**Effect of Topical Anesthesia on Episcleral Venous Pressure in Normal Human Subjects**

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Submitted: December 23, 2014
Accepted: March 25, 2015

Citation: Malihi M, McLaren JW, Sit AJ. Effect of topical anesthesia on episcleral venous pressure in normal human subjects. Invest Ophthalmol Vis Sci. 2015;56:2968–2970. DOI: 10.1167/iovs.15-16325

**PURPOSE.** Topical anesthetics can reduce episcleral venous pressure (EVP) and IOP in rabbits. In this study, we investigated the effect of topical anesthesia on EVP in normal human subjects.

**METHODS.** We included in this study 30 eyes of 15 healthy volunteers who were habitual soft contact lens wearers. The EVP was measured before and at 5 and 10 minutes after instillation of topical proparacaine 0.5% in one eye. The EVP was measured by using a custom objective venomanometer. We compared EVP at 5 and 10 minutes after proparacaine to EVP before instilling proparacaine.

**RESULTS.** There was no significant difference between EVP in eyes receiving topical anesthetic at 5 or 10 minutes (7.2 ± 2.2 and 7.6 ± 2.7 mm Hg, respectively; mean ± SD) compared to contralateral eyes (6.9 ± 2.5 and 7.3 ± 2.6 mm Hg, respectively; P = 0.10). As well, EVP was not significantly different 5 or 10 minutes after topical anesthesia compared to baseline in either the eyes receiving anesthetic or the contralateral eyes (all P > 0.10; minimum detectable difference, 1.4–1.9 mm Hg, α = 0.05, β = 0.20, n = 30 eyes).

**CONCLUSIONS.** The EVP in human eyes is not affected significantly by topical anesthetics.

Keywords: episcleral venous pressure, aqueous humor dynamics, intraocular pressure

Glaucoma is a pressure-sensitive, chronic progressive optic neuropathy, and a leading cause of visual loss and blindness. The only currently available treatment for glaucoma is reduction of IOP by modifying the physiologic variables that determine IOP. The contributions of these variables to steady-state IOP is best described by the modified Goldmann equation

\[ IOP = \frac{1}{c} (Q - U) + EVP, \]

where \( Q \) is the rate of aqueous humor formation, \( IOP \) is the intraocular pressure, \( EVP \) is the episcleral venous pressure, \( c \) is the conventional outflow facility, and \( U \) is the pressure-insensitive uveoscleral outflow rate. This model distinguishes the two paths of aqueous humor loss from the eye, the trabecular route, and the uveoscleral route. Flow through the uveoscleral route is thought to be insensitive to pressure, while aqueous humor flow rate through the trabecular route depends on a hydrostatic pressure difference (\( IOP - EVP \)) and the resistance to aqueous outflow (\( 1/c \)). Itraocular pressure is easily measured in the clinic, although EVP is much more difficult to measure. Nevertheless, accurate estimates of EVP are critical to understanding aqueous humor dynamics and are necessary to calculate the flow rate through the uveoscleral path.\(^1–4\) Episcleral venous pressure has been measured invasively by direct cannulation of episcleral veins in animals,\(^5–8\) but in humans it must be measured noninvasively by measuring the pressure required to collapse an episcleral vein to a predetermined endpoint.\(^2,6–9,11\) This measurement generally requires topical anesthesia.

The effect of topical anesthesia on EVP in humans is unknown. Zamora and Kiefe\(^6\) reported a significant decrease in the EVP in rabbits after instilling topical proparacaine, while they measured pressure directly in a cannulated episcleral vein. A similar effect in human eyes, if it exists, could bias our measurements of IOP under topical anesthesia. It also would influence the calculation of aqueous humor dynamics parameters, such as uveoscleral outflow. In this study, we measured EVP in human volunteers before and after topical proparacaine anesthesia.

**MATERIALS AND METHODS**

Healthy subjects who were habitual soft contact lens wearers with refractive errors ranging between −4.00 and +2.00 diopters, were recruited from students and employees of Mayo Clinic, Rochester, MN, USA and local area residents. All subjects underwent a complete dilated eye examination, and individuals with glaucoma, IOP of 22 mm Hg or above, history of intraocular surgery or trauma, retinal pathology, diabetes, or current use of beta blockers or corticosteroids were excluded. In addition, subjects who could not tolerate the touch of the measurement tip of the episcleral venomanometer against their conjunctiva without topical anesthesia were excluded. Habitual soft contact lens wearers were selected for this reason. Participants were asked to avoid excess caffeine intake or large deviations from their normal sleep cycle on the day of the examination. All subjects provided written consent to participate after discussion of the risks of the study. Our study followed the Declaration of Helsinki (1989) and was approved by Institutional Review Board at Mayo Clinic.

**Measurement Protocol**

The study was completed in two visits. On the first visit, baseline EVP was measured in both eyes without topical anesthesia. Subjects then were assigned to receive one drop of topical proparacaine 0.5% randomized to the right or left eye. Episcleral...
Table. Episcleral Venous Pressure With and Without Topical Anesthetic

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<thead>
<tr>
<th>Eye</th>
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<tbody>
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Episcleral venous pressure was measured at 5 or 10 minutes after topical anesthesia. The measurement was synchronized with pressure inside the chamber. Image recorded by a high-definition video camera. Each video frame was synchronized with pressure inside the chamber. Image analysis software was used to determine changes in the vessel brightness and the pressure in the chamber when the vessel just began to collapse was assumed to be equal to the EVP.12

Computerized Venomanometry

The method for measuring EVP has been described in detail elsewhere.2 In brief, through a slit-lamp biomicroscope, episcleral veins were identified as vessels that were straighter and deeper than conjunctival vessels and often were bifurcated. The transparent inflatable chamber of the venomanometer was placed against the conjunctiva over the area of the episcleral vein, and a computer-controlled motor drive pressurized the measurement tip at a constant rate. As the pressure increased, the vein collapsed, and this process was recorded by a high-definition video camera. Each video frame was synchronized with pressure inside the chamber. Image analysis software was used to determine changes in the vessel brightness and the pressure in the chamber when the vessel just began to collapse was assumed to be equal to the EVP.12

Statistical Analysis

This study was powered to detect a 20% decrease in EVP after treatment with topical anesthesia, assuming a starting pressure of 7.6 ± 2.6 mm Hg (mean ± SD).3 In comparison, Zamora and Kiel8 reported a 30% decrease in EVP after application of topical anesthetic. A sample size of 30 eyes of 15 wearers who were tolerant of eye contact by the venomoter was used. The subjects gave a 95% chance of finding a difference of 1.4 mm Hg.

RESULTS

We included 30 eyes of 15 volunteers in the study. Subjects included 12 females and 3 males, all regular contact lens wearers who were tolerant of eye contact by the venomanometer tip without anesthesia. Mean age was 32.8 ± 12.0 years (range: 20–53 years). All subjects were Caucasian (reflecting the ethnic profile of Olmsted County, MN, USA, and the surrounding area) and low myopes, with a mean refractive error of –2.7 ± 0.7 diopters (spherical equivalent).

The Table summarizes the EVP measurements before and after instillation of topical anesthetic drops. There was no significant difference in the best estimate of EVP between eyes that received anesthetic and contralateral eyes based on repeated measures ANOVA (P = 0.53). As well, there was no significant difference in the best estimate of EVP between the right and left eyes (7.1 ± 2.6 and 7.2 ± 2.6 mm Hg, respectively, P = 0.9).

There was no overall difference between EVP in the anesthetized-treated and contralateral eyes (P = 0.53). For eyes that received topical anesthetic, the baseline estimate of EVP at 0% vessel compression was 7.5 ± 2.8 mm Hg. At 5 and 10 minutes after receiving anesthetic, there was no significant change in the EVP (7.2 ± 2.2 and 7.6 ± 2.7 mm Hg, P = 0.53 and P = 0.49, respectively). Similarly, with all other compression endpoints, mean EVP 5 or 10 minutes after topical anesthesia was not significantly different from EVP at baseline in either the eye that received anesthetic or the contralateral eye (P > 0.10; minimum detectable difference, 1.4–1.9 mm Hg, $\alpha = 0.05, \beta = 0.20, n = 30$ eyes).

DISCUSSION

Our study did not detect any effect of topical anesthetic on EVP in humans, in contrast with the significant decrease in the EVP after instillation of proparacaine in rabbits reported by Zamora and Kiel.8 Several differences between rabbits and humans could explain this observation.

The most obvious difference between the two studies, other than the species, was the methods used to measure EVP. In the animal studies, EVP was measured directly by vessel cannulation, a method that cannot be used in humans. However, EVP measured in humans by using earlier “pressure chamber” techniques is subject to a number of limitations.2,3 This measurement is primarily limited by the variability and imprecision associated with the lack of a clear endpoint to indicate when a vessel has collapsed by a specific amount, or more critically, when the vessel has just begun to collapse, which indicates that the applied pressure is equal to the venous pressure. As well, manually-operated devices can be biased by the user because the user can feel the rotation of the pressure dial during the measurement and can inadvertently (and subconsciously) adjust the dial position by the appearance of the vein. The subjectivity of this measurement makes detection of small changes in EVP difficult. In our study, we used an objective technique for computerized venomanometry, based on the same principles as the older methods, but with the chamber pressure being increased at a constant rate by a motor drive, and the collapse of the vein being recorded in a video stream. Each video frame was synchronized with a pressure measured by a pressure transducer. Image processing techniques permitted objective identification of EVP at the very beginning of vessel collapse, which provides the best estimate of EVP based on ideal tube laws and previous studies by Gaasterland and Pederson.2,7 Although other endpoints may provide overestimates of EVP, they may still be used to assess changes, and similar analyses for the 90% and 50% patency endpoints also showed no significant difference after application of topical anesthetic drops.

Zamora and Kiel8 suggested that the episcleral circulation is under tonic neural control and that either an upstream resistance site is under tonic vasodilatory control or a downstream site is under vasoconstrictor control. If either of these sites were blocked by topical anesthetic, EVP would decrease. This is consistent with the effect of other vasoactive substances, such as nitroprusside, verapamil, or nitric oxide on episcleral veins.13–16 The lack of a decrease in EVP after topical application of proparacaine in human subjects in our study can

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Episcleral venous pressure was measured at 5 or 10 minutes after topical anesthesia was not significantly different from EVP at baseline in either the treated eye or in the contralateral eye.
be explained by several factors. First, the intact conjunctiva in our subjects may have reduced penetration of anesthetic to the episcleral vessels. In contrast, invasive techniques in animal studies involve cannulation of episcleral veins after removal of the overlying conjunctiva, exposing the veins to higher concentrations of anesthetic. This may have produced the transient drop in EVP reported by Zamora and Kiel,8 but absent in our study. Second, in animal studies, the use of general anesthesia may have altered the neurohumoral balance of the episcleral veins, rendering them more susceptible to anesthetic effects. Third, the anatomy and physiology of the episcleral veins and their role in IOP hemostasis in rabbits may be different from that in human eyes. Fourth, Zamora and Kiel8 only applied topical anesthetic to a small region of the eye. The episcleral vasculature forms a plexus, and localized application of topical anesthetic may have induced a local vasoconstriction or vasodilation of episcleral vessels and changes in EVP in a small region. This could potentially lead to shunting of blood to other regions, reducing local EVP. In contrast, diffuse application of topical anesthetic over the entire surface of the eye in humans may result in no generalized decrease in EVP. It also is possible that chronic contact lens use that was sufficient to desensitize the afferent nerves in the limbal region (and allow tolerance to touch without anesthetic) could potentially modify the efferent nerves and mask a neurogenic response. Finally, it is possible that our subjects experienced a small decrease in EVP that was not detected by our sample size.

Zamora and Kiel8 also reported a decrease in IOP after applying topical anesthetic, although the magnitude of this decrease was less than that of EVP. Similarly, Sarchahi and Bozorgi17 reported a significant decrease in IOP (more than 33%) in rabbits 10 minutes after use of topical anesthetics. In humans, however, instilling topical anesthetics appears to have a smaller effect on IOP. While some investigators have suggested a small decrease in IOP with topical anesthetics, others have found no change.20 As well, some studies have suggested that topical anesthesia may result in changes in corneal thickness, and this could artifactually change the IOP measurement.20–22 In our study, we did not measure IOP in order to avoid the risk of possible effects of ocular manipulation on EVP. However, our results suggested that if topical anesthetics reduce IOP in humans, the reduction is unlikely to be caused by a change in EVP.

Finally, there was no difference compared to baseline in EVP at 5 or 10 minutes after topical anesthesia in either the treated or untreated eyes. This suggests that topical anesthesia has no delayed effect, and that EVP estimates are not affected by repeated measurements.

In summary, measurement of EVP in humans is not affected by topical anesthesia, either directly or by systemic absorption. This provides reassurance that EVP measured noninvasively but with topical anesthetic can be used in investigations of aqueous humor dynamics, particularly for calculating uveoscleral flow, which cannot be measured directly. In studies of aqueous humor dynamics in humans, topical anesthetic will not inadvertently alter EVP or induce spurious results.

Acknowledgments

Presented in part at the annual meeting of the Association for Research in Vision and Ophthalmology, Fort Lauderdale, Florida, United States, May 2011.

Supported in part by BrightFocus Foundation (AJS), unrestricted departmental grant from Research to Prevent Blindness, the Mayo Foundation for Medical Education and Research, and by a Schaub Special Scholar award from Research to Prevent Blindness (AJS). The authors alone are responsible for the content and writing of the paper.

Disclosure: M. Malahi, None; J.W. McLaren, None; A.J. Sit, None

References