Operative Complications of Glaucoma Drainage Implant Tube Insertion Through the Sulcus for Pseudophakic Eye

Satoko Asaoka, MD,*† Toshimitsu Kasuga, MD, PhD,*
Toru Matsunaga, MSc,‡ Yusuke Hayashi, MD,*† Yosuke Asada, MD, PhD,*
Satoshi Iwamoto, MD, PhD,* Toshiaki Hirakata, MD, PhD,*
Rio Honda, MD, PhD,* Hanako Obazawa, MD,§ Hidenori Sasaki, MD, PhD,||
Toshihiko Ohta, MD, PhD,† and Akira Matsuda, MD, PhD*†

Precis: Malposition of the tube through the ciliary sulcus is more frequently observed with the Ahmed glaucoma valve (AGV) than the Baerveldt drainage implant (BDI) due to the weaker rigidity of the Ahmed tube.

Purpose: To report intraoperative and early postoperative complications of ciliary sulcus tube insertion of glaucoma drainage implants (GDIs).

Patients and Methods: We performed retrospective analysis of 104 eyes of 94 patients with GDI tube insertion through the ciliary sulcus were performed. The rigidities of tubes were also examined using a microcompression tester.

Results: The mean observation period was 20.0 (range, 6 to 60) months. Thirteen eyes were treated with the BDI and 91 were with the AGV. The mean age of the patients was 69.3 (34 to 90) years. The mean intraocular pressure was 27.9 mm Hg before surgery and 12.9 mm Hg after surgery (P < 0.01). Upon tube insertion 49/91 eyes (46%) with the AGV required reinsertion of the tube due to mal-positioning, whereas only 1/13 (8%) eyes with BDI did (P < 0.01). Transient hypophemia (12 eyes) and hypotony (12 eyes) were observed as early postoperative complications with the AGV. Seven eyes with hypotony were treated by proline stenting of the tube. We could not accomplish sulcus insertions in 4 eyes. Microcompression analysis of the tubes showed that the BGI tube was more rigid than that of the AGV.

Conclusions: Ciliary sulcus insertion of the tube is an effective method to control intraocular pressure. The tube of the AGV was more difficult to insert through the sulcus than the BDI due to its weaker rigidity.

Key Words: glaucoma drainage implants, ciliary sulcus, rigidity of tube

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From the *Department of Ophthalmology, Juntendo University School of Medicine; †SEED Co. Ltd, Tokyo, Japan; ‡Department of Ophthalmology, Juntendo University Shizuoka Hospital, Izuno-kuni; §Department of Ophthalmology, Koshigaya Municipal Hospital, Koshigaya; and ||Department of Ophthalmology, Asama General Hospital, Saku, Japan.

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Reprints: Akira Matsuda, MD, PhD, Laboratory of Ocular Atopic Diseases, Department of Ophthalmology, Juntendo University School of Medicine, 2-1-1 Hongo, Bunkyo-Ku, Tokyo 113-8431, Japan (e-mail: akimatsu@juntendo.ac.jp).

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Glaucoma drainage implants (GDIs) have become one of the choices for treatment of refractory glaucoma cases due to their ability to control intraocular pressure (IOP). However, one of the serious complications of these implants is corneal endothelial cell loss. Ciliary sulcus tube insertion is preferred in the case of the nonvitrectomized, pseudophakic eyes because several reports have shown that the rate of corneal endothelial cell loss increases when the position of the inserted tube is near the corneal endothelium. On the other hand, we sometimes encountered intraoperative and early postoperative complications in sulcus-inserted GDI procedures. In this study we carried out retrospective analysis of patients treated with sulcus-inserted GDIs to elucidate intraoperative and early postoperative complications. We noticed that the tube of the Ahmed glaucoma valve (AGV, New World Medical Inc., Rancho Cucamonga, CA) was more difficult to insert through the sulcus than the Baerveldt glaucoma drainage implant (BDI, Johnson & Johnson Surgical Vision Inc., Santa Ana, CA), so we compared the rigidities of the tubes of the AGV and BDI using a microcompression analyzer for the purpose of evaluating how easily the tube would buckle during the tube insertion procedure.

PATIENTS AND METHODS

We carried out retrospective analysis of 104 eyes of 94 patients treated with GDIs. All patients were Japanese. The characteristics of the eyes enrolled in this study are summarized in Table 1. All the patients had a history of previous ocular surgery and 83/104 (80%) of the eyes had a history of previous glaucoma surgery (Table 1). All the eyes were pseudophakic [12 eyes had combined procedures of both AGV insertion and cataract surgery with intraocular lens (IOL) insertion]. All the procedures were performed by 2 experienced surgeons (T.K. and A.M.) and ciliary sulcus tube insertion was performed as previously described. The pupil of the patient was dilated preoperatively and a fornix-based conjunctival incision was made. After insertion of the GDI plate in the appropriate position, the anterior chamber was filled with a viscoelastic.

A 23-G needle was inserted through the sulcus into the space between the iris and IOL and then the tip of tube was pushed into the sulcus space. We placed the beveled tip near the center of the visual axis so as to be visible at the pupillary margin with an undilated pupil as described previously. Microcompression analyses of the tubes was carried out using 5 tubes (2 BDI and 3 AGV) obtained during the surgery. The tubes were trimmed to the length of...
2.1 mm and compression analysis was performed using a microcompression tester (Shimadzu Corporation, Kyoto, Japan). The clinical part of this study was carried out as a retrospective, observational study without any interventions, and was approved by the ethics review committee of the Juntento University Hospital (No. 16-287). The study was conducted in accordance with the tenets of the Declaration of Helsinki.

### RESULTS

The mean observation period was 20.0 (range, 6 to 60) months. Thirteen eyes were treated with the BDI (BG 101 to 350) and 91 with the AGV (FP7). The mean age of the patients was 69.3 (34 to 90) years. The mean IOP was 27.9 mm Hg before surgery and 12.9 mm Hg after surgery (P < 0.01). With the AGV, 42/91 eyes (46%) required reinsertion of the tube due to malposition, whereas with the BDI, the tubes were placed in the appropriate sulcus position from behind the IOL during surgery due to poor visibility, and postoperative ultrasound analysis showed that the tube had strayed into the vitreous cavity (Fig. 2). Vitrectomy was carried out to restore the function of the GDI. We could not accomplish sulcus insertions in 3 eyes due to iris prolapse during the procedures (Fig. 3). In these cases, the tube tips were inserted into the anterior chamber.

For microcompression analysis, we cramped the trimmed tubes between the upper and lower pistons and compressed them at the speed of 5 mm/min (Fig. 4A). Compression powers were recorded during the procedures (Fig. 4B). Microcompression analyses of the tubes showed that the maximum compression force of the BDI before bending was 0.24 ± 0.02 N (mean ± SD) and that of the AGV was 0.14 ± 0.05 N. The compression force of the BDI was significantly higher than that of the AGV (P < 0.01, Mann Whitney U test). To confirm the reproducibility of the results, the tube malposition of the AGV was recorded during the procedures (Fig. 4B).

### TABLE 1. Eye Characteristics and Postoperative Complications

| Glaucoma Type | AGV (91 Eyes) | BDI (13 Eyes) | Total (Eyes) |
|---------------|--------------|---------------|--------------|
| POAG          | 36           | 6             | 42           |
| Exfoliative   | 17           | 2             | 19           |
| Childhood     | 4            | 1             | 5            |
| Neovascular   | 2            | 1             | 3            |
| Secondary     | 27           | 3             | 30           |
| Chronic angle closure | 51  | 5 | 56  |
| Age at the time of surgery (mean ± SD) | 69.4 ± 12.4 | 59.3 ± 14.2 | 69.3 ± 12.4 |
| Average length of follow-up (mo, mean ± SD) | 17.3 ± 9.9 | 39.8 ± 11.9 | 20.0 ± 12.6 |

### TABLE 2. Type of Tube Malpositions and Remediation Procedures

| Type of Tube Malpositions | AGV (42 Eyes) | BDI (1 Eye) | Total (Eyes) |
|---------------------------|--------------|-----------|--------------|
| Straying into vitreous cavity | 8           | 0         | 8            |
| Straying into Zinn’s zonule/lens capsule | 10 | 0 | 10 |
| Straying into an unidentifiable position | 19 | 0 | 19 |
| Straying behind the IOL (5 Eyes) | 5 | 1 | 6 |
| Remediation procedures from vitreous cavity | | | |
| Add viscoelastic and insert again | 1 | 0 | 1 |
| Insert from another point | 2 | 0 | 2 |
| 4-0 proline assisted insertion | 4 | 0 | 4 |
| Vitrectomy (leave tube in vitreous cavity) | 1 | 0 | 1 |
| Remediation procedures form Zinn’s zonule/lens capsule | | | |
| Add viscoelastic and insert again | 1 | 0 | 1 |
| Insert from another point | 3 | 0 | 3 |
| 4-0 proline assisted insertion | 4 | 0 | 4 |
| Convert to anterior chamber | 1 | 0 | 1 |
| Tube insertion | | | |
| Remediation procedures from behind the IOL | | | |
| Add viscoelastic and insert again | 1 | 0 | 1 |
| Fixing using Sinskey hook | 4 | 1 | 5 |
| Remediation procedures from an unidentifiable position | | | |
| Add viscoelastic and insert again | 1 | 0 | 1 |
| Insert from another point | 10 | 0 | 10 |
| 4-0 proline assisted insertion | 6 | 0 | 6 |
| Convert to anterior chamber | 2 | 0 | 2 |

AGV indicates Ahmed glaucoma valve; BDI, Baerveldt drainage implant; IOL, intraocular lens; POAG, primary open-angle glaucoma.
microcompression experiments were carried out twice for BDI tubes and 3 times for AGV tubes and the results were essentially the same.

As early postoperative complications, we found that 12 eyes had hypotony with choroidal detachment and/or a shallow anterior chamber from postoperative day 1 to day 3 (Figs. 5A, B). For 5 eyes, the hypotony was resolved by conservative treatment using atropine eye drops. The remaining seven eyes were treated by 3-0 proline stenting of the tube (Fig. 5C). Twelve eyes with hyphema were observed from postoperative day 1 to postoperative day 2. All the hyphema resolved without any interventions. Ten eyes with hyphema resolved within 2 weeks, but it took 4 to 6 weeks for the remaining 2 cases. Intraoperative hemorrhage after needle insertion (Fig. 5D) was observed in 3 eyes with hyphema formation (Fig. 5E).

**DISCUSSION**

Previous reports showed that ciliary sulcus insertion of a tube was an effective method to control IOP. For most of the cases in this study, it was possible to insert a 23-G needle into the sulcus 2 to 2.5 mm posterior to limbus. However, even in cases in which we succeed in making needle tracks in the proper position, the tube tips may stray into the vitreous cavity, the zonules of Zinn, or unidentified positions (usually behind Elschnig’s pearls). In this study, a relatively high number of eyes (43/104 eyes) required reinsertion of the tube due to malpositioning. We recorded all of our sulcus insertion operative procedures using a video recorder, and checked the procedures post-operatively, listing all the problems during sulcus insertion, including minor ones (which we were able to handle by additional viscoelastic injections, or by changing the tube position with a Sinskey hook). This process may have contributed to the relatively high rate of tube malposition in our cases. To solve malposition problems, we usually (1) change the tube position intracamerally using a Sinskey hook, (2) close the original needle insertion using a 10-0 nylon suture and make a new insertion point, or (3) increase the sulcus space by injecting additional viscoelastic (Table 2). However, in some cases, these rescue procedures do not work well. Moreover, addition of viscoelastic induced iris prolapse (Fig. 3) in 3 cases, and we had to give up sulcus insertion. It should be noted that before the addition of viscoelastic, we should digitally check the IOP, and if it is too high, the previously injected viscoelastic should be removed before the addition of new viscoelastic to increase the space between the iris and IOL.

To tackle these problems, we previously reported 4-0 proline-assisted sulcus tube insertion of AGVs. With the aid of 4-0 proline thread inserted into the tube lumen, the rigidity of the tube was increased. This helped the tubes to proceed into the appropriate position through the sulcus in 14 cases (Table 2). After insertion of the tube with the stent, the proline thread was removed from the paracentesis site using microforceps. We noticed that the tubes of AGVs were more difficult to insert through the sulcus than those of BDIs, and thought this might have been due to the weak rigidity of the tube of the AGV compared with that of the BDI. To confirm these phenomena, we performed microcompression analysis of the tubes and confirmed the tube of the BGI was more rigid than that of the AGV (Fig. 4). This finding further supports the usefulness of 4-0 proline-assisted
sulcus tube insertion to increase the rigidity of the tube of the AGV.

As postoperative complications, we observed hyphema and hypotony. All 11 hypotonic eyes were observed in cases with AGVs and 7 eyes required tube stenting to normalize IOP as reported previously (Fig. 5C). There was hypotony in 3 eyes with uveitis-associated secondary glaucoma eyes, 2 eyes with secondary glaucoma-associated with multiple

FIGURE 2. The tube tip strayed into the vitreous cavity after ciliary sulcus tube insertion in post corneal keratoplasty eye. To insert the tube of Ahmed valve, a 27-G needle was inserted from 2.5 mm posterior to the limbus into the space between the iris and intraocular lens (A). The inserted tube was visible during the operation (arrow); however, its precise location (position relative to the intraocular lens) was not clear (B). The day after the operation anterior optical coherence tomography analysis revealed that the tube tip (arrowhead) had strayed into the vitreous cavity (C).

FIGURE 3. Iris prolapse due to viscoelastic insertion to maintain expanded space between the iris and intraocular lens. To insert the tube from the sulcus, viscoelastic was inserted into the space between the iris and intraocular lens (A). Because of raised intraocular pressure, iris prolapse was observed at the corneal incision at the 12 o’clock position made for cataract surgery (B). The tube insertion position was converted from the ciliary sulcus to the anterior chamber (C).
ocular operations and 2 eyes with neovascular glaucoma. In these cases, a decrease of aqueous production may have played some role in the hypotony. For cases with a high risk of hypotony, we now use temporal tube ligation with 7-0 Vicryl intraoperatively.\(^\text{10}\) Hyphema tends to be mild and resolve spontaneously; however, one report showed that it was associated with a poor prognosis.\(^\text{11}\) Some cases of hyphema can be anticipated by intraoperative hemorrhage after needle puncture (Fig. 5D). In those cases, we tried to maintain IOP by using viscoelastic at the end of the operation. Limitations of this study are: (1) we only analyzed intraoperative and early postoperative complications of ciliary sulcus tube insertion, so long-term complications of this insertion method are still unknown, (2) lack of clinical data of GDIs with anterior chamber tube insertion for comparison of corneal endothelial cell loss, the efficacy of IOP control and safety profiles, and (3) the relatively small number of the BDI insertion group which may reduce the power of statistical analysis.

In conclusion, we showed intraoperative and early postoperative complications of sulcus tube insertion in GDIs. Malposition of the tube of the AGV tends to be common probably due to its weak rigidity, and transient hyphema and hypotony might be related to the immediate aqueous outflow in the AGV. Since sulcus insertion of the AGV has some superior points\(^\text{12}\) (ie, it is less invasive in the corneal endothelium than anterior chamber insertion, immediate relief of high IOP and smaller invasiveness of the operation compared with the BDI), it is important to perform surgery with the knowledge of common pitfalls.

FIGURE 4. Microcompression analyses of the tubes obtained from the Ahmed valves (AGV) and the Baerveldt drainage implant (BDI). The tubes were trimmed to 2.1 mm in length and inserted between the upper and lower plungers of a microcompression analyzer (A). The compression force applied to the tubes was recorded (B). The force rose until just before bending and the maximum compression force (N) was recorded for the BDI (left), and AGV (right). Significantly higher maximum compression forces was needed to bend the BDI than to bend the AGV. The photograph and schema (A) were taken and drawn by T.M.

FIGURE 5. Hypotony and hyphema after sulcus tube insertion of Ahmed valve. Because of hypotony, a shallow anterior chamber and anterior shift of the tube tip were observed 1 day after ciliary sulcus tube insertion (A). Choroidal detachment was observed (B). A 3-0 prolene stent was inserted into the rumen of the tube intracameraly and the complications due to hypotony were resolved (C). A small amount of intraocular hemorrhage after needle insertion was observed when additional viscoelastic was inserted into the space between the IOL and iris via the inferior temporal position (D). Two days after surgery, hyphema and hemorrhage along with the inserted tube were observed (E).
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