and ROI 2 were also not statistically significant.

TABLE 2. Mean raw signal intensity values of EX-DCR cases for the ROIs examined before and after repeated blinking (activation of "pump" mechanism) and statistical significance of respective differences (paired samples t-test)

ROI	Before blinking	After blinking	*p*
1	36.81	36.62	0.52
2	5.89	5.95	0.29
3	6.03	6.87	0.04

EX-DCR, external dacryocystorhinostomy; ROI, regions of interest.

TABLE 3. Mean raw signal intensity values of EN-DCR cases for the ROIs examined before and after repeated blinking (activation of "pump" mechanism) and statistical significance of respective differences (paired samples t-test)

ROI	Before blinking	After blinking	*p*
1	36.39	36.45	0.40
2	6.04	6.14	0.18
3	6.01	7.10	0.02

EN-DCR, endonasal dacryocystorhinostomy; ROI, regions of interest.

DISCUSSION

This study evaluated "lacrimal pump" function using MRI after EN-DCR and EX-DCR. Results imply that "lacrimal pump" is active following both procedures, although its function may be better preserved with the former approach.

Various "lacrimal pump" theories have been proposed, all describing an interplay between the individual components of the lacrimal drainage apparatus (canaliculi, superior and inferior lacrimal sac), resulting in movement of tears from the conjunctival to the nasal anatomical compartments.[1–3,11–13] Models of negative or positive lacrimal sac pressure during orbicularis oculi muscle contraction rely on different mechanisms of lacrimal entrance in the sac.[6,12,13] However, irrespective of intrasac pressure changes during blinking, all models point to the importance of orbicularis contraction and relaxation for the effectiveness of tear drainage.[6,12,13] Previous studies have used cine-MRI techniques to evaluate the kinetics of lacrimal drainage in human nasolacrimal ducts, suggesting that fluid travels in the form of a bolus through the sac and that a threshold volume at the lower end of the sac is required to pass through the nasolacrimal duct.[3] This study did not examine lacrimal drainage through the normal pathway (nasolacrimal duct) and did not explore the mechanism of lacrimal drainage during different phases of eyelid movement (orbicularis oculi muscle contraction or relaxation). Instead, it compared the effectiveness of blinking as a tear drainage mechanism between EN-DCR and EX-DCR, by measuring changes in signal intensity (corresponding to water signal) of conjunctival and middle nasal meatus areas (ROIs 2 and 3, respectively) produced by repeated blinking (and thus activation of the "pump" function, irrespective of its exact mechanism). Differences in signal intensity at ROI 3 between EN-DCR and EX-DCR cases could

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possibly be related to differences in the structure of the rhinostomy site between the 2 techniques, causing increased pooling in the EN-DCR ostium, compared with the EX-DCR ostium. However, the fact that EN-DCR cases displayed increased signal intensity (and thus increased water outflow) in ROI 3 following blinking, compared with EX-DCR cases, implies that this technique may preserve the pump features of the lacrimal outflow better than EX-DCR. This may be because various anatomical elements associated with lacrimal outflow, including collagen, elastic, and reticular fibers, and a vascular plexus surrounding the lacrimal sac and nasolacrimal duct may be more severely affected by the surgical manipulations during the external approach than during the endonasal approach, as previously suggested.[14] Furthermore, taking into account that all patients studied had normal eyelids preoperatively, findings imply that severing the superficial part of the medial canthal tendon may affect the lacrimal pump, even in cases where the tendon has been eventually repaired and that external techniques with smaller incisions or preservation of the anterior limb of the canthal tendon may offer better preservation of the lacrimal pump. However, apart from changes on anatomical structures, an external incision may also affect eyelid function through the disruption of orbicularis oculi muscle innervation.[15] Previous studies have suggested that EX-DCR may be followed by lagophthalmos, implying an effect of this approach on eyelid dynamics.[15]

A study using manometric measurements of the lacrimal sac pressure has also concluded that “lacrimal pump” is functional following DCR and that the suction power mechanism may be more effective after EN-DCR than after EX-DCR.[6] However, lacrimal manometry is interventional (includes the insertion of a catheter in the sac through the canaliculi) and thus may not reflect physiologic lacrimal outflow. On the contrary, the instillation of normal saline in the conjunctival fornix used in the present study mimics more accurately normal outflow conditions.[16,17] We did not use gadolinium as a contrast-enhancing agent in the conjunctival sac because the resulting pronounced increase in signal intensity can compromise delineation of fluid flow in the sac, as other studies have also suggested.[3]

Previous studies have reported that the rhinostomy size is generally larger in EX-DCR than in EN-DCR and that the effective size of the anastomotic aperture in both cases is on the average 60% of the osseous aperture because of the local development of scar tissue.[18,19] Findings from this study are in agreement with these reports, although differences between the EN-DCR and EX-DCR groups were not statistically significant. The fact that the difference in signal intensity of ROI 3 between preblinking and postblinking intervals was significantly correlated with the osseous rhinostomy diameter in both EX-DCR and EN-DCR groups probably reflects a more effective passage in enlarged osteotomies. The fact that the respective correlation with the postoperative interval was not statistically significant in both groups implies that the effective size of the anastomotic aperture is established early in the postoperative course. A previous study has also concluded that soft-tissue changes occur mainly during the first 2 postoperative weeks and that further scarring has minimal effects on the rhinostomy size.[18]

The small number of cases and the retrospective design may be considered weak points of this study. On the other hand, the fact that mean age and postoperative interval were similar in both EN-DCR and EX-DCR groups, whereas silicone stents were used for the same time postoperatively in both groups possibly increase the validity of results. Furthermore, the fact that signal intensity at ROI 1 (the globe area used as control) did not differ between preblink and postblink intervals implies that differences in signal intensity detected reflect actual changes in MRI signal intensity. Future research in this area could include patients with persistent post-DCR epiphora despite a patent anastomosis on irrigation. The fact that the “lacrimal pump” is important as a lacrimal drainage mechanism even after DCR implies that in such cases epiphora may possibly be attributed to a defective “lacrimal pump” mechanism. Therefore, such patients could be candidates for alternative procedures aimed at restoring the effectiveness of orbicularis oculi muscle function at the medial canthal area, including horizontal shortening of the lower eyelid or correction of medial canthal tendon laxity.

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