Different compression sutures combined with intracameral air injection for acute corneal hydrops

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Abstract

\textbf{AIM:} To evaluate the efficacy and safety of full-thickness sutures combined with intracameral air injection (FTS-AI) versus pre-Descemet’s membrane sutures combined with intracameral air injection (PDS-AI) in the management of acute corneal hydrops in keratoconus.

\textbf{METHODS:} The research included 8 patients (8 eyes) suffering from acute corneal hydrops caused by keratoconus. Four patients were randomly assigned to FTS-AI. And the other four were randomly assigned to PDS-AI. Corneal oedema, visual acuity, corneal thickness were assessed during follow-up.

\textbf{RESULTS:} The demographics, preoperative duration of symptoms and severity of corneal hydrops between the two groups were not significantly different. The mean corneal oedema resolution time after FTS-AI and PDS-AI were 11±1.15 and 15±1.41d, respectively ($P$=0.005). The maximum corneal thickness of the scarred region decreased in both groups at one week postoperatively ($P$<0.05). No obvious difference was found in the mean maximal corneal thickness between the two groups postoperatively. The BCVA improved significantly after FTS-AI and PDS-AI at three months postoperatively. No obvious difference was found in the BCVA after FTS-AI and PDS-AI at three months postoperatively.

\textbf{CONCLUSION:} FTS-AI and PDS-AI are safe and effective therapies to accelerate the resolution of corneal oedema in acute corneal hydrops secondary to keratoconus. Despite faster resolution of corneal oedema in the FTS-AI group, we recommend PDS-AI to avoid potential endothelium cell damage.

\textbf{KEYWORDS:} keratoconus; acute corneal hydrops; full-thickness sutures; pre-Descemet’s membrane sutures; intracameral air injection

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INTRODUCTION

As a component of ectatic corneal disorders, acute corneal hydrops is brought by rupture of Descemet’s membrane (DM) and endothelium. Corneal hydrops occurred in approximately 2.6%-2.8% of patients with keratoconus\textsuperscript{[1-2]}. It is hard for acute corneal hydrops to regress spontaneously, and long-lasting oedema may cause many potential complications, such as infection, pseudocyst formation, malignant glaucoma, corneal perforation, neovascularization, and a high risk of graft rejection\textsuperscript{[3-5]}. Eventually, leaving a visual-impairing scar, which needs keratoplasty to restore visual function. The traditional treatment regimen includes topical eye drops, such as hypertonic saline, antibiotics, cycloplegics and corticosteroids\textsuperscript{[5]}. In the last ten years, repeated intracameral injection of air/gas had been reported to accelerate the resolution of oedema, but this procedure may increase the risk of pupillary block glaucoma, intrastromal migration of gas, and endothelium dysfunction\textsuperscript{[6-8]}. Sometimes, the air/gas bubble can get access to the potential space and stop re-apposition of the edges in patients with large gaping tears and stromal clefs. Based on the above situations, compression sutures, including full-thickness sutures (FTS) and pre-DM sutures (PDS) combined with intracameral air/gas injection have been reported effective in the administration of acute corneal hydrops\textsuperscript{[9-11]}. In this study, we aim to compare the efficacy and safety of FTS combined with intracameral air injection (FTS-AI) versus PDS combined with intracameral air injection (PDS-AI) in acute corneal hydrops caused by keratoconus. For all we know, no research compares the clinical results between FTS-AI and PDS-AI.

SUBJECTS AND METHODS

Ethical Approval  Approved by the Institutional Review
Eight patients (8 eyes) with acute corneal hydrops caused by keratoconus presented to our institute between January 2019 and December 2020, who was randomly assigned to received FTS-AI or PDS-AI, were included. All the patients were men. The mean age was 18.4±2.45y (range, 14-22y). All patients suffered from spontaneous and sudden onset of reduced visual acuity, pain, redness, and epiphora in the eyes within 2wk. The collection of data was made preoperatively and at 1d, 1wk, 1mo (±3d), and 3mo (±3d) postoperatively. Best-corrected visual acuity (BCVA), slit-lamp examination, intraocular pressure (IOP) and the maximum corneal thickness, measured by anterior segment optical coherence tomography (AS-OCT; Carl Zeiss Meditec, Germany), were noted. No one needed repeated air injection. The mean corneal oedema resolution time after FTS-AI and PDS-AI were 9.50±2.08 and 9.25±2.06d, respectively (P=0.686). No complication happened and all participants completed the follow-up. No significant differences were found in the demographics, preoperative duration of symptoms and severity of corneal hydrops between the two groups (Table 1). The mean age of participants in FTS-AI and PDS-AI groups was 19±2.16y (range 17-22y) and 17.75±2.87y (range 14-21y), respectively (P=0.51). The mean duration of symptoms before FTS-AI and PDS-AI was 9.50±2.08 and 9.25±2.06d, respectively (P=0.87). The mean maximal corneal thickness, evaluated by AS-OCT, before FTS-AI and PDS-AI was 2.04±0.20 and 1.95±0.23 mm, respectively (P=0.686). No complication happened and all participants completed the follow-up.

Surgical Procedure Surgeries were carried out by a single experienced surgeon under peribulbar anaesthesia. First, after removing the epithelium, the surgeon marked the rupture site and delineated the torn edges of DM. If it is difficult to distinguish the torn edges of DM, a limbal paracentesis was conducted at the 10-o’clock position, and an injection of an air bubble into the anterior chamber (AC) was made to improve the visibility. Then, an FTS or PDS using 10-0 nylon suture was applied at the margin of the oedematous cornea and clear cornea, and retrieved from the opposite clear cornea. At the end of the procedure, an injection of an air bubble to fill half of the AC was made (Figure 1). Patients shall lie down in supine position for at least 8h postoperatively. Postoperative therapy included 1% prednisolone acetate eye drops (Allergan, Ireland) three times a day, 0.5% levofloxacin eye drops (Santen Pharmaceutical, Japan) four times a day, and 0.5% tropicamide phenylephrine eye drops (Santen Pharmaceutical, Japan) to dilate the pupil four times a day until the air bubble in the AC completely absorbed. Compression sutures were removed when they received keratoplasty.

DISCUSSION The DM rupture in keratoconus is used to be considered as the cause of corneal hydrops. There are two conditions necessary
for the healing process: first, it is necessary to reattach the retracted or rolled DM to the stroma, and afterwards, the endothelium cells must enlarge and slowly migrate to cover the whole flaw.

In recent years, more and more surgical interventions have emerged to accelerate the resolution for corneal hydrops. As early as 1988, Zusman et al. proposed that intracameral sulfur hexafluoride (SF₆) injection could repair DM detachment.
Afterwards, various kinds of agents like air\cite{14-15}, SF$_6$\cite{16}, perfluoropropane (C$_3$F$_8$)\cite{17-18}, sodium hyaluronate\cite{19}, intrastromal fluid drainage with air tamponade\cite{20}, tissue glue\cite{21}, intracameral platelet-rich plasma injection\cite{22}, and descemet membrane endothelial keratoplasty (DMEK)\cite{23-24} have been proven effective in treating acute corneal hydrops. Among these techniques, intracameral air/gas injection has been widely proven for the acceleration of the resolution of corneal oedema\cite{25-26}. In 2008, Vanathi et al\cite{16} reported that through intracameral air injection, corneal oedema subsided within 20.1±9.0d versus 64.7±34.6d who received conventional treatment in patients with corneal hydrops. However, the nonexpansibility and rapid absorption of air limit the usage in such patients. Undiluted C$_3$F$_8$ expands 4 times in 4d, and 14% dilution persists in the AC for about 6wk. SF$_6$ expands twice in 24 to 48h, and it takes 2wk for entire absorption from the AC\cite{16}. Nevertheless, there are some limits to these approaches: first, C$_3$F$_8$ may be toxic to the endothelium cells\cite{27}; second, the long duration of the gas increases the possibility of secondary glaucoma\cite{3}; third, some tiny bubbles can penetrate the stroma, which can prevent the re-apposition of intrastromal clefts; what’s more, Basu et al\cite{28} found that even after injection of C$_3$F$_8$, a gap between the two ends of the split DM could be found histopathologically after the edema subsided. Based on the above reasons, compression sutures combined with intracameral air/gas injection have emerged these years. Compression sutures can shorten the edges of the DM tear and facilitate anatomical re-apposition. Rajaraman et al\cite{10} proposed using intracameral C$_3$F$_8$ injection and FTS can effectively hasten the resolution of oedema compared to simply C$_3$F$_8$ intracameral injection. In 2015, Yahia Chérif et al\cite{8} found that intracameral air injection and PDS also could hasten the corneal oedema resolution, and theorized that the source of the corneal hydrops were posterior stromal breaks. In 2019, Parker et al\cite{29} found that the entire elimination of DM did not generate hydrops in patients with keratoconus. In contrast, eyes underwent Bowman layer transplantation complicated by accidental perforation of posterior corneal stroma and DM elicited a typical corneal hydrops. This research further demonstrated the pathophysiological mechanism of corneal hydrops, indicating that it is not sufficient for a flaw at the level of DM for the elicitation of an acute corneal hydrops, unless accompanied by a flaw in the most posterior stroma layers (the so-called Dua’s layer) at the same time\cite{29}.

Mohebbi et al\cite{30} raised that FTS combined intracameral SF$_6$ injection was effective and safe in treating corneal hydrops. Zhao et al\cite{14} found that PDS-AI possessing superior clinical outcomes than thermokeratoplasty for administrating acute corneal hydrops in keratoconus\cite{31}. From aforementioned researches, the meantime for resolving corneal oedema was longer in Yahia Chérif et al\cite{8} and Zhao et al’s\cite{14} research than Rajaraman et al’s\cite{10} and Mohebbi et al’s\cite{30} research (15 and 14 vs 8.87±4.98 and 11.5±6.5d). From the above statistics, it is hard for us to distinguish that is the suture depth or the injection agents the decisive factor for accelerating corneal oedema resolution. Because the PDS group used air while the FTS group used gas. So in our study, all patients were injected air in the AC. The result showed that the meantime for corneal

<p>| Table 2 Baseline and postoperative stands for maximum corneal thickness |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline (mm)</th>
<th>1wk (mm)</th>
<th>1mo (mm)</th>
<th>3mo (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTS-AI</td>
<td>2.04 (1.82, 2.26)</td>
<td>0.9 (0.86, 0.96)</td>
<td>0.59 (0.53, 0.7)</td>
<td>0.44 (0.4, 0.54)</td>
</tr>
<tr>
<td>P$^a$</td>
<td>-</td>
<td>1.000</td>
<td>0.171</td>
<td>0.006</td>
</tr>
<tr>
<td>P$^a$</td>
<td>-</td>
<td>1.000</td>
<td>0.086</td>
<td>0.001</td>
</tr>
<tr>
<td>P$^a$</td>
<td>0.686</td>
<td>0.886</td>
<td>1.000</td>
<td>0.486</td>
</tr>
</tbody>
</table>

FTS-AI: Full-thickness sutures combined with intracameral air injection; PDS-AI: Pre-Descemet’s membrane sutures combined with intracameral air injection. Bonferroni-modified $P$ value was reported to occupy various comparisons. $^a$Intragroup comparison with baseline; $^b$Intragroup comparison.

<p>| Table 3 Baseline and postoperative best modified visual acuity (logMAR) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline</th>
<th>1wk</th>
<th>1mo</th>
<th>3mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTS</td>
<td>2.19 (1.85, 2.3)</td>
<td>1.27 (1.22, 1.4)</td>
<td>0.91 (0.92, 1.22)</td>
<td>0.73 (0.9, 1.0)</td>
</tr>
<tr>
<td>P$^a$</td>
<td>-</td>
<td>1.000</td>
<td>0.120</td>
<td>0.001</td>
</tr>
<tr>
<td>P$^a$</td>
<td>-</td>
<td>1.000</td>
<td>0.171</td>
<td>0.006</td>
</tr>
<tr>
<td>P$^a$</td>
<td>0.343</td>
<td>1.000</td>
<td>0.686</td>
<td>0.343</td>
</tr>
</tbody>
</table>

FTS-AI: Full-thickness sutures combined with intracameral air injection; PDS-AI: Pre-Descemet’s membrane sutures combined with intracameral air injection. Bonferroni-modified $P$ value was reported to occupy various comparisons. $^a$Intragroup comparison with baseline; $^b$Intragroup comparison.
Comparing different compression sutures for corneal hydrops

Oedema resolution is still longer in the PDS-AI group than the FTS-AI group (15±1.41 vs 11±1.15d). Hence, we suspect this is related to the early recovery of corneal endothelium pump. On the other hand, no obvious difference was found in BCVA and the maximum corneal thickness of the scarred area at 3mo after surgery. Considering the potential damage to the endothelium cells in the FTS group, just a few days earlier oedema resolution time and the similar outcomes of BCVA and corneal thickness, we prefer PDS-AI management in treating acute corneal hydrops to avoid unnecessary endothelium cell damage.

This research has several limitations such as small sample size and retrospective nature. Besides, using a slit-lamp to estimate the corneal oedema resolution is subjective. Nevertheless, because both groups have the same difference, this may not be a great concern. Additionally, we did not evaluate the status of endothelium cells before or after the operation. In future study, if possible, comparing the clinical and histopathological correlation between the two surgical procedures may be more instructive.

FTS-AI and PDS-AI are safe and effective therapies to reduce the period of corneal oedema in acute hydrops secondary to keratoconus. Despite the less time for corneal oedema resolution in the FTS-AI group, we recommend PDS-AI to avoid potential endothelium cell damage.

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