A new bleb-independent surgery namely penetrating canaloplasty for corticosteroid-induced glaucoma: a prospective case series

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Abstract

● AIM: To report the outcomes of penetrating canaloplasty for corticosteroid-induced glaucoma in a case series.
● METHODS: Penetrating canaloplasty is a bleb-independent filtering surgery unifying canaloplasty and trabeculectomy. In this study, the surgery was performed to restore the natural outflow through surgically expanded Schlemm’s canal and generated trabeculum ostium. A total of 10 eyes of 8 patients were treated with penetrating canaloplasty for corticosteroid-induced glaucoma. Intraocular pressure (IOP) and the number of anti-glaucoma medications at postoperative 3, 6, 12, 18, 24, 36, and 48mo were documented as primary endpoint. Complications after the surgery were recorded as secondary endpoint.
● RESULTS: Penetrating canaloplasty was accomplished successfully for all 10 eyes, with a mean follow-up of 20.4±13.0mo (range 6-48mo). The mean preoperative IOP and number of anti-glaucoma medications were 45.1±6.5 mm Hg and 3.3±0.5 respectively. The mean post-operative IOP at 3, 6, 12, 18, 24, 36, and 48mo were 15.8±6.0, 14.7±3.3, 15.3±2.0, 15.6±2.6, 17.5±1.8, 16.5±4.9, and 14.0 mm Hg. The number of anti-glaucoma medications at these time points were all 0. This surgery failed to control the IOP in 1 mo after surgery. Choroidal detachment developed in one eye but responded well to conservative treatment.
● CONCLUSION: Penetrating canaloplasty is effective for corticosteroid-induced glaucoma without serious complications, making it a viable or preferred alternative option.
● KEYWORDS: penetrating canaloplasty; corticosteroid-induced glaucoma; intraocular pressure; bleb-independent filtering surgery

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INTRODUCTION

Secondary intraocular pressure (IOP) elevation is common in steroid responders to glucocorticoids[1-2]. Long-term ocular hypertension may bring with glaucomatous optic nerve damage, that is, corticosteroid-induced glaucoma[3-5]. The underlying mechanism may involve increased resistance of aqueous humor in flowing through the trabecular meshwork (TM)[6]. Besides trabeculectomy[7-8], a standard surgical procedures for glaucoma, corticosteroid-induced high IOP can be managed with trabeculotomy[9], trabectome[10], nonpenetrating deep sclerectomy[11], canaloplasty[12], viscocanalostomy[13], gonioscopy-assisted transluminal trabeculotomy (GATT)[14], Kahook Dual Blade goniotomy[15], Ahmed glaucoma valve[16], and XEN Gel Stent[17]. However, their outcomes have not been assessed with large case-control studies. Multiple studies have revealed the superiority of canaloplasty to trabeculectomy in treating open angle glaucoma[18-19]. Matlach et al[20] conducted a prospective randomized clinical trial, showing that canaloplasty and trabeculectomy had comparable IOP-lowering efficacy after 2y for primary open angle glaucoma (POAG), but in the former
antimetabolites use and vision-threatening complications were avoided\cite{21,22}. Brusini et al\cite{12} reported favorable mid-term outcomes of canaloplasty in patients with corticosteroid-induced glaucoma. Researchers have reported successful viscocanalostomy in three cases with corticosteroid-induced glaucoma\cite{23,24,25}. Considering the outflow resistance mainly increases in TM, tension suture aided canaloplasty can be combined with trabeculectomy to bypass the TM, thus channeling the aqueous humor into the expanded Schlemm’s canal. Since trabeculectomy is a penetrating surgery, we coined this combination as “penetrating canaloplasty”. This surgery can reflect Cairns’s concept, in which aqueous humor is drained through trabeculectomy-formed fistula into the Schlemm’s canal, thus realizing the internal filtration. Our previous study has reported a favorable outcome of penetrating canaloplasty in primary angle-closure glaucoma\cite{24,25} and traumatic angle recession glaucoma\cite{26}. Herein we presented the preliminary surgical outcomes of penetrating canaloplasty for corticosteroid-induced glaucoma.

SUBJECTS AND METHODS

Ethical Approval  This is a prospective interventional study (No.ChiCTR1900020511). The study complied with the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of the eye hospital of Wenzhou Medical University (YX2018-016). Every subject voluntarily signed the consent form.

Subjects and Preoperative Examinations  All patients were diagnosed with corticosteroid-induced glaucoma that was medically uncontrolled (with a definite history of corticosteroid use, IOP still rises to more than 21 mm Hg under maximal tolerable medical treatment, with concomitant glaucomatous optic disc damage and corresponding visual field defects). Inclusion criteria: 1) corticosteroid induced high IOP; 2) IOP exceeded 30 mm Hg after maximal medical interventions, despite cessation of corticosteroid therapy (if possible) for at least 3mo; 3) fundus and visual field showed concomitant glaucomatous optic disc damage and corresponding visual field defects; 4) gonioscopy demonstrated wide and open angles and an intact Schlemm’s canal. Exclusion criteria: 1) other secondary glaucoma, 2) refusal to sign the consent form.

Use of corticosteroid was recorded. All participants received a comprehensive ophthalmic examination within one week before the surgery, which included best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, gonioscopy, IOP measurement with Goldmann applanation tonometer, fundus examination with a 90 D and non-mydriatic fundus photography, and Humphrey SITA standard 24-2 perimeter, and retinal nerve fiber layer assessment with spectral-domain optical coherence tomography (OCT).

Surgery  This surgery was pioneered by Dr. Liang YB and patented in the United States (http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahml%2FPTO%2Fsearch-bt.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=15%2F362,478&OS=15/362,478&RS=15/362,478). All 8 patients (10 eyes) underwent penetrating canaloplasty by an experienced glaucoma surgeon Liang YB. The procedures are listed below.

1) A superior rectus traction suture or a corneal bridle traction suture was placed to expose the surgical field, then a fornix-based conjunctival incision and a 4×4 mm² superficial scleral flap of 1/2 scleral thickness were constructed.

2) Beneath the first flap, a smaller and deeper scleral flap (2×2 mm²) was sculpted. A routine paracentesis incision was made to lower the IOP, so as to obviate the risk of trabeculodesceme membrane detachment. Schlemm’s canal was opened and unroofed by the removal of the external wall. The deep scleral flap (2×2 mm²) was then dissected away and both ostia of the canal were repeatedly visco-dilatated with high molecular weight hyaluronic acid (Healon GV), just as procedures in viscocanalostomy.

3) The illuminated microcatheter (iTrack by iScience Interventional, Menlo Park, CA, USA) was then inserted and advanced through the 360° Schlemm’s canal, until out of the opposite end.

4) After ligation of a 10-0 polypropylene wire to the distal tip of the microcatheter, the laser microcatheter was retreated. Every two hours, the high polymer sodium hyaluronate (Helon GV, pharmaia company, USA) was injected to expand the Schlemm’s canal with the aid of a special screw-driven syringe. After the withdrawal of the microcatheter, the suture was then replaced in the Schlemm’s canal. After the Schlemm’s canal was fully expanded, the suture was knotted under tension.

5) The trabecular tissue (2×2 mm²) deep at Schlemm’s canal was cut off and forwarded. The respective iris root was cut.

6) Finally, the superficial scleral flap was tightly sutured with 10-0 prolene suture to ensure a watertight closure preventing any bleb formation. The conjunctival flap was then sutured with 10-0 prolene sutures to the peripheral cornea. Patients were treated with tobramycin and dexamethasone eye drop and ointment, which were tapered in one month after surgery. IOP and anterior segment were measured after surgery.

Follow-up and Outcome Measurements  Patients were intensively followed up on the first week after the surgery and the following time points (1, 3, 6, 12, 18, 24, 36, and 48mo). The main observation index included all baseline examinations and IOP, number of glaucoma medications, intra- and postoperative complications, and additional interventions. Morphology of the filtering bleb was assessed using slit-lamp microscope and ultrasound biological microscopy (UBM).
Surgery was defined as success according to postoperative IOP ≤ 21 mm Hg and IOP reduction by ≥ 20% with (qualified success) or without (complete success) medical treatment. Antiglaucomatous medications were prescribed when IOP was above 21 mm Hg (Figure 1).

**Statistical Analysis** SPSS Statistics 20.0 (Statistical Product and Service Solutions, IBM, USA) was used for statistical analysis. Student’s t-test was applied to compare IOP values before and after surgery. Value of P < 0.05 was considered statistically significant.

**RESULTS**

Basic characteristics of the patients are summarized in Table 1.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Gender</th>
<th>Age (y)</th>
<th>Eye</th>
<th>Cause of corticosteroid-induced glaucoma</th>
<th>Primary disease</th>
<th>Preop. IOP (mm Hg)</th>
<th>NOM</th>
<th>BCVA</th>
<th>Follow-up length (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Zhou××</td>
<td>M</td>
<td>24</td>
<td>OD</td>
<td>Methylprednisolone p.o.</td>
<td>SLE</td>
<td>48.3</td>
<td>3</td>
<td>NLP</td>
<td>48</td>
</tr>
<tr>
<td>2. Liu××</td>
<td>F</td>
<td>28</td>
<td>OD</td>
<td>Prednisolone acetate eye drops; prednisolone p.o.; intravitreal injection of triamcinolone acetoni</td>
<td>Panuveitis</td>
<td>55.7</td>
<td>4</td>
<td>0.5</td>
<td>36</td>
</tr>
<tr>
<td>3. Chen××</td>
<td>M</td>
<td>25</td>
<td>OD</td>
<td>Dexamethasone eye drops; prednisolone acetate p.o.; intravitreal injection of triamcinolone acetoni</td>
<td>Behcet’s disease</td>
<td>40.9</td>
<td>3</td>
<td>0.3</td>
<td>24</td>
</tr>
<tr>
<td>4. Ni××</td>
<td>M</td>
<td>30</td>
<td>OS</td>
<td>Prednisolone acetate eye drops; prednisolone p.o.; periocular injection of methylprednisolone; retrobulbar injection of triamcinolone acetoni</td>
<td>Panuveitis</td>
<td>38.8</td>
<td>4</td>
<td>0.6</td>
<td>18</td>
</tr>
<tr>
<td>5. Jiang××</td>
<td>M</td>
<td>52</td>
<td>OS</td>
<td>Dexamethasone eye drops; posterior sub-Tenon’s capsule injection of triamcinolone acetoni</td>
<td>Iridocyclitis; CME</td>
<td>38.3</td>
<td>3</td>
<td>0.1</td>
<td>18</td>
</tr>
<tr>
<td>6. Guan××</td>
<td>M</td>
<td>9</td>
<td>OS</td>
<td>Dexamethasone eye drops</td>
<td>Allergic conjunctivitis</td>
<td>47.7</td>
<td>3</td>
<td>0.6</td>
<td>18</td>
</tr>
<tr>
<td>7. Guan××</td>
<td>M</td>
<td>9</td>
<td>OD</td>
<td>Dexamethasone eye drops</td>
<td>Allergic conjunctivitis</td>
<td>36.7</td>
<td>3</td>
<td>0.8</td>
<td>18</td>
</tr>
<tr>
<td>8. Wang××</td>
<td>M</td>
<td>7</td>
<td>OD</td>
<td>Intravitreal injection of triamcinolone acetoni</td>
<td>Uveitis</td>
<td>43.6</td>
<td>3</td>
<td>0.4</td>
<td>12</td>
</tr>
<tr>
<td>9. Mi××</td>
<td>F</td>
<td>20</td>
<td>OD</td>
<td>Prednisolone acetate</td>
<td>SLE</td>
<td>47.5</td>
<td>3</td>
<td>FC/20 cm</td>
<td>6</td>
</tr>
<tr>
<td>10. Chen××</td>
<td>M</td>
<td>26</td>
<td>OS</td>
<td>Dexamethasone eye drops; prednisolone acetate p.o.; posterior sub-Tenon’s capsule injection of triamcinolone acetoni</td>
<td>Behcet’s disease</td>
<td>53.5</td>
<td>4</td>
<td>0.7</td>
<td>6</td>
</tr>
</tbody>
</table>

Mean±SD - 23±13.3 - - - 45.1±6.5 3.3±0.5 - 20.4±13.0

Preop. IOP: Preoperative intraocular pressure; NOM: Number of glaucoma medications; BCVA: Best-corrected visual acuity; NLP: No light perception; FC: Fingers counting; SD: Standard deviation; SLE: Systemic lupus erythematosus; CME: Cystoid macular edema.

Gonioscopy confirmed that prolene sutures were precisely positioned within the Schlemm’s canal for the entire follow-up period in all cases. UBM after penetrating canaloplasty shows no subconjunctival filtration bleb (Figure 2). Microhyphaema occurred in 3 eyes, but disappeared within one week through spontaneous absorption. Postoperative transient IOP spike occurred in two eyes which cropped up from one week to one month after surgery. One eye developed choroidal detachment which responded well to conservative treatment. No other complications were observed during or after the surgery. For
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Figure 2 Picture of ultrasound biological microscopy after penetrating canaloplasty Star: Visible deep sclera pool; Yellow arrow: Trabeculectomy-formed fistula; Blue arrow: Peripheral iridotomy; Red arrow: Precisely positioned tension suture within the arrow: Trabeculectomy-formed fistula; Blue arrow: Peripheral Star: Visible deep sclera pool; Yellow

penetrating canaloplasty

Table 2 Pre- and postoperative intraocular pressure

<table>
<thead>
<tr>
<th>Time points</th>
<th>n</th>
<th>IOP (mm Hg)</th>
<th>NOM</th>
<th>P</th>
<th>IOP reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop.</td>
<td>10</td>
<td>45.1±6.5</td>
<td>3.3±0.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Postop. 3mo</td>
<td>9</td>
<td>15.8±6.0</td>
<td>0</td>
<td>&lt;0.01</td>
<td>65.6</td>
</tr>
<tr>
<td>Postop. 6mo</td>
<td>9</td>
<td>14.7±3.3</td>
<td>0</td>
<td>&lt;0.01</td>
<td>68.0</td>
</tr>
<tr>
<td>Postop. 12mo</td>
<td>7</td>
<td>15.3±2.0</td>
<td>0</td>
<td>&lt;0.01</td>
<td>65.6</td>
</tr>
<tr>
<td>Postop. 18mo</td>
<td>6</td>
<td>15.6±2.6</td>
<td>0</td>
<td>&lt;0.01</td>
<td>65.1</td>
</tr>
<tr>
<td>Postop. 24mo</td>
<td>4</td>
<td>17.5±1.8</td>
<td>0</td>
<td>&lt;0.01</td>
<td>61.8</td>
</tr>
<tr>
<td>Postop. 36mo</td>
<td>2</td>
<td>16.5±4.9</td>
<td>0</td>
<td>&lt;0.01</td>
<td>68.3</td>
</tr>
<tr>
<td>Postop. 48mo</td>
<td>1</td>
<td>14.0</td>
<td>0</td>
<td>&lt;0.01</td>
<td>71.0</td>
</tr>
</tbody>
</table>

The failed surgery is not included in this analysis. n: Number of cases at the postop. time point; IOP: Intraocular pressure; NOM: Number of glaucoma medications. The P-values for the t-test results between preoperative and postoperative data.

In this case series, penetrating canaloplasty was successfully performed in all the 10 eyes, and the IOP in 9 eyes was decreased without anti-glaucoma medications. Follow-up data proved the encouraging efficacy and safety of this surgery. The average age of 10 cases was 23±13.3y, an age lower than that of POAG cases[7]. If treated with a routine trabeculectomy, these patients might be plagued with problems related to subconjunctival bleb for a long time. As an internal filtration surgery for restoring the physiological channel, penetrating canaloplasty does not depend on the maintenance of the filtration bleb.

In conclusion, penetrating canaloplasty is effective for corticosteroid-induced glaucoma without any serious complications, making it a viable or preferred surgical choice.

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