A SIMPLE AND EVOLUTIONAL APPROACH PROVEN TO RE-CANALIZE THE NASOLACRIMAL DUCT OBSTRUCTION
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ABSTRACT

Aim: To evaluate a new approach of re-canalization of nasolacrimal duct obstruction (RC-NLDO) in the treatment of the nasolacrimal duct obstruction (NLDO) and chronic dacryocystitis.

Methods: 583 patients with 641 eyes suffering from NLDO and chronic dacryocystitis were enrolled in this study. The RC-NLDO was performed in 506 eyes, with 135 eyes underwent external dacryocystorhinostomy (EX-DCR) as controls. Patient follow-up for 54 months was evaluated by symptoms, dye disappearance test, lacrimal irrigation and digital subtraction dacryocystogram. The RC-NLDO was also performed in 12 rhesus monkeys for histopathological examination.

Results: The clinical success rates were 93.1% in 506 cases of RC-NLDO, and 91.11% in 135 cases of EX-DCR. The success rates for second surgery were achieved in 85.19% on RC-NLDO and 40.0% on EX-DCR. No major intra- or post-operative complications were observed in the RC-NLDO group. The mean operative duration was 12.5 minutes for RC-NLDO while 40.3 minutes for EX-DCR (P<0.001). Pathological study in rhesus monkeys demonstrated that the RC-NLDO wounded epithelium in nasolacrimal duct healed completely within 1 month without granulation tissue formation.

Conclusion: Our findings demonstrated that the RC-NLDO was a simple and effective approach proven to re-canalize the obstructed nasolacrimal duct with a comparable success rate to EX-DCR.

Abbreviation: RC-NLDO, re-canalization of nasolacrimal duct obstruction; EX-DCR, external dacryocystorhinostomy.

Key Words: nasolacrimal duct obstruction, dacryocystitis, wound healing, epithelium
INTRODUCTION

Nasolacrimal duct obstruction (NLDO) and chronic dacryocystitis are common ophthalmic diseases. The External dacryocystorhinostomy (EX-DCR) has been the most effective and standard surgery in treating these conditions since 1904 when it was reported by Toti.\(^1\) However, EX-DCR is an invasive, relatively complex and time-consuming procedure that causes a facial cutaneous scar. Many patients prefer to suffer tearing rather than undergo this surgery.\(^2\)\(^,\)\(^3\) The improvement on DCR has been made recently, such as the endonasal DCR and endocanalicular laser DCR. These approaches were promising, but still necessitate bone removal and require costly equipment. These surgical procedures were reported to have less effective results than EX-DCR and need a marked learning curve.\(^4\)\(^-\)\(^9\) The approach of the EX-DCR and these new procedures is to create a bypass draining system, rather than to restore the obstructed nasolacrimal duct.

Re-canalization of nasolacrimal duct obstruction (RC-NLDO) was an evolutionally developed surgical approach for treating these conditions to restore the native nasolacrimal duct, using a simple instrument, the Lacrimal Canalizer, which we created in 1994.\(^10\) Since then, this approach has been widely adopted by many ophthalmologists in China for its simplicity, safety, efficacy and minimal invasion.\(^11\)\(^-\)\(^15\) In the present study, we report the long-term follow-up results of RC-NLDO in the clinical treatment for 506 cases of NLDO and chronic dacryocystitis, as well as the histopathological evidence from animal experiments. The relative indication, contraindication, surgical technique, postoperative care, complications, advantages and disadvantages of the RC-NLDO were discussed.
MATERIALS AND METHODS

Patients

This study was adhered to the tenets of the Declaration of Helsinki and was approved by Institutional Review Board (IRB)/Ethics Committee of Zhongshan Ophthalmic Center, Sun Yat-sen University. All cases were chosen from outpatients who were diagnosed with NLDO and/or chronic dacryocystitis. Every patient underwent preoperatively comprehensive ophthalmic and intranasal examination. Dacryocystogram or digital subtraction dacryocystogram was performed in some cases.

A total of 641 eyes of 583 consecutive patients were recruited from July 2003 to June 2006 with their signed informed consent forms, including 135 eyes of 126 patients underwent the EX-DCR and 506 eyes of 457 patients underwent the RC-NLDO. There was no statistical difference of patient demographics between these two groups. The male-to-female ratio was approximately 1:3; the average age was 50 years. The duration of symptoms was ranged from 6 months to 26 years (mean, 5.1 years) in RC-NLDO group and from 6 months to 17 years (mean, 4.7 years) in EX-DCR group.

Instrument used for RC-NLDO

An instrument used for re-canalization of nasolacrimal duct obstruction was Lacrimal Canalizer consisted of a console and its accessories (Figure 1). The console can discharge a power current (50-150 W) with 500 KHz frequency. The high-frequent lacrimal (HFL) probe is made of copper-silver alloy with 1.2mm in diameter and 140mm in length. Its tip is 2.0mm long, smooth, blunt, and naked (without insulating coat on the surface), the features were capable of cauterizing the blocked tissue in nasolacrimal duct.

Surgical Procedures

The EX-DCR was performed under local anesthesia in a standardized fashion.9 The RC-NLDO was performed under local infiltration anesthesia with 2% lidocaine hydrochloride. The inferior nasal meatus was packed with a pledget soaked in 0.5% Alcaine Eye Drops (Alcon, Fort Worth, Texas) and 1% ephedrine hydrochloride solution two times and keeping it in place. The HFL probe was inserted into the nasolacrimal duct until the packed pledget was moving, a clue indicating the probe tip was into the nasal cavity. Then, the electrocautery was performed during the time when the probe had been pulling back in a slowly retrograde way. The blocked tissue in nasolacrimal duct was easily cauterized by the energy and became a charred crust tube. The cautery was stopped when probe was near out of the nasolacrimal duct. The HFL probe was then re-inserted into the nasolacrimal duct to check any remaining obstruction. If there was a resistance, the electrocautery procedure was repeated until the HFL probe passed freely and smoothly through the nasolacrimal duct. The lacrimal drainage system was then irrigated with antibiotic solution.

Postoperative Care

All patients were prescribed the topical antibiotic eye drops and a nasal mucosa astringent 4 times a day for 10 days. The lacrimal passage was irrigated with antibiotic solution weekly in the first half month after surgery. Postoperative evaluation and long term follow-up were performed by the same doctors.

Criteria Defining the Clinical Effects

Clinical success was defined with the results of dye disappearance test, lacrimal irrigation and symptoms. The “full success” was scored if the fluorescent stain was positive in 5 minutes, indicating the free nasolacrimal passage, and the symptoms were completely resolved. The lacrimal irrigation was performed if no fluorescent stain was found, or the stain was found in longer than 10 minutes.
The “partial success” was scored if the pledget was stained with fluorescein after lacrimal irrigation and there was no reflux. The “partial success” was also scored for the patient who had some symptoms but no reflux in lacrimal irrigation. The “failure” was defined as no improvement or recurrence in tearing with severe reflux in irrigation at the last follow-up.

**Histopathological Study after RC-NLDO in Rhesus Monkeys**

Twelve rhesus monkeys (1.5–2 years old and weighing 4-6 kg) were purchased from Guangdong Medical Laboratory Animal Center, Guangdong, China. Experimental procedures were performed with adherence with the ARVO statement for the Use of Animals in Ophthalmic and Vision Research. One eye randomly chosen from each monkey was performed RC-NLDO and another eye of each animal were used as untreated normal controls. The surgery and postoperative care were performed at the same manner to the patients as described above. The animals were killed by overdose of barbiturates at 7 days, 1 month, 2 months and 3 months after surgery. Specimens including canaliculi, lacrimal sac, and nasolacrimal duct were carefully collected for histopathological examination.
RESULTS

Patient Pre-operative Conditions

The patient pre-operative conditions were summarized in Table 1. The duration of symptoms ranged from 6 months to 26 years (mean, 5.1 years) in RC-NLDO group, and from 6 months to 17 years (mean, 4.7 years) in EX-DCR group. There were 49 (9.67%) recurrent cases suffering tearing from a previously unsuccessful surgery (EX-DCR or silicone intubation) in RC-NLDO group, and 10 (7.41%) recurrent cases in EX-DCR group. The follow-up period after surgeries was ranged in 12-54 months (mean 28.5 months).

Table 1 Pre-operative Conditions of Patients in Two Groups

<table>
<thead>
<tr>
<th>Preoperative Conditions</th>
<th>RC-NLDE Group n (% of total [506])</th>
<th>EX-DCR Group n (% of total [135])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>506 (100.0%)</td>
<td>135 (100.0%)</td>
</tr>
<tr>
<td>NLDO</td>
<td>125 (24.80%)</td>
<td>51 (37.78%)</td>
</tr>
<tr>
<td>Chronic dacryocystitis</td>
<td>255 (50.40%)</td>
<td>72 (53.33%)</td>
</tr>
<tr>
<td>Mucocele</td>
<td>14 (2.77%)</td>
<td>2 (1.48%)</td>
</tr>
<tr>
<td>Fistulae</td>
<td>10 (1.98%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Small lacrimal sac</td>
<td>45 (8.80%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Atrophic rhinitis</td>
<td>8 (1.58%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Failed to EX-DCR</td>
<td>23 (4.55%)</td>
<td>3 (2.22%)</td>
</tr>
<tr>
<td>Failed to silicone intubation</td>
<td>26 (5.14%)</td>
<td>7 (5.19%)</td>
</tr>
</tbody>
</table>

*P < 0.05

EX-DCR = external dacryocystorhinostomy
RC-NLDO = re-canalization of nasolacrimal duct obstruction

Clinical Effects of RC-NLDO and EX-DCR Treatments

The surgical outcomes were summarized in Table 2. The operative duration for RC-NLDO ranged in 8-19 minutes (12.5 ± 2.6 minutes) was significantly shorter than 30-50 minutes (40.3 ± 4.7 minutes) for EX-DCR (P<0.001, Student’s t test). In RC-NLDO group, the full success was defined in 440 (86.96%) eyes, partial success in 31 (6.13%) cases, and recurrent in 35 (6.92%) cases. The total success rate reached to 93.08% (471/506) with a single treatment. A total of 27 failed cases underwent a secondly repeated surgery 3 months later. After second surgery, 20 (74.07%) cases achieved full success; 3 (11.11%) cases achieved partial success, only 4 (14.81%) cases failed again. The total success rate of secondly repeated surgery was 85.19%. In EX-DCR group, the full success with symptoms completely resolved was defined in 118 (87.14%) cases, the partial success was in 5 (3.70%) cases, and the failed in 12 (8.89%) cases. The total success rate reached 91.11% (123/135). A total of 10 failed cases underwent a repeated surgery, in which 4 (40.0%) cases were successful and 6 (60.0%) cases were failed. There was no statistical difference in surgical outcomes between these two groups for the primary surgery (P = 0.816), while a significant difference was found for the recurrent patients (P < 0.013). The digital subtraction dacryocystogram showed that the reconstructed cavity of nasolacrimal duct by RC-NLDO was much wider than normal (Figure 2).
### Table 2  Clinical Outcome in Two Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>RC-NLDE</th>
<th>EX-DCR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Primary surgery</td>
<td>506</td>
<td>100.0</td>
<td>135</td>
</tr>
<tr>
<td>Full success</td>
<td>440</td>
<td>86.96</td>
<td>118</td>
</tr>
<tr>
<td>Partial success</td>
<td>31</td>
<td>6.13</td>
<td>5</td>
</tr>
<tr>
<td>Total success</td>
<td>471</td>
<td>93.08</td>
<td>123</td>
</tr>
<tr>
<td>Failure</td>
<td>35</td>
<td>6.92</td>
<td>12</td>
</tr>
<tr>
<td>Second surgery</td>
<td>27</td>
<td>100.0</td>
<td>10</td>
</tr>
<tr>
<td>Full success</td>
<td>20</td>
<td>74.07</td>
<td>4</td>
</tr>
<tr>
<td>Partial success</td>
<td>3</td>
<td>11.11</td>
<td>0</td>
</tr>
<tr>
<td>Total success</td>
<td>23</td>
<td>85.19</td>
<td>4</td>
</tr>
<tr>
<td>Failure</td>
<td>4</td>
<td>14.81</td>
<td>6</td>
</tr>
</tbody>
</table>

*P = 0.816, two-sample t test (a = 0.05).

**P = 0.013, two-sample t test (a = 0.05).

EX-DCR = external dacryocystorhinostomy
RC-NLDO = re-canalization of nasolacrimal duct obstruction

### Complications of RC-NLDO and EX-DCR

In EX-DCR group, one patient (0.74%) suffered postoperative bleeding immediately after surgery; eight patients (5.93%) reported transient pain in the upper segment of the maxillary bone, but it was tolerable; and 30 patients (22.22%) complained on their visible scars. No infection or uncontrolled bleeding occurred. In RC-NLDO group, four patients (0.79%) had postoperative periocular subcutaneous hematoma. There were no other complications observed in this group.

### Histopathological Results of Rhesus Monkeys Underwent RC-NLDO

In normal rhesus monkey, the lacrimal sac is lined by stratified columnar epithelium containing scattered goblet cells on a broad basement membrane while the nasolacrimal duct is lined by a double layer of epithelium, a superficial layer of columnar cells and a basal layer of nonkeratinized squamous cells (Figure 3 A-B). It differs histologically from the lacrimal sac in that it lacks goblet cells.

The healing process of epithelium in nasolacrimal duct after RC-NLDO surgery in rhesus monkey was evaluated by histopathological examinations. Cross-sections of the specimens obtained immediately after RC-NLDO displayed the intact epithelium of lacrimal sac and a nearly total loss of epithelium in nasolacrimal duct with a few residual cells appeared as small islands on the basal membrane (Figure 3 C-D). Sections of the specimens collected one week after surgery showed notable migration of cells from adjacent residual epithelia. The epithelial cells formed a single layer and loosely covered the surface of basement membrane. Scattered or focal infiltrations of inflammatory cells were visible in lamina propria (Figure 3 E-F). Specimens from one month after surgery displayed a completely healed epithelium with two layers of cells similar to the normal controls. There was no visible inflammatory cell infiltration in lamina propria (Figure 3 G-H). The epithelia in specimens from 2 to 3 months later became the morphologically and histologically normal (Figure 3 I-L). No granulation tissue was noted in all specimens.
The ideal treatment for NLDO is to re-canalize the obstructed duct and restore normal anatomical structure and physiological function of lacrimal drainage system. The EX-DCR is a successful operation with a success rate of 80-95%. But it is an relatively complex procedure, and involves a skin incision and bone removal to create a mucosal fistula from lacrimal sac directly into the nasal cavity, which leaves a facial cutaneous scar and disruption of the medial canthal anatomy. In order to overcome these disadvantages, a number of therapeutic developments and promising advances in DCR have been reported recently, such as endonasal (endoscopic) DCR and endocanalicular laser DCR. But these new techniques have obvious disadvantages, such as time consuming and a marked learning curve. In addition, the EX-DCR and these new approaches do not restore the obstructed nasolacrimal duct, but make a bypass draining system, which is not a physiological tear passage.

Re-canalization of the nasolacrimal duct obstruction (RC-NLDO) was a simple and evolutional approach for treating NLDO and chronic dacryocystitis. In the last 5 years, we have been conducting this study with up to 54 month long term follow-up to evaluate the RC-NLDO approach with comparison to EX-DCR. Our findings demonstrated that the RC-NLDO was a highly successful approach with an overall success rate at 93.18% for primary surgery and 85.19% for secondly repeated surgery. The pathological study in rhesus monkeys further confirmed that the surgically wounded epithelium in nasolacrimal duct was starting healing in a week and completely recovered within 1 month, which created a wide re-canalized cavity.

RC-NLDO has achieved a high success rate that was comparable to EX-DCR. This may be due to the following factors: 1) Larger lumen creation (Figure 2B): In laser treatment, the cavity created is narrower due to limited diameter (0.4-0.6mm) of laser fiber. However, in RC-NLDO, the diameter of HFL probe is 1.2mm. According to the formula “$S = \pi r^2$”, the re-opened area ($S=1.13\text{mm}^2$) of the duct cavity in cross section by RC-NLDO was 4-9 fold larger than that laser created cavity ($0.13-0.28\text{mm}^2$). According Poiseuille's law the flow resistance is the fourth power inversely proportional to the radius of duct, the tears flow resistance through the cavity created by RC-NLDO would be 16-81 fold less than that created by laser treatment. 2) Lower incidence of false passage formation: No false passage formation is essential for success. In normal conditions, the soft tissue of the membranaceous nasolacrimal duct is tightly adhered to its surrounding osseous nasolacrimal duct. Therefore, in the situation of no false passage formation, the direction of surgical scar contraction is eccentrically, which pulls the soft tissue to the wall of osseous nasolacrimal duct, thus the gently contract from surgical scar do not reduce the success rate. If the false passage formed, the direction of surgical scar contract was pulling itself towards center of the reconstructed nasolacrimal duct, which would narrow or block the cavity. The false passage could be avoid in most cases if the electrocautery was performed simultaneously during slowly withdrawing the HFL probe after its tip inserted into nasal cavity during the RC-NLDO procedure.

The RC-NLDO technique has other advantages, such as (1) minimal trauma and no facial cutaneous scar due to the surgery performed without cutaneous incision and bone excision; (2) less disruption of lacrimal pump function due to the surgery restored a physiological tear passage without making a bypass draining system; (3) simpler, easier and faster (average 12.5 minutes) procedure that was similar to a conventional lacrimal probing.

Usually, the lower canaliculus is ascendant in tear drainage (about 75%). Thus the superior
canaliculus was chosen for HFL probe to pass through, which protected the function of tear drainage in case unexpected damages occurred. The most obstructed points could be penetrated by rotational manipulation along with slight force during electrocautery. In the procedure, the obstructed tissue was cauterized to an eschar crust tube tightly adhering to the wall of the re-opened cavity, as a transitory sustaining to the wall of reconstructed nasolacrimal duct. Additionally, during withdrawing the HFL probe, the rotational manipulation could maintain the eschar crust tube intact, and minimize the risk of postoperative bleeding, inflammation and synechia.

The RC-NLDO is also a choice of treatment for patients who suffer from lacrimal sac mucocele, obstructed lacrimal duct with atrophic rhinitis or small lacrimal sac. The RC-NLDO is suitable for patients who failed to respond to a previous EX-DCR. RC-NLDO does not suitable for treating the obstruction of osseous nasolacrimal duct, which could be treated with EX-DCR. Contraindication for RC-NLDO also includes acute dacryocystitis, suspicion of malignancy and patients suffering from severe hypertension or severe cardiac disease (especially with pacemaker).

In conclusion, a simple and evolutional approach RC-NLDO has been evaluated by long-term follow-up in a large patient population and animal pathological examination, and the findings demonstrated that this new approach is proven to re-canalize the nasolacrimal duct obstructions. When compared with EX-DCR, RC-NLDO is a new option for treating NLDO and chronic dacryocystitis with a similar or better clinical success rate. The advantages include its efficacy, minimal invasion, safety and simplicity. RC-NLDO is also an optimal choice for recurrent patients who failed to respond to EX-DCR and for patients with small lacrimal sacs or atrophic rhinitis who are not suitable for EX-DCR.
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**Competing Interest:** None declared.
FIGURE LEGENDS

Figure 1. Lacrimal Canalizer (model WZC-Ⅲ) with accessories. I. The main instrument contains an on/off switch (A), an output power control (B) and a reset button (C) with three cable connectors (1, 2 and 3) for connections to accessories: a positive electrode cable that links to the high frequency lacrimal probe (see part II), the negative electrode tongs (D) and foot pedal (E), respectively. II. Lacrimal probe images showing: A. its 2.0mm long, naked (without insulating coat on the surface) and conducting tip with 1.2mm in diameter; B. Its 80 mm long and 1.2mm in diameter probe body with a thin layer of nontoxic and insulating coat on the surface; C. A 60mm long and 5mm in diameter head part of the probe covered by a rubber layer; D. A special “buckle” structure of the probe top.

Figure 2. The digital subtraction dacryocystogram. A. Before RC-NLDO surgery, the completely obstructed right nasolacrimal duct and the normal left one were observed; B. Three weeks after RC-NLDO operation, free flow of the contrast medium through the re-canalized nasolacrimal duct to the inferior meatus was observed.

Figure 3. Representative images showing histo-morphological structures of nasolacrimal duct mucosa in cross-sections of rhesus monkeys before and after RC-NLDO surgery. A-B. Normal morphological structure of nasolacrimal duct mucosa in rhesus monkey; C-D. Nasolacrimal duct Mucosa in rhesus monkey immediately after RC-NLDO surgery, showing a nearly total loss of epithelium in nasolacrimal duct with a few residual cells on the basal membrane. E-F. One week after surgery, showing notable migration of cells from adjacent residual epithelia. The epithelial cells formed a single layer and loosely covered the surface of basement membrane. Scattered or focal infiltrations of inflammatory cells were visible in lamina propria. G-H. One month after surgery, showing a completely healed epithelium with two layers of cells similar to the normal controls. There was no visible inflammatory cell infiltration in lamina propria. I-J. Two months after surgery. K-L. Three months after surgery. The epithelia in specimens from 2 to 3 months later became the morphologically and histologically normal. Magnifications: x 200 in images A, C, E, G, I and K; and x 400 in B, D, F, H, J and L.
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