The Effect of Nebulized Dorzolamide/Timolol Fixed Combination Mist versus Drops on Retrobulbar Blood Flow and Intraocular Pressure in Glaucoma Patients

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Key Words: nebulized mist; dorzolamide/timolol fixed combination; retrobulbar blood flow; intraocular pressure; primary open-angle glaucoma.

Summary. Objective. The aim of this study was to evaluate intraocular pressure (IOP), retrobulbar blood flow (RBF), and ocular side effects after the application of topical dorzolamide/timolol (DTFC) drops vs topical nebulized DTFC mist in patients with primary open-angle glaucoma.

Material and Methods. A total of 15 POAG patients were enrolled in a prospective study. Retrobulbar blood flow was measured in the ophthalmic (OA) and central retinal (CRA) arteries using color Doppler imaging. DTFC mist or drops were applied to the experimental eye, and it was examined after 15 and 60 minutes. DTFC mist was applied 6 times for 30 seconds using a misting device.

Results. DTFC mist significantly increased peak-systolic (PSV) and end-diastolic (EDV) velocities after 15 and 60 minutes in both the arteries (OA: increase of 12.5% and 9.6% in PSV, P=0.01; increase of 25.8% and 23.1% in EDV, P=0.03; CRA: increase of 11.5% and 8.7% in PSV, increase of 32% and 21.6% in EDV, respectively, P<0.05). DTFC drops had a similar effect on PSV and EDV in the CRA after 15 and 60 minutes (increase of 8.1% and 9.6% in PSV; increase of 17.1% and 23% in EDV, respectively, P=0.03), but a significant effect on PSV and EDV in the OA was documented only after 15 minutes (increase of 9% and 21.4%, respectively, P=0.02). DTFC mist reduced the resistance index in the CRA after 15 and 60 minutes (decrease of 8.5% and 10.2%, respectively, P=0.04). Both methodologies showed a significant decrease in IOP after 15 and 60 minutes (P<0.05). All patients complained of ocular irritation after drop application, and 1 patient complained of general weakness after mist treatment.

Conclusions. Nebulized DTFC mist significantly reduced IOP and increased blood flow in the OA and the CRA, causing no ocular irritation as compared with traditional DTFC drop methodology.

Introduction

Primary open-angle glaucoma (POAG) is a progressive optic neuropathy that leads to the loss of retinal ganglion cells and optic nerve damage (1). Although glaucoma is a multifactorial disease, elevated intraocular pressure (IOP) remains the most important known risk factor (2). Clinical studies have demonstrated that certain patients with POAG suffer from reduced ocular blood flow (OBF), which may be primarily of vascular origin or secondary to IOP elevation (3, 4). Some authors have hypothesized that the death of retinal ganglion cells and the optic nerve head may be due to ischemia as a result of elevated IOP or reduced oxygen supply because of reduced blood flow (5–8).

The conventional treatment of POAG is the topical application of IOP-lowering drugs. It is known that certain drugs, even formulated in an eye drop, may have an impact on OBF and its regulation. Some data support increased blood flow and the enhancement of OBF regulation with carbonic anhydrase inhibitors. These appear to exceed a pressure-lowering effect alone. Several studies have shown the capability of dorzolamide to increase various OBF parameters (9–14), although other studies have failed to show a similar effect (15–17). A vasodilative effect of dorzolamide might be explained by induced acidosis in local tissues. Contrary to dorzolamide, timolol may cause vasoconstriction by blocking β-2 receptors. Some studies reported that a single instillation of timolol did not have a significant effect on retrobulbar blood flow (RBF) (18–21). It has been shown that the addition of dorzolamide to timolol monotherapy decreases IOP and increases retinal

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blood flow in the superficial retinal vasculature in both healthy patients and patients with POAG (9).

IOP-lowering eye drops pose several problems of drug delivery. First, the exposed anterior ocular surface has limited permeability and is continuously washed by tear fluid. Due to the limited permeability of the ocular surface and natural clearance and drainage, eye drops usually contain large amounts of active ingredients, which are potentially wasted. To resolve permeability problems in the eye, penetration enhancers are often added to topical pharmaceutical compositions, which are known as irritants potentially causing severe ocular irritation (22). Due to an unpleasant nature and difficulty of the instillation process, patients show lower compliance with treatment regimens. The topical administration of medications in a drop form also increases the possibility of causing corneal abrasion due to an inadvertent contact of the bottle tip with the cornea.

Attempting to overcome the current disadvantages of eye drops and to improve the administration of eye drugs, research on the application of misting has been started. The application of medications to the eyes using nebulized mist may have an advantage of accurate dosing, economical use of active ingredients with increased bioavailability of active compounds, increased patient compliance, and reduced risk of corneal abrasion as compared with the current drop methods.

The aim of our study was to compare the effects of topical DTFC drops and topical nebulized topical dorzolamide/timolol fixed combination (DTFC) mist on IOP and RBF and evaluate complaints in POAG patients.

Material and Methods
A total of 15 POAG (30 eyes) patients were enrolled into a prospective, open-label, cross-over clinical trial. The study procedures were carried out according to the Declaration of Helsinki, and the study protocol was approved by the Medicine Review Board, Lithuanian University of Health Sciences (BE2.9). The Department of Ophthalmology, Indiana University School of Medicine, provided services as the data analysis center for RBF images. The study objectives and methods were explained to all patients before the examination. All the patients signed an informed consent form.

The inclusion criteria were as follows: 1) adult patients aged more than 18 years with a diagnosis of POAG or ocular hypertension; 2) willingness to sign informed consent before the study; and 3) best-corrected visual acuity of Snellen equivalent of 20/40 or better.

The exclusion criteria were as follows: 1) mean deviation lower than or equal to –12 dB in Humphrey Visual Fields central 24-2 SITA Standard; 2) the cup-to-disc ratio equal or greater than 0.9; 3) previous eye diseases other than refractive error; 4) previous orbital or ocular trauma; 5) previous renal, hepatic, or respiratory diseases and asthma; 6) previous allergy to either of the study medications; 7) pregnancy or breastfeeding; and 8) contraindications to DTFC.

The color Doppler imaging (CDI; Accuvix, Korea) system was used for RBF measurements in the ophthalmic (OA) and central retinal (CRA) arteries. In each vessel, peak systolic velocity (PSV) and end-diastolic velocity (EDV) were determined, and the resistive index (RI) was calculated.

The patients attended the Clinic of Ophthalmology, Hospital of Lithuanian University of Health Sciences, for 2 study visits, each lasting about 1 hour. At enrollment, all the patients received timolol maleate monotherapy in both eyes. After baseline timolol measurements (IOP and RBF), the patients were randomly assigned for the application of DTFC drops or mist for the first treatment (right eye) and were crossed-over to the alternative arm during the second visit (left eye). After the DTFC drop/mist application, the patients were laid down for 15 minutes; IOP was measured in the supine position using a Tonopen applation tonometer (Reichert, USA), and RBF was examined. After 1-hour rest, all the measurements were repeated. The patients’ eyes were washed out with timolol maleate for 1 week, and a second set of baseline measurements were performed. After the baseline measurements, DTFC mist or drops were applied to another eye (left eye), and the same examinations as during the first visit were carried out after 15 and 60 minutes (Fig.). Nebulized DTFC mist was applied 6 times for 30 seconds using a misting device. Topical DTFC drops (Cosopt, Merck&Co; INC, Whitehouse station, USA) were given from a traditional bottle.

Statistical data analysis was performed by using the SPSS 17.0 program for Windows. All variables were described by descriptive statistics. The analysis of the quantitative variables included calculation of the mean (SD). Continuous data were compared by the Student t test for independent samples. The nonparametric Mann-Whitney test was used when the assumption of normal data distribution was rejected. The paired t test was used to evaluate the difference between the two variables for each case to see if the average difference is significantly different from zero. The level of significance was set at $P<0.05$.

Results
A total of 15 POAG patients (73.3% of women and 26.7% of men) with a mean age of 62.4 (SD, 11.3) years were enrolled into the study. The char-
characteristics of patients are shown in Table 1. The mean duration of glaucoma treatment was 3.3 years (SD, 3.9). The mean best-corrected logMar visual acuity was 0.26 (SD, 0.2), and no significant differences in visual acuity measured during both the visits were documented. Moreover, there were no significant differences in IOP and RBF measured at the baseline between the eyes ($P>0.05$).

Both treatment methodologies showed a significant decrease in IOP after 15 and 60 minutes. IOP decreased by 5.7% ($P=0.01$) after 15 minutes and by 10.2% ($P=0.002$) after 60 minutes using DTFC mist, and by 4% ($P=0.01$) and 9.3% ($P<0.001$), respectively, using DTFC drops.

Changes in RBF velocities and the RI after the application of different DTFC methodologies are shown in Table 2. The application of DTFC mist showed a significant increase in velocities in the CRA and the OA as compared with the baseline measurement after the application of timolol ($P<0.05$). DTFC mist also reduced the RI in both vessels, but a significant effect was seen just in the CRA after 15 (a decrease by 8.5%, $P=0.01$) and 60 minutes (a decrease by 10.2%, $P=0.04$).

The application of DTFC drops had a similar effect on PSV and EDV in the CRA after 15 and 60 minutes ($P<0.05$) (Table 2). However, a significant effect PSV and EDV in the OA was seen only after 15 minutes (an increase in PSV and EDV by 9%)

**Table 1. Patients’ Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4 (26.7)</td>
</tr>
<tr>
<td>Female</td>
<td>11 (73.3)</td>
</tr>
<tr>
<td>Age, mean (SD) [range], years</td>
<td>62.4 (11.3) [38–76]</td>
</tr>
<tr>
<td>Glaucoma treatment, mean (SD), years</td>
<td>3.3 (3.9)</td>
</tr>
<tr>
<td>Systemic medications</td>
<td></td>
</tr>
<tr>
<td>Beta blockers</td>
<td>6 (40)</td>
</tr>
<tr>
<td>ACE inhibitors</td>
<td>4 (26.7)</td>
</tr>
<tr>
<td>Angiotensin II inhibitors</td>
<td>1 (6.7)</td>
</tr>
<tr>
<td>Aspirin</td>
<td>4 (26.7)</td>
</tr>
<tr>
<td>Other drugs</td>
<td>5 (33.3)</td>
</tr>
</tbody>
</table>

Values number (percentage) unless otherwise stated. ACE, angiotensin-converting-enzyme.

**Table 2. Changes in Color Doppler Imaging Parameters Applying Different Treatment Methodologies**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mist Application, %</th>
<th>Drop Application, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After 15 min</td>
<td>After 60 min</td>
</tr>
<tr>
<td>OA PSV, cm/s</td>
<td>↑ 12.5*</td>
<td>↑ 9.6*</td>
</tr>
<tr>
<td></td>
<td>↓ 2.3</td>
<td>↓ 3.1</td>
</tr>
<tr>
<td>EDV, cm/s</td>
<td>↑ 25.0*</td>
<td>↑ 23.1*</td>
</tr>
<tr>
<td>RI</td>
<td>↓ 8.5*</td>
<td>↓ 10.2*</td>
</tr>
<tr>
<td>CRA PSV, cm/s</td>
<td>↑ 11.5*</td>
<td>↑ 8.7*</td>
</tr>
<tr>
<td></td>
<td>↓ 3.2*</td>
<td>↓ 5.0</td>
</tr>
<tr>
<td>EDV, cm/s</td>
<td>↑ 32.0*</td>
<td>↑ 21.6*</td>
</tr>
<tr>
<td>RI</td>
<td>↓ 8.5*</td>
<td>↓ 10.2*</td>
</tr>
</tbody>
</table>

OA, ophthalmic artery; CRA, central retinal artery; PSV, peak systolic velocity; EDV, end diastolic velocity; RI, resistive index. *$P<0.05$, a significant change comparing the timolol baseline values and those after 15 or 60 minutes (paired-sample t test).
changes in RBF using ocular irritants in healthy patients (24).

Our pilot study shows a vast therapeutic potential for improved noninvasive delivery methods of glaucoma medications to ocular tissues. This advancement in drug delivery holds the potential to increase patient compliance and more important an increase in retrobulbar circulation, also avoiding unpleasant ocular irritation.

Conclusions
Nebulized topical dorzolamide/timolol fixed combination mist significantly reduced intraocular pressure and increased blood flow in the ophthalmic and central retinal arteries, causing no ocular irritation as compared with the traditional topical dorzolamide/timolol fixed combination drop methodology.

Acknowledgments
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Conflict of Interest
I.J. receives research grants from MSD, Santen, Pharmalight and serves as a lecturer and consultant for Alcon, Allergan, MSD, Santen.

A.H. received remuneration from MSD and Alcon for serving as a lecturer and Merck, Pharmalight, Sucampo Pharmaceuticals, XLVision, Nanoretina and ONO Pharmaceuticals, for serving as a consultant. The investigator also holds an ownership interest Adom (which all relationships above are pursuant to IU’s policy on outside activities).

No competing financial interests exist.

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