

## Gonioscopy-assisted transluminal trabeculotomy in neovascular glaucoma: Salvaging the conventional outflow pathway

Jacob A. Kanter, Pathik Amin, Rahul Komati, Anna G. Mackin, David Dao, Lincoln T. Shaw, Dimitra Skondra, Mary Qiu\*

Department of Ophthalmology and Visual Science, University of Chicago Medical Center, Chicago, IL, USA

### ARTICLE INFO

#### Keywords:

Neovascular glaucoma  
Gonioscopy-assisted transluminal trabeculotomy  
Peripheral anterior synechiae

### ABSTRACT

**Purpose:** To report a case of acute neovascular glaucoma with partial synechial angle closure secondary to central retinal vein occlusion that underwent gonioscopy-assisted transluminal trabeculotomy as well as near-monthly anti-vascular endothelial growth factor (VEGF) injections and panretinal photocoagulation (PRP) treatments.

**Observations:** Nine months after GATT, the patient had achieved intraocular pressure control on no medications. However, she was lost to follow up for 4 months and received no anti-VEGF or PRP during that time; she re-presented with acute NVG and complete synechial closure, and ultimately underwent aqueous shunt implantation.

**Conclusions and Importance:** To our knowledge, this is the first reported attempt of an *ab interno* angle surgery to successfully restore aqueous outflow through the conventional outflow pathway in an eye with acute NVG and partial synechial angle closure. We posit that this can be an effective approach to achieve IOP control in NVG with at least partially open angles, as long as sufficient anti-neovascular treatments are administered until the underlying neovascular drive achieves quiescence.

### 1. Background

Neovascular glaucoma (NVG) is a secondary glaucoma usually associated with posterior segment ischemia, most commonly proliferative diabetic retinopathy and central retinal vein occlusion (CRVO).<sup>1</sup> The goals of NVG management are (1) regressing active neovascularization and suppressing the underlying source of the neovascular drive and (2) controlling intraocular pressure (IOP) to prevent progressive glaucomatous optic neuropathy.<sup>1</sup> The first goal is achieved through intravitreal anti-vascular endothelial growth factor (anti-VEGF) injections and panretinal photocoagulation (PRP). The second goal often requires IOP-lowering surgery since IOP-lowering medications may be insufficient to control IOP, especially if the angle has started to become synechially closed.

Historically, surgical IOP-lowering strategies in NVG patients included reducing aqueous production via cyclodestructive procedures

and/or increasing aqueous outflow via *ab externo* trabeculectomy or aqueous shunt, and the procedure choice is often guided by ambulatory visual potential. In the setting of NVG, aqueous shunts are generally favored over *ab externo* trabeculectomy due to higher success rates and lower complication rates.<sup>2</sup> However, aqueous shunts also carry with them the potential for serious complications including erosion and infection, corneal decompensation, and hypotony.

Microinvasive glaucoma surgeries (MIGS) were originally introduced as a less invasive treatment option for mild to moderate primary open angle glaucoma (POAG) at the time of cataract surgery, but several angle-based MIGS have been shown to be effective for a variety of open angle glaucomas and have evolved to become a less invasive alternative to trabeculectomy and aqueous shunt surgeries in numerous other clinical scenarios. Angle-based MIGS target the iridocorneal angle and bypass, incise, or excise trabecular meshwork (TM). One such angle-based MIGS is gonioscopy-assisted transluminal trabeculotomy

**Abbreviations:** CRVO, central retinal vein occlusion; GATT, gonioscopy-assisted transluminal trabeculotomy; IOP, intraocular pressure; IVB, intravitreal bevacizumab; MIGS, microinvasive glaucoma surgeries; NVA, neovascularization of the angle; NVG, neovascular glaucoma; NVI, neovascularization of the iris; OD, oculus dexter (right eye); OS, oculus sinister (left eye); PAS, peripheral anterior synechiae; POAG, primary open angle glaucoma; PRP, panretinal photocoagulation; TM, trabecular meshwork; VA, visual acuity; VEGF, vascular endothelial growth factor.

\* Corresponding author. Department of Ophthalmology and Visual Science, University of Chicago Medical Center, 5841 S. Maryland Ave, Chicago, IL, 60637, USA.

E-mail address: [maryqiu@bsd.uchicago.edu](mailto:maryqiu@bsd.uchicago.edu) (M. Qiu).

<https://doi.org/10.1016/j.ajoc.2022.101668>

Received 22 April 2022; Received in revised form 14 July 2022; Accepted 20 July 2022

Available online 31 July 2022

2451-9936/© 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

(GATT), first described by Grover et al., in 2014: a nasal goniotomy is performed, a catheter or suture is inserted into Schlemm's canal and advanced for 360°, the tip is retrieved, and the ends of the catheter are pulled to perform an *ab interno* 360° trabeculotomy. GATT has been reported to be efficacious in a variety of open angle glaucomas, but angle closure (especially synechial angle closure in the setting of NVG) has generally been considered a contraindication to GATT.<sup>3</sup> However, GATT has been successfully performed in the setting of peripheral anterior synechiae (PAS) in chronic angle closure.<sup>4</sup>

Herein we report a case of acute NVG secondary to CRVO that underwent GATT and subsequently achieved medication-free IOP-control for 9 months, during which time the patient received near-monthly intravitreal anti-vascular endothelial growth factor (anti-VEGF) injections as well as PRP. To our knowledge, this is the first reported attempt of an *ab interno* angle surgery to restore aqueous outflow through the conventional outflow pathway in an eye with acute NVG and partial synechial angle closure.

## 2. Case report

A 57-year-old African American female with type II diabetes mellitus and uncomplicated cataract surgery 6 months earlier in the left eye [oculus sinister (OS)] presented with 3 weeks of worsening vision and 2 days of pain in that eye, as well as headache and nausea. The visual acuity (VA) was hand motion, IOP was 45 mmHg on 0 IOP-lowering medications, and the pupil was minimally reactive with a relative afferent pupillary defect by reverse. The cornea had microcystic edema, the anterior chamber was deep and quiet with no hyphema, the iris had 360° of neovascularization of the iris (NVI) at the pupillary margin, and a 1-piece intraocular lens was in the capsular bag. Gonioscopy revealed neovascularization of the angle (NVA) with approximately 50% synechial angle closure. The fundus exam was limited by corneal edema, and B-scan ultrasonography revealed that the retina was attached. Three rounds of topical IOP-lowering medications (timolol, brimonidine, dorzolamide) and oral acetazolamide 500mg were administered, and the IOP improved to 33 mmHg. Anterior chamber paracentesis was performed, and intravitreal bevacizumab (1.25 mg in 0.05 mL) (IVB) was administered. The patient was started on 4 topical IOP-lowering medications OS (dorzolamide, timolol, brimonidine, latanoprost) and oral acetazolamide extended release 500mg 3 times per day.

By day #7 after the acute NVG presentation, VA OS had improved to counting fingers, IOP OS had improved to 13 mmHg on the same 4 topical IOP-lowering medications and oral acetazolamide extended release 500mg 3 times per day, and the NVI was nearly completely regressed; the oral acetazolamide was reduced to 500mg extended

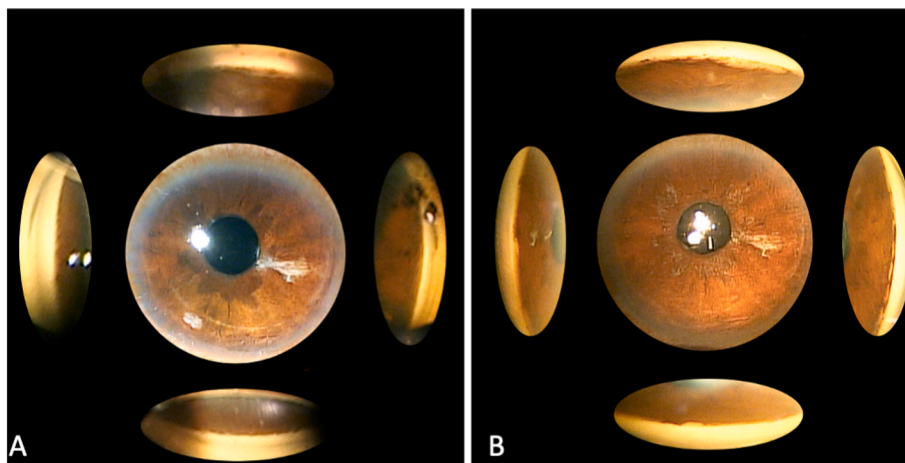
release once per day, and she subsequently underwent PRP OS with the retina service on day #10. By day #35, VA OS had improved to 20/200 (limited by CRVO), IOP OS had risen to 22 mmHg on 5 topical medications (dorzolamide, timolol, brimonidine, latanoprost, netarsudil) and oral acetazolamide 500mg extended release once per day, the NVI and NVA was completely regressed, and gonioscopy revealed that the extent of synechial angle closure had increased to approximately 75% (Fig. 1A), although the anterior aspect of the nasal trabecular meshwork was visible and appeared to be surgically accessible. GATT was offered to restore the physiologic aqueous outflow through the conventional outflow pathway and reduce dependence on medications (especially chronic use of oral acetazolamide) while delaying or avoiding an aqueous shunt. She elected to proceed with GATT and underwent IVB#2 to prevent recurrent NVA in preparation for the upcoming GATT. Due to the need for insurance authorization, the GATT could not be performed until day #54, at which point the IOP OS had risen to 35 mmHg on the same regimen of 5 topical IOP-lowering medications and oral acetazolamide 500mg extended release once per day.

The GATT was performed through a temporal 1.2mm paracentesis with the iTrack illuminated microcatheter (Nova Eye Medical, Adelaide, Australia), with Healon Pro (Johnson & Johnson Surgical Vision, Inc., Santa Ana, California) in the anterior chamber (Video 1). At the end of the surgery, approximately 75% of the Healon Pro was left in the anterior chamber to tamponade reflux bleeding from Schlemm's canal. Intravitreal triamcinolone (2 mg in 0.05 mL) was administered to prevent macular edema and, more importantly, reduce postoperative inflammation which could result in recurrent peripheral anterior synechiae (PAS).

Supplementary video related to this article can be found at <https://doi.org/10.1016/j.ajoc.2022.101668>

On postoperative day 1, IOP was 40 mmHg due to the large amount of Healon Pro which had been purposely left in the anterior chamber; the paracentesis was burped and the IOP improved to 8 mmHg. After the GATT, the patient was recommended to continue monthly IVB injections until enough sessions of fill-in PRP could be performed to permanently suppress the underlying neovascular drive. Due to the patient's transportation difficulties, serial IVBs could not be administered exactly 1 month apart, and the number of days between IVB #3 - #8 was 53 days, 51 days, 33 days, 44 days, 54 days, and 30 days, respectively. There were two occasions when gonioscopy revealed a hint of early recurrent NVA (51 days after IVB#3, and 54 days after IVB#6), which subsequently regressed with prompt same-day IVB. One session of fill-in PRP was performed in between IVB #4 and #5 for recurrent NVA.

By postoperative month 9, which was 11 months after the acute NVG presentation, VA OS was still stable at 20/200, IOP was 16 mmHg on



**Fig. 1.** A) 360-degree gonioscopic view of the patient's left eye following regression of NVA and prior to GATT, revealing approximately 75% synechial closure with the trabecular meshwork visible nasally. B) 360-degree gonioscopic view 9 months following GATT shows scattered PAS, but greater than 50% is anatomically open.

zero IOP-lowering medications, there was no active NVI or NVA, and gonioscopy revealed that there were still some areas with PAS, but the angle was more than 50% open (Fig. 1B). At this point, the physiologic aqueous outflow through the conventional outflow pathway was presumed to be restored by the GATT, and the patient was recommended to continue monthly IVB until more sessions of fill-in PRP could be performed to permanently suppress the underlying neovascular drive.

However, before more sessions of fill-in PRP could be performed, the patient became lost to follow-up for a duration of 4 months, and she re-presented with IOP of 49 mmHg on 0 IOP-lowering medications, recurrent florid NVI and NVA, a 1.5mm layered hyphema, and her angle had become 100% synechially closed. Prompt *trans*-scleral cyclophotocoagulation followed by more serial IVBs, fill-in PRP, and a Baerveldt 350 aqueous shunt (Johnson & Johnson Surgical Vision, Inc., Santa Ana, California) in the sulcus were ultimately required to achieve long-term IOP control and quiescence of the underlying neovascular drive. She ultimately underwent a total of 14 IVBs and 3 PRP sessions. The VA OS remains 20/200 19 months after initial presentation.

### 3. Discussion

Commonly utilized surgical IOP-lowering strategies in NVG patients include aqueous shunts and cyclophotocoagulation.<sup>5</sup> There are many reports on outcomes of valved and non-valved aqueous shunts, *ab externo* trabeculectomy, and cyclophotocoagulation for IOP-control in NVG, but there is a paucity of literature surrounding the feasibility of surgically salvaging the conventional outflow pathway in NVG. In 2013, Nadal et al. described a technique to surgically remove fibrovascular tissue from angles with NVG following anti-VEGF treatment<sup>6</sup> but there are no reports to date about attempting *ab interno* angle-based MIGS techniques in NVG eyes.

While aqueous shunts are commonly regarded as the gold standard IOP-lowering surgery in the setting of NVG, they have a variety of potential complications that include diplopia, iris or cornea chafing, corneal decompensation, tube or plate exposure, tube-associated infections and hypotony-related complications. Furthermore, valved aqueous shunts may become occluded by a fibrovascular stalk of tissue growing into the valve,<sup>7</sup> and excessive encapsulation of endplates may increase the resistance to aqueous outflow and cause IOP to rise. In NVG patients undergoing aqueous shunts, 20–50% either require additional surgeries to control IOP or progress to no light perception within 1–2 years.<sup>8</sup> A recent study of 140 patients with NVG found the average age at the time of aqueous shunt placement to be 65 years<sup>9</sup>; therefore, there could potentially be several decades after aqueous shunt surgery during which the aforementioned complications could occur.

Given the safety and efficacy profile of aqueous shunts in the setting of NVG, we propose that attempting to surgically salvage the conventional outflow pathway with an angle-based MIGS procedure, whenever anatomically possible, may delay or avoid an aqueous shunt and its associated complications. Though GATT has to this point been utilized in open angles, our patient's 9 months of postoperative IOP control show that it can be effective in NVG with PAS, as long as the nasal angle is accessible.

Angle-based MIGS offer the potential to surgically restore the conventional outflow pathway, and a 360-degree GATT is the most extensive amongst the angle-based MIGS procedures. To date, the most widely accepted indications for GATT are primary and secondary open angle glaucomas while the presence of synechial angle closure, especially from a neovascular etiology, is generally considered to be a contraindication for angle-based MIGS. To our knowledge, this is the first reported attempt of an *ab interno* angle surgery to restore aqueous outflow through the conventional outflow pathway in an eye with acute NVG and partial synechial angle closure.

There are two critical clinical features which qualified this patient for an attempted GATT: complete regression of active anterior segment neovascularization and a surgically accessible nasal angle. This patient's

NVI and NVA had completely regressed by the time she underwent GATT, and she continued to undergo serial IVB postoperatively to prevent recurrent NVA and progressive synechial angle closure. Given that this patient's IOP was 34 immediately prior to the GATT with no NVI or NVA and a partially closed angle, it is likely that a translucent fibrovascular membrane was present in the "open" regions of the angle, and was contributing to obstruction of aqueous outflow.<sup>10</sup> Since she had no anterior segment neovascularization at the time of GATT, she did not experience any more intra- or postoperative bleeding than a typical GATT patient. A significant amount of Healon Pro was purposely left in the anterior chamber at the end of the surgery to tamponade potential reflux bleeding from Schlemm's canal. Although the paracentesis required burping on postoperative day 1, she did not have any layered hyphema throughout her entire postoperative course, and her visual acuity remained within 1 Snellen line of 20/200 throughout the entire postoperative course. The second clinical feature that was critical to this patient's GATT was the location, more so than the extent, of her pre-operative synechial angle closure. Despite approximately 75% synechial angle closure, the anterior aspect of the nasal trabecular meshwork was visible and surgically accessible, and the microcatheter was able to be inserted into Schlemm's canal. If the nasal angle was completely synechially closed, then goniosynechiolysis under direct visualization could be attempted to expose the nasal trabecular meshwork to perform the goniotomy to begin the GATT, or the initial goniotomy could be performed at a different clock-hour location, depending on the patient's angle and facial anatomy. Once the microcatheter has been successfully advanced for 360° and subsequently retrieved and pulled to perform the 360-degree *ab interno* trabeculectomy, the catheter will mechanically lyse all PAS throughout the entire angle, regardless of the extent of PAS. We therefore advocate for the consideration of GATT in an eye with NVG with regressed anterior segment neovascularization, at least a partially open angle, good visual potential, and a commitment to ongoing anti-VEGF treatment.

However, GATT in eyes with NVG is not without risks. There is already a relatively high hyphema rate after routine GATT even in uncomplicated eyes without any prior NVA, so the hyphema risk might be expected to be even higher in eyes with NVG, even if the NVA appears regressed at the time of the GATT. Although our patient did not develop a postoperative hyphema, other patients with NVG may have occult NVA or NVI, which could make postoperative hyphema much more likely. Every effort should be made to regress active NVA with anti-VEGF injections before attempting an angle-based MIGS; however, subclinical neovascularization may persist even in the setting of recent anti-VEGF treatment. Furthermore, when performing GATT on an eye with PAS, there is a theoretical risk of iridodialysis and/or cyclodialysis when the PAS are manipulated during goniosynechiolysis or trabeculectomy.

In our patient, the cause of eventual GATT failure was the formation of new PAS due to recurrent neovascular disease. In the setting of GATT in NVG, is critical to prevent recurrent NVA and its associated fibrovascular membrane (which contracts to form new PAS) to keep the angle open and maintain the function of the conventional outflow pathway. The development of PAS and progressive synechial angle closure is directly linked to the underlying neovascular drive. As a result, close collaboration with the retina service is critical so the retina specialist can perform anti-VEGF injections and/or PRP to fully regress the anterior segment neovascularization prior to attempting GATT, and the retina specialist can continue to perform serial anti-VEGF injections until full dense PRP can be completed, to permanently prevent NVA recurrence and maintain the success of the GATT.

Due to various factors precluding her from making several appointments, our patient developed recurrent NVA three times following the GATT: the first two occurrences were 51 and 54 days after the last IVB; the angle remained anatomically open and the NVA regressed with prompt IVB. However, the third episode of recurrent NVA occurred 4 months after the last IVB after being lost to follow up for a prolonged period of time; at this point, the angle had become entirely synechially

closed and surgically unsalvageable.

Attempting to salvage the conventional outflow pathway with an angle-based MIGS such as GATT is the most physiologic surgical IOP-lowering procedure, and given this patient's relatively young age, we wanted to attempt to spare her a lifetime of all of the aforementioned potential tube-related complications. Aqueous outflow post-GATT is also more physiologic compared to an eye with an aqueous shunt, which results in a safer lowering of IOP.<sup>11</sup> However, in the setting of NVG, we would caution that this approach should only be attempted in reliable patients who can commit to frequent follow-up visits for serial intravitreal anti-VEGF injections and PRP (which often requires multiple sessions). Our patient's IOP remained in the normal range on zero IOP-lowering medications up to 9 months after the GATT. However, her IOP became precipitously elevated again after a 4-month lapse in follow-up, leading to recurrent NVA and 100% synechial closure. At that point, the conventional outflow pathway was no longer surgically salvageable, and an aqueous shunt was ultimately required. We cannot know if the GATT would have remained effective at controlling the IOP if this patient had not been lost to follow-up for 4 months, but it is plausible that the GATT's efficacy could have persisted indefinitely if the underlying neovascular drive had continued to be suppressed with serial anti-VEGF until more sessions of fill-in PRP could have been performed to completely and permanently suppress the underlying neovascular drive.

#### 4. Conclusion

Attempting to salvage the conventional outflow pathway with an angle-based MIGS procedure, such as GATT, is a feasible surgical IOP-lowering strategy in the setting of NVG when the active anterior segment neovascularization has regressed, and the nasal angle is surgically accessible, even in the setting of partial synechial closure. Delaying or avoiding an aqueous shunt, and its associated complications, may be particularly beneficial in this relatively younger NVG patient population. Pre- and postoperative control of the underlying neovascular drive is critical to ensure short- and long-term success. Further research is needed to evaluate the long-term safety and efficacy of this collaborative multi-disciplinary approach.

#### Patient consent

Written consent to publish this case has not been obtained. This report does not contain any personal identifying information.

#### Funding

Support from the Bucksbaum Institute for Clinical Excellence Pilot Grant.

#### Authorship

All authors attest that they meet the current ICMJE criteria for Authorship.

#### Declaration of competing interest

The following authors have no financial disclosures: JAK, PA, RK, AGM, DD, LTS, DS, MQ.

#### Acknowledgements

None.

#### References

- Palma C, Kim D, Singh AD, et al. Neovascular glaucoma. In: Shaarawy, et al., eds. *Glaucoma. second ed.* 2014:425–433.
- Rodrigues GB, Abe RY, Zangalli C, et al. Neovascular glaucoma: a review. *Int J Retin Vitr.* 2016;2:26.
- Grover DS, Godfrey DG, Smith O, et al. Gonioscopy-assisted transluminal trabeculotomy, ab interno trabeculotomy: technique report and preliminary results. *Ophthalmology.* 2014;121:855–861.
- Fontana L, De Maria M, Iannetta D, Moramarco A. Gonioscopy-assisted transluminal trabeculotomy for chronic angle-closure glaucoma: preliminary results. *Graefes Arch Clin Exp Ophthalmol.* 2022 Feb;260(2):545–551.
- Havens SJ, Gulati V. Neovascular glaucoma. *Dev Ophthalmol.* 2016;55:196–204.
- Nadal J, Carreras E, Kudsieh B, et al. Neovascular glaucoma treatment with extraction of anterior chamber fibrovascular tissue. *Jama Ophthalmology.* 2013;131:1083–1085.
- Pinto JM, Ferreira NP, Pinto LA. Ahmed valve upstream obstruction caused by fibrous ingrowth: surgical approach. *J Glaucoma.* 2017;26(10):e236–e238.
- Taylor R, Kinsella MT, Clarke JC. Long-term outcome of intravitreal Bevacizumab followed by Ahmed valve implantation in the management of neovascular glaucoma. *Semin Ophthalmol.* 2018;33:606–612.
- Shalaby WS, Myers JS, Razeghinejad R, et al. Outcomes of valved and nonvalved tube shunts in neovascular glaucoma. *Ophthalmol Glaucoma.* 2021 Mar-Apr;4(2):182–192.
- John T, Sassani JW, Eagle RC. The myofibroblastic component of rubeosis iridis. *Ophthalmology.* 1983;90(6):721–728.
- Fellman RL, Mattox C, Singh K, et al. American glaucoma society position paper: microinvasive glaucoma surgery. *Ophthalmol Glaucoma.* 2020 Jan-Feb;3(1):1–6.