Radial Optic Neurotomy Using Nasal and Temporal Approach Incisions

Histopathologic Study in Human Cadaver Eyes

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Objective: To examine the structural effect of radial optic neurotomy (RON) using nasal and temporal approach incisions on the nasal side of the optic nerve (ON) using dominant and nondominant hands in human cadaver eyes.

Methods: Transvitreal RON was performed in 9 eyes with a microvitreoretinal blade by a right-handed surgeon. A nasal approach was used in 4 left eyes (using the right hand) and in 2 right eyes (using the left hand), and a temporal approach was used in 3 right eyes (using the right hand). Histologic sections were examined for depth of nerve penetration and for effect on critical structures.

Results: The scleral canal was fully incised in all cases. The mean depth of nerve penetration was 555 µm (725 µm using the nasal approach and 246.7 µm using the temporal approach) (P = .12). The globe was not ruptured in any eye. In a single right eye approached temporally using the right hand, the adventitial sheath of the central retinal artery was lacerated.

Conclusions: RON in human cadaver eyes results in lysis of the scleral canal at the ON head. Greater depth and improved safety of incision can be achieved by always approaching the incision from the nasal side of the ON using the dominant or nondominant hand.

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T RANSVITREAL RADIAL OPTIC neurotomy (RON) has recently been described as a surgical management for central retinal vein occlusion,1-7 combined choroiretinal artery and central retinal vein occlusion,8 and nonarteritic anterior ischemic optic neuropathy,9 as well as for the treatment of acute functional impairment associated with optic nerve (ON) drusen.10 The rationale of RON in central retinal vein occlusion is to alleviate the compartment syndrome that led to occlusion of the central retinal vein, which is housed within the inelastic scleral outlet.1 RON transvitreally penetrates the scleral ring and lamina cribrosa at the level of the proposed location of the thrombus.11

The mechanism of action of neurotomy is uncertain and has been questioned by some authors.12 Complications associated with this procedure are visual field defects, vitreous hemorrhage, subretinal hemorrhage, peripapillary retinal detachment, and choroidal neovascularization.13-17 There are few studies2-10 on the histopathologic effects of RON.

It is hypothesized that incision of the full depth of the scleral canal at the ON will allow better blood flow in the central retinal vein in a compartment syndrome model. Because RON is a traumatic procedure performed on delicate and critical structures, safety should be considered before effectiveness. The objectives of the present study were to examine histologically the effects of such incisions on human cadaver eyes and to correlate the nasal and temporal approaches for performing RON on the nasal side of the optic disc using the dominant and nondominant hands in terms of depth and width of ON penetration, vessel wall damage, and globe perforation.

METHODS

Nine human cadaver eyes were selected with consent from the institutional eye bank for the RON procedure by a right-handed surgeon (M.A.A.) using an unmodified 20-gauge microvitreoretinal (MVR) blade having sharp edges on both sides in a transvitreal approach. Following removal of a sclerocorneal button with limbal margins, 2 sclerotomies were created using the MVR blade for the introduction of a fiberoptic light probe and a 20-gauge MVR blade. An operating microscope was used for visualization and illumination. A radial incision into the nasal margin of the ON was performed using the MVR blade without removal...
of the vitreous. A nasal approach was used in 4 left eyes (using the right hand) and in 2 right eyes (using the left hand) (Figure 1A and B), and a temporal approach (Figure 2) was used in 3 right eyes (using the right hand).

All tissue samples were embedded in paraffin, and 5-µm sections were obtained in various orientations (1 axial, 1 sagittal, and 7 coronal). Microscopic examination of permanent hematoxylin-eosin slides was used to assess for scleral canal incision and to determine whether damage to ON vasculature occurred. The mean ON area of decompression was measured using commercially available software (Optimus version 6.5; Media Cybernetics, LP, Silver Spring, Maryland). The depth of ON penetration was measured by counting the number of serial sections comprising the incision and then multiplying by 5 µm per section to determine the total depth of ON penetration (Figure 3). Using the Optimus viewer, the mean ON area of the proximal-most slide containing the incision and the distal-most slide containing the incision was taken to calculate the mean ON area (Figure 4A, B, and C). Every fourth section within the incision was viewed using the Optimus viewer, the areas of intra-ON incision (decompression area) were measured, and the areas were averaged to calculate the mean decompression area. The percentage decompression area was calculated as the ratio of the mean decompression area divided by the mean ON area. All incision slides were reviewed; the slide with the greatest radial ON incision length was determined and was measured linearly to obtain the maximum length of ON penetration. This incision was then measured circumferentially, and this was recorded as the maximum width of ON penetration. Finally, the incision slides were reviewed, and the greatest length of aggregate ON and retinal and scleral incision was determined and was measured linearly to calculate the maximum cut length.

RESULTS

In 7 eyes, coronal sections were of adequate quality for complete analysis. In 2 eyes, the axial and sagittal sections provided information on depth of penetration and potential damage to critical structures (Table). In 8 of 9 eyes, the central retinal vein and artery remained undisturbed. In a single right eye approached from the temporal side using the right hand, the adventitial sheath of the central retinal artery was lacerated, while the lumen, tunica media, and tunica intima were unaffected (Figure 5). The scleral canal was fully incised in all cases, with a mean depth of 555 µm. The mean depth of ON penetration was 725 µm in eyes in which the nasal approach was used and 246.7 µm in eyes in which the temporal approach was used (P = .12). The mean area of ON decompression was 1.12% of the ON area. The nerve fiber layer was minimally disrupted in all eyes. The globe was not ruptured in any eye.
In addition to containing the ON, the scleral outlet is the space through which the central retinal artery and central retinal vein pass into and out of the eye. The scleral outlet contains the lamina cribrosa and is encompassed by the scleral ring. As the ON approaches the eye, it consists of myelinated nerve fibers, central retinal artery, and central retinal vein and has a diameter of 3.0 mm. However, the internal diameter of the optic disc and scleral outlet is 1.5 mm. Therefore, it has been suggested that relaxation of the scleral outlet by RON might be an effective surgical treatment option for scleral outlet compartment syndromes, including central retinal vein occlusion. In view of the potential serious complications of RON, Opremcak et al stressed the importance of a consistent incision; the incision is created in a radial fashion using an MVR blade on the nasal side of the optic disc, approaching the center of the cribriform plate with an insertion depth of just beyond the widest portion of the diamond-shaped tip. Modifications of the MVR blade using a blunt lancet and a guarded RON knife have also been used to produce a safe incision. Although care should be taken to avoid major retinal vessels, it can be difficult to do so, and a case of central retinal artery occlusion has been reported after RON.

Opremcak et al used human cadaveric eyes to investigate the anatomy of the scleral outlet and the best approach to relax the cribriform plate and scleral ring, as well as to determine the location, angle, and depth of penetration using the MVR blade without globe perforation. Measurements for these incisions were not reported. Czajka et al performed histologic examination of the ON after RON in 14 porcine eyes and demonstrated loci of hemorrhage, interstitial edema, reactive gliosis, and rare inflammatory cells with complete axonal nerve fiber loss distal to the neurotomy site at 3 weeks. In a surgical technique study of cadaver human, porcine, and rabbit eyes, Lit et al demonstrated that puncture of the lamina cribrosa using a specially designed lancet tip having a sharp cutting edge on 1 side and an opposing blunt edge was possible without serious injury to the ON. This procedure differs from the technique and instrumentation used during RON. Tao et al studied the histopathologic findings of normal miniature pig eyes after RON and found localized ON atrophy at the incision site.

The histopathologic examination in our study shows that RON in the human cadaver eye reproducibly results in lysis of the scleral canal at the ON head. Damage to the peripheral wall of a major retinal vessel occurred in 1 eye in which the incision was approached temporally. This approach impairs the surgeon’s view of the central retinal vessels (Figure 2). Adverse events such as this can be avoided by always approaching the incision from the nasal aspect of the nerve even if this requires the surgeon to use the nondominant hand (Figure 1). Clear corneal phacoemulsification using the nondominant left hand has been previously shown to be safe and efficacious. The procedure of incising the optic disc once at the nasal aspect using the nondominant hand is comparatively brief and should be safe for many retina surgeons. Comfort with the procedure can be enhanced through wet laboratory practice.

A recent histologic study of 111 human globes found a mean ± SD central lamina cribrosa thickness of 378.1 ± 117.8 µm and a mean ± SD scleral thickness at the optic disc border of 276.7 ± 76.1 µm (range, 120-540 µm). Our study demonstrated a greater mean depth of penetration with incisions created from a nasal approach (725 µm) vs a temporal approach (246.7 µm). Therefore, incisions from a nasal approach are more likely to com-
Figure 5. Photomicrograph of a human cadaveric right eye after radial optic neurotomy approached from the temporal side using the right hand showing that the adventitial sheath of the central retinal artery was lacerated, while the lumen, tunica media, and tunica intima were unaffected (arrow) (hematoxylin-eosin, original magnification ×10).

The histologic findings of RON in human cadaver eyes support the anatomical claims made by originators of the procedure. RON in the human cadaver eye reproducibly results in incision of the scleral canal at the ON head without globe rupture occurring. We cannot conclude from this study if there are secondary changes in the central retinal vein. Damage to major retinal vessels can more reliably be assessed of globe rupture occurring. We cannot conclude from this study if there are secondary changes in the central retinal vein. Damage to major retinal vessels can more reliably be assessed.

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REFERENCES


Table. Characteristics of Radial Optic Neurotomy of Human Cadaveric Eyes in Terms of Incision Approach and Histopathologic Analysis

<table>
<thead>
<tr>
<th>Eye No.</th>
<th>Incision Approach</th>
<th>Section</th>
<th>Optic Nerve Penetration Depth/ Maximum Length/ Maximum Width, µm</th>
<th>Maximum Cut Length, µm</th>
<th>Decompression, %</th>
<th>Scleral Canal Incised</th>
<th>Damage to Vessels</th>
<th>Rupture of Globe</th>
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<tr>
<td>1/Left</td>
<td>Nasal</td>
<td>Coronal</td>
<td>145/634/288</td>
<td>870</td>
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<td>2/Right</td>
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<td>Coronal</td>
<td>525/952/151</td>
<td>1007</td>
<td>1.70</td>
<td>Yes</td>
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<tr>
<td>3/Right</td>
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<td>Coronal</td>
<td>310/688/323</td>
<td>688</td>
<td>1.64</td>
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<tr>
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<td>Coronal</td>
<td>305/676/374</td>
<td>947</td>
<td>1.18</td>
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<td>5/Right</td>
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<td>Coronal</td>
<td>115/393/260</td>
<td>836</td>
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<td>No</td>
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<td>Nasal</td>
<td>Axial</td>
<td>1020/NA/NA</td>
<td>NA</td>
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<td>Yes</td>
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<td>1400/NA/NA</td>
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<td>160/688/172</td>
<td>942</td>
<td>0.73</td>
<td>Yes</td>
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Abbreviation: NA, not available because of artifacts.
Spider Vision

Most spiders are known for excellent mechano-reception, which helps them detect tiny vibrations useful in finding web-entangled prey, but some have remarkable vision rivaling that of humans. Jumping spiders belonging to the genus *Portia* have the highest optical spatial acuity and most complex behavior. They do not spin webs like other spiders; instead they hunt much like cats by spotting, stalking, and pouncing on their prey. These spiders have 2 large principal eyes in the center of their faces (Figure). These eyes are capable of seeing size, color, and shape at distances of up to a foot. There are also 6 secondary eyes located around the sides and back of the body that provide wide-angle vision used for detecting movement. The principal eye of the spider is a telescopic eye tube that has a corneal lens in the front and a second lens in the back (as in a Galilean telescope) that focus light onto a 4-layered retina. The fovea is small and provides only a narrow field of vision that the spiders can build into a detailed image by scanning objects. The visual acuity generated is one-fifth of the visual acuity of human beings, which is enough to recognize (and attack) video images of prey. The spiders can track prey by using muscles to pivot their eye tubes inside their heads. The intricate eye movements may be the key to explaining the complex behavior of animals with such tiny brains. Scientists hope that studying *Portia*’s vision and complex behavior will help in understanding the mechanisms of intelligent behavior and in designing better robots.

*Figure. Portia spider.*