Effect of Nylon Wick Technique on Early Intraocular Pressure Control in Nonvalved Aqueous Shunt Surgery

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Aqueous shunt devices have become an increasingly popular surgical treatment for glaucoma.1 Medicare data between 1995 and 2004 demonstrate a steady increase in the use of these devices.2,3 Although the most commonly used nonvalved device is the Baerveldt implant (Johnson & Johnson Vision, Jacksonville, FL), the nonvalved Ahmed ClearPath (New World Medical, Cucamonga, CA) was recently approved. Given their nonvalved status, these shunts require an early restriction of fluid flow to minimize hypotony while awaiting the formation of a fibrous capsule around the plate of the implant. The most common method of restricting flow during the initial postoperative period is to ligate the nonvalved tube with an absorbable suture, which usually dissolves around postoperative week 5 to 6, at which time there is a sufficient fibrous capsule to prevent hypotony. Ripcord sutures are used by some surgeons to provide an additional option for intraocular pressure (IOP) control while awaiting ligature dissolution.

Because nonvalved devices do not function to lower IOP until the ligature suture dissolves, IOP control is often dependent on medications in the initial period. Patients often need to use multiple topical or oral medications during this time. Various surgical techniques have been utilized to allow aqueous outflow and achieve some degree of IOP control before implant encapsulation. Venting fenestrations may be created within the tube lumen proximal to the suture ligation.4 The idea of a sutured wick to provide a scaffold for aqueous egress has been previously explored with the use of a 7-0 Vicryl (polyglactin) suture in addition to fenestrations.5 However, this intervention showed no significant difference in immediate postoperative IOP control or number of medications compared with fenestrations only.

The purpose of this study is to retrospectively compare 2-month surgical outcomes of patients who underwent nonvalved aqueous shunt implantation with a nylon wick technique to the outcomes of those with fenestrations only. Given the noninflammatory nature of nylon suture material, we hypothesized that patients who received nylon wicks would have lower IOP and glaucoma medication usage in the immediate postoperative period before spontaneous dissolution of the ligature suture.

METHODS

This single-center study was approved by the Duke University Institutional Review Board in adherence to the Health Insurance Portability and Accountability Act and all tenets of the Declaration of Helsinki. Retrospective chart review included all patients who underwent nonvalved aqueous shunt implantation by a single surgeon (L.W.H.). Cases were identified by searching the electronic medical record using Current Procedural Terminology code 66180 (aqueous

Precis: The use of nylon wicks with fenestrations in nonvalved aqueous shunt surgery significantly reduces intraocular pressure (IOP) and glaucoma medication usage in the immediate postoperative period compared with the use of fenestrations alone.

Purpose: To compare early postoperative IOP and medication usage in patients undergoing implantation of a nonvalved aqueous shunt device with fenestrations only or nonvalved wicks with nylon wicks.

Methods: A retrospective review of all nonvalved aqueous shunt insertions completed by one surgeon (L.W.H.) was completed using current procedure terminology. Patients undergoing Baerveldt or ClearPath 350 mm² aqueous shunt insertion with fenestrations only (n = 37) or with fenestrations with nylon wicks (n = 92). All devices were ligated with 7-0 Vicryl (polyglactin) suture, and either 4 fenestrations or 2 fenestrations and 2-9 nylon wicks were placed anterior to the ligature. Data regarding visual acuity (VA), IOP, number of glaucoma medications, and complications were collected from the preoperative visit just before surgery, postoperative day 1, week 3 (POW3), week 5, and month 2 (POM2). The main outcome measures were VA, IOP, number of glaucoma medications, and complications at all postoperative time points.

Results: There were no differences in logMAR VA between the 2 groups at any time point. At POW3, IOP was significantly lower in the wick group (14.6 ± 7.7 mm Hg, P = 0.03). Number of glaucoma medications used was significantly reduced in the wick group at POW3 (0.5 ± 0.9 vs. 1.0 ± 1.2, P = 0.02) and POM2 (0.7 ± 1.0 vs. 1.4 ± 1.3, P = 0.02). There was no significant increase in the overall rate of complications in the wick group, but there was a higher rate of transient hyphema (20% vs. 8%, P = 0.02).

Conclusions: The use of 2 nylon wicks with fenestrations in nonvalved aqueous shunt device implantation can significantly lower IOP and medication burden while awaiting the dissolution of the ligature suture.

Key Words: glaucoma, aqueous shunt, intraocular pressure, nonvalved, Baerveldt, ClearPath

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shunt to extraocular equatorial plate reservoir) and subsequently identifying those who received a Baerveldt or ClearPath 350 mm² aqueous shunt. The clinical chart was reviewed to ensure a surgical indication of uncontrolled IOP. The nylon wick technique was utilized starting January 1, 2019 through March 15, 2020, and the use of nylon wicks was confirmed with a review of the operative note. Those patients who did not receive wicks were identified between June 1, 2013 and January 31, 2014 as previously described; this cohort was used as a control group in a previous study by the same authors.5

Implantation of the aqueous shunt by the authors has been previously described.5 In brief, all aqueous shunt surgeries were performed in a similar manner with sub-Tenon’s block. A fornical peritomy was initiated ~4 mm posterior to the limbus. A 6-0 prolene or nylon suture was used as a ripcord per the surgeon’s discretion; this suture was already preplaced in the ClearPath device but was backloaded into the Baerveldt implant when desired and secured using a 7-0 Vicryl (polyglactin) suture ~2 mm anterior to the plate. Occlusion was verified using a balanced salt solution on a cannula. After placement of the device in the appropriate quadrant, the eyelets were sutured to the sclera using 9-0 nylon suture. The tube was shortened as required. A 22-G needle was then utilized to create a scleral tract beginning ~3 mm posterior to the limbus, and the tube was placed in the anterior chamber (AC), sulcus, or pars plana per the surgeon’s discretion. Patients in the fenestrations only group had 4 fenestrations placed in the anterior tube using a 15-degree paracentesis blade that was inserted one-third of the total length (BVI, Waltham, MA; Fig. 1A). Those patients in the wick group had 2 fenestrations placed in the same manner, followed by two 9-0 nylon wicks on a TG140-8 spatulated needle placed through the tube—one anterior and 1 posterior to the fenestrations, both proximal to the occlusive ligature suture (Fig. 1B). These wicks were ~8 to 10 mm in length and laid flat on the scleral surface. Beading of aqueous along these wicks was confirmed using ophthalmic sponges. The tube was then tied down in a figure-of-eight manner using a 9-0 nylon suture between the 2 nylon wicks (overlying the fenestrations; Fig. 1C). Of note, this suture was tied with sufficient tension to appose the tube to the sclera without compressing the tube. A scleral or corneal patch allograft was then placed over the tube, covering the wicks and fenestrations, taking care to ensure that the allograft did not pull on the underlying wicks. The patch graft was neither sutured nor glued as is done routinely in this practice. The conjunctival incision was then closed with

**FIGURE 1.** A, A 15-degree paracentesis blade is used to make 2 fenestrations halfway between the sclerostomy and ligature suture. The blue 6-0 prolene ripcord suture is visible. B, Two full passes with a TG140-8 spatulated needle containing 9-0 nylon suture are made anterior and posterior to these 2 fenestrations, both of which are anterior to the ligature suture. An 8-10 mm piece of nylon suture is cut to remain as the wick in each location. C, Final appearance after a 9-0 nylon figure-of-eight style suture is used to stabilize the tube to the scleral surface. Of note, this suture is tied with sufficient tension to appose the tube to the sclera without compressing the tube, which would otherwise cause the fenestrations to gape open. A scleral or corneal patch allograft is then placed over the tube and the conjunctival incision is closed. Figure 1 can be viewed in color online at www.glaucomajournal.com.
both interrupted and running 8-0 Vicryl suture. If viscoelastic material was used at any point during the surgery, it was removed with irrigation before the conclusion of the surgery; no viscoelastic material was left in the eye at the end of the case in either group. All glaucoma medications were stopped in the surgical eye and resumed at the surgeon’s discretion postoperatively. Patients in both groups were placed on the same anti-inflammatory regimen, topical prednisolone 4 times daily with a subsequent weekly taper.

Inclusion criteria included age more than 18 years with inadequately controlled glaucoma (as defined by IOP greater than target despite maximally tolerated medical therapy) and placement of a Baerveldt 350 mm$^2$ or ClearPath 350 mm$^2$ implant. Exclusion criteria were any concurrent procedures with the exception of uncomplicated cataract surgery or any abnormality that could affect tonometry measurements. Only 1 eye per patient was enrolled; if both eyes were eligible for enrollment, then only the first eye that underwent surgery was included in the study. Baseline data collected from the preoperative appointment included: age, gender, race, glaucoma diagnosis, ocular history (including prior treatments and procedures), best-corrected Snellen visual acuity (VA), IOP, glaucoma medications, and relevant slit-lamp findings. Combination formulations of glaucoma medications were counted as 2 separate medications. Postoperative data collected included VA, IOP, and number of glaucoma medications from postoperative day 1 (POD1), week 3 (±1 wk; POW3), week 5 (±1 wk; POW5), and month 2 (±2 wk; POM2) as per the standard-of-care postoperative schedule of the surgeon. Visits between these typical postoperative visits were reviewed if necessary. Additional data collected included removal of ripcord and assessment for complications, including but not limited to hyphema (defined as IOP ≤5 mm Hg), wound leak, hyphema, tube exposure, and infection.

Statistical analyses were conducted using R 3.6.0 (R Core Team, Vienna, Austria). Continuous variables were compared using a 2-tailed Student’s $t$ test. Categorical parameters were evaluated using the Fisher exact test. A $P$-value <0.05 was considered statistically significant.

RESULTS
A total of 173 patients who underwent aqueous shunt surgery were identified with the above search criteria, of which 155 underwent nonvalved aqueous shunt insertion. A total of 34 cases were excluded because of the placement of a 250 mm$^2$ device. An additional 29 cases were excluded because of other concurrent glaucoma surgery, such as bleb shutdown, removal of a shunt device, or double tube surgery. A total of 92 patients who received fenestrations with nylon wicks were then identified. The group of 37 patients who received 4 fenestrations only were identified from our prior publication and used as the control group. All of these patients received Baerveldt 350 mm$^2$ aqueous shunts.

Baseline characteristics of the 2 groups are presented in Supplemental Table S1 (Supplemental Digital Content 1, http://links.lww.com/JIG/A455). Of note, there were a few parameters that differed between the 2 groups. There were more right eyes in the wick group. Tube implant characteristics differed between the 2 groups as well, specifically tube location and quadrant of implantation. Of note, baseline VA, IOP, and number of medications did not significantly differ between the 2 groups.

Postoperative outcomes are presented in Supplemental Table S2 (Supplemental Digital Content 2, http://links.lww.com/JIG/A455). There were no differences in any parameters at POD1 between the 2 groups. LogMAR VA did not significantly differ between the 2 groups at any time points. IOP was significantly lower in the wick group at POM3 (14.6 ± 7.7 vs. 18.1 ± 8.7 mm Hg, $P = 0.03$). The percentage of IOP decrease compared with baseline was significantly lower at POM3 in the wick group (−28.2 ± 38.9% vs. −10.0 ± 48.3%, $P = 0.03$). The number of glaucoma medications was also significantly lower in the wick group at POW3 (0.5 ± 0.9 vs. 1.0 ± 1.2, $P = 0.02$) and POM2 (0.7 ± 1.0 vs. 1.4 ± 1.3, $P = 0.02$). The number of medications was lower in the wick group at POW5 but did not reach statistical significance (0.7 ± 1.0 vs. 1.1 ± 1.1, $P = 0.08$).

Table 1 describes complications in the 2 groups. There was no significant increase in the overall rate of complications in the wick group ($P = 0.05$), but there was a higher rate of hyphema with wick placement (28% vs. 8%, $P = 0.02$). The majority of complications in the wick group were because of hyphema or hyphema. There was no difference in the rate of AC reformation in the 2 groups ($P = 0.62$). Of note, 26% of patients in the wick group had ripcords pulled, in contrast to 38% in the fenestrations only group, but this difference was not statistically significant ($P = 0.20$). There were no cases of infection or hypopyon in either group.

A total of 5 eyes in the wick group and 1 eye in the fenestration group required additional surgery ($P = 0.67$). The eye in the fenestration group underwent surgery to repair a wound leak that caused persistent hyphema. The 5 surgeries performed in the wick group included 2 AC washouts, a tube repositioning because of occlusion of the tube by the iris, repair of a wound leak, and retying of a loose ligature suture.

DISCUSSION
Nylon wicks provide significant additional postoperative IOP control and minimize the use of glaucoma medications while awaiting the dissolution of the ligature suture in nonvalved aqueous shunt surgery. The use of these wicks seems to provide an advantage over fenestrations alone, which has become the standard practice with nonvalved shunts for the majority of glaucoma surgeons.5,6,7 We decided to use fenestrations as the control group for this reason, although we do recognize that placing 4 fenestrations using a paracentesis

| TABLE 1. Complications in Eyes Receiving Fenestration Versus Fenestration With Nylon Wicks |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Fenestration     | Fenestration + Wicks | $P$   |
|                  | (N = 37)         | (N = 92)          |      |
| Ripcord pulled   | 14 (38)          | 24 (26)           | 0.20*|
| Overall complications | 13 (35) | 51 (55)         | 0.05*|
| Hyphema          | 7 (19)           | 30 (33)           | 0.14*|
| Wound dehiscence | 5 (13)           | 8 (9)             | 0.52*|
| or leak          |                  |                  |      |
| Hyphema          | 3 (8)            | 26 (28)           | 0.02*|
| Elevated IOP    | 0 (0)            | 3 (3)             | 0.56*|
| requiring “burp” |                  |                  |      |
| AC reformation   | 2 (5)            | 3 (3)             | 0.62*|
| Additional surgery | 1 (3)     | 5 (5)             | 0.67*|

*Fisher exact test. AC indicates anterior chamber; IOP, intraocular pressure.
blade may be more intensive than the typical regimen of many providers. Nonetheless, we believe that the addition of nylon wicks in addition to fenestrations provides excellent additional IOP control during the first 5-6 weeks after aqueous shunt implantation.

VA did not significantly differ between the 2 groups at any time points, suggesting that even with lower IOPs, there was no compromise in VA. The use of wicks provided significant IOP lowering, notably at POW5. We would not have expected IOP to differ between the groups at POD1, as fenestrations likely function well on the first postoperative day. However, their utility may reduce as scar tissue forms. IOP control was similar at other time points, but with fewer medications in the wick group. The decrease in IOP medications was significant at both POW3 and POM2 but not POD1 or POW5. Again, we would not have expected a difference at POD1, as the majority of patients were patched overnight postoperatively. The wick group had 1 patient who independently removed his patch and administered his previously prescribed medications before his POD1 visit. We noted a significant decrease in our sample size at POW5, possibly because of patients being evaluated by local providers; of note, many patients cared for at this tertiary care institution were referred from the community. The decrease in sample size may have contributed to the nonsignificance noted at POW5. In addition, it is possible that early tube opening may have contributed to nonsignificance of the IOP difference at POW5, especially because the window period for POW5 datapoints could have included patients examined at POW6.

The overall decrease in the use of glaucoma medications suggests an important benefit to the patient. He or she may feel encouraged to be using fewer medications immediately after surgery, as there is a sense that the aqueous shunt is already working in some capacity. This benefit can be significant, especially when given medication intolerance is often an indication for surgical intervention. There have also been anecdotal discussions regarding a potential association between the increased use of aqueous suppressants and AC shallowing upon tube opening because of suppression of the ciliary body. The use of wicks would potentially preclude such a situation.

There was a trend toward a reduced rate of ripcord removal with nylon wicks, although the difference between the 2 groups did not reach statistical significance (26% vs. 38%, P=0.20). The incidence of hyphema was greater in the wick group (28% vs. 8%, P=0.02). The majority of these events were at POD1 and were transient, likely because of surgical technique or perhaps transient hypotony. We have no reason to believe that the placement of nylon wicks through the tube in the subconjunctival space would induce additional bleeding in the AC. Only 1 case carried a diagnosis of neovascular glaucoma; we would not otherwise expect fragile vessels in the AC to rupture because of the change in IOP leading to a hyphema. Nonetheless, it is essential to consider the patient’s risk factors for bleeding (eg, use of anticoagulants or advanced age) when using the nylon wick technique. The number of fenestrations and/or wicks could be altered depending on patient characteristics per the surgeon’s discretion.

Hypotony was noted in 33% of wick cases and 19% of fenestration only cases (P=0.14). Although the numerical definition of hypotony (ie, IOP ≤5 mm Hg) was observed at one or more visits in these 30 wick patients, only 3 patients (3%) required AC reformation during the study period. This estimate includes POM2 visits, at which time the tube would be expected to be open and fully functional. Of note, we have observed that even when numerical hypotony occurs after wick placement, the vast majority of patients maintain a remarkably deep AC with stable VA; it seems as though the nylon wicks create a “steady state” in the AC with balanced aqueous ingress and egress. There was an initial concern that the wicks might induce hypotony after the dissolution of the ligature suture, given the lower IOPs in the immediate postoperative period. However, this was not observed. We would posit that after tube opening, aqueous follows the path of least resistance and flows toward the plate in a laminar manner, rather than trickle out through the wicks in a turbulent manner.

Given the retrospective nature of this study, there were differences in the baseline characteristics of the 2 groups. There were more right eyes in the wick group (closer to 50%), which we believe is likely because of the larger sample size. Tube implant characteristics differed as well, specifically tube location within the eye and quadrant of implantation. The latter may have been because of a higher rate of prior surgery in the superotemporal quadrant among eyes in the wick group, which we do not believe would affect the function of the wicks. As expected, there was a significant difference in the type of nonvalved shunt, as the ClearPath device was not available when the control group underwent surgery. We do not believe that these findings would have altered IOP control or medication usage in the immediate postoperative period.

The use of nylon wicks for IOP control in the immediate postoperative period addresses a major limitation of nonvalved aqueous shunts, namely the delay in the function of the device. Valved surgical devices, such as the Ahmed FP7 device (New World Medical, Cucamonga, CA), are often used by surgeons because of the immediate function of the shunt and its overall safety profile. Nonetheless, both the Ahmed versus Baerveldt and Ahmed Baerveldt comparison studies demonstrated improved efficacy of the larger nonvalved Baerveldt implant compared with the smaller Ahmed FP7 device.8-11 In some patients with severe glaucoma with split-fixation, double tube surgery (ie, concurrent implantation of Ahmed FP7 and Baerveldt devices) has been described as a technique that provides immediate IOP lowering while ensuring long-term efficacy.12 However, this surgery is inherently time-intensive and utilizes a significant amount of conjunctival space. The use of nylon wicks in a nonvalved aqueous shunt may provide a viable alternative to this procedure, and the Ahmed FP7 in certain scenarios, given the immediate reduction in IOP. Prior studies have evaluated the use of fenestrations and/or wicks. In the prior study by Rothman et al,5 one 7-0 Vicryl (polyglactin) suture was utilized as a wick, but was not shown to have any benefit in terms of reduced IOP and medication usage. Of note, the comparison evaluated in Rothman and colleagues involved 4 fenestrations versus 3 fenestrations and 1 Vicryl (polyglactin) wick, compared with the current study’s evaluation of 4 fenestrations versus 2 fenestrations and 2 nylon wicks. The difference in results could be because of the number of wicks utilized. Another hypothesis is that polyglactin is inherently proinflammatory material; polyglactin may attract fibroblasts and other extracellular matrix components, leading to rapid scar formation around the wick and tube, thus minimizing aqueous egress. In contrast, nylon is less inflammatory. 9-0 nylon was utilized, as this suture was already being used for the
stabilization of the implant eyelets to the sclera; this technique does not require a new suture to be opened.

Yadgarov et al\textsuperscript{13} utilized a 10-0 monofilament polyglactin suture as a wick. The authors demonstrated that IOP reduction from preoperative levels was significant with minimal adverse events. However, there was no control group for comparison in this study. Viscoelastic was injected into the AC and left in place per the surgeon’s discretion. Akil et al\textsuperscript{14} described a venting stitch modification in 24 patients undergoing Baerveldt implantation and compared them with 37 patients undergoing unmodified shunt implantation (no stitch or fenestrations). The venting stitch used was a 10-0 nylon suture placed in a partial thickness manner within the cornea and sclera that then traverses through the tube and is tied, with the knot rotated into the cornea or sclera. The authors found a significant decrease in postoperative IOP and the number of medications used before tube opening compared with the control group. Notably, the control group had no fenestrations placed; we do not know how this technique would compare with fenestrations alone. Although this technique does have the advantage of the suture being accessible for removal in the clinic, it may induce some degree of tension along the suture tract within the tube, possibly leading to gaping of this orifice, which could lead to unpredictable aqueous egress. It also involves the use of an additional suture that to the best of our knowledge, is not typically used in aqueous shunt surgery.

The strengths of this study include the use of a robust control group that reflects the most common technique for perioperative IOP control in nonvalved aqueous shunts, namely fenestrations. The sample size in our study is one of the largest in comparison with those referenced above. Limitations include its retrospective nature and a notable difference in the time period when the 2 techniques were used. It is important to note that the surgeon did not change his surgical technique in any other manner during this period that would otherwise affect immediate postoperative IOP control. Because of the retrospective nature of this work, there were some patients who were lost to follow-up at certain time points, likely because of their continued care with local providers.

In summary, the placement of nylon wicks anterior to the occlusive ligature suture in nonvalved aqueous shunt devices provides early IOP control and minimizes the number of glaucoma medications required in the immediate postoperative period. Although there is a slightly increased rate of hyphema, we believe that such events could be mitigated with preoperative consideration of a patient’s risk factors and appropriately revising the number of fenestrations and/or wicks. We encourage readers to incorporate the use of nylon wicks into their surgical practice. The results of this study may serve as the basis for a larger prospective study to establish optimal postoperative management guidelines to maximize efficacy and minimize complications in nonvalved aqueous shunt surgery.

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