This retrospective study evaluated the safety and efficacy of the fornical conjunctival pedicle flap for repair of conjunctival-deficient tube erosions. Additionally, we report the split-lid technique, a procedural improvement if fornix access is difficult. We identified 15 eyes of 14 consecutive patients with complex tube erosions. The mean age was 72.8 years and 33.3% had diabetes mellitus. Most patients were functionally monocular and 80% had undergone 4 or more prior ocular surgical procedures. There was no difference between the following preoperative and postoperative values: visual acuity, intraocular pressure, or number of glaucoma medications. The mean follow-up time after pedicle flap repair was 49 months. There were no recurrent erosions allowing for preservation of the drainage implant with excellent intraocular pressure control. This study demonstrates the relative long-term safety and success of this novel technique.

Glaucoma drainage devices (GDDs) are frequently used for the treatment of glaucoma. The Tube Versus Trabeculectomy Study demonstrated the long-term safety and efficacy of GDDs.1-3 Additionally, 2 ongoing studies are evaluating the safety and efficacy of Ahmed valve implants vs Baerveldt implants.4,5 Medicare claims data between 1995 and 2004 demonstrate an 184% increase in GDD use (from 2728 in 1995 to 7744 in 2004).6 Sequential surveys of the American Glaucoma Society membership showed the selection of GDDs as the preferred surgical approach in 8 clinical scenarios, an increase from 17.3% in 1996 to 50.8% in 2008.7,8 As more surgeons are depending on GDDs to manage glaucoma, there will be a commensurate increase in the number of short-term and long-term postoperative complications.9-11 One of the more challenging postoperative complications to manage is tube erosion, especially in eyes that have extensive conjunctival scarring secondary to numerous ophthalmic surgical procedures. Huddleston et al10 retrospectively evaluated eyes that underwent tube erosion repair and found that 45% of tube erosion repairs required an additional surgical repair, and in 15% of cases, the GDDs required removal. This group reported that patients with diabetes mellitus experienced a nearly 3 times higher risk for failing the revision than patients without diabetes mellitus.10 Their experience underscores the challenging nature of these patients.

We have previously described a technique using an interpolated conjunctival pedicle flap as a novel approach to repair eroded GDD tubes.12 After performing this technique for several years, we now report both the relative long-term safety and efficacy of this procedure on a greater number of patients, as well as a major improvement in the procedure, the split-lid technique (useful when access to the fornix is difficult).

METHODS

After obtaining institutional review board approval, we retrospectively reviewed the medical records at Glaucoma Associates of Texas and identified 15 eyes of 14 sequential patients (10

Author Affiliations: Glaucoma Associates of Texas (Drs Grover, Godfrey, and Fellman), and Oculoplastic Associates of Texas (Dr Merritt), Dallas.
female and 4 male) who presented with GDD tube erosions in the setting of extensively scarred conjunctiva. The mean age was 72.8 years (range, 56-83 years). Twelve of the 14 patients were white. One-third of the patients had diabetes mellitus and 13.3% were diagnosed as having an autoimmune disease. The types of glaucoma and 13.3% were diagnosed as having

TABLE 1. Demographics and Clinical Course of Study Subjects

<table>
<thead>
<tr>
<th>Case/Eye/ Age, y/Sex</th>
<th>Diagnosis</th>
<th>Shunt Type</th>
<th>Previous Surgery</th>
<th>Time to Erosion, mo</th>
<th>Follow-up Time After Repair, mo</th>
<th>Initial Patch Type</th>
<th>Patch Graft Used for Repair</th>
<th>Repeat Erosion</th>
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</thead>
<tbody>
<tr>
<td>1/OD/74/F</td>
<td>IG</td>
<td>AVI</td>
<td>Trab, AGI, PCiol</td>
<td>22</td>
<td>19</td>
<td>Pericardium</td>
<td>Cornia</td>
<td>No</td>
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<tr>
<td>2/OD/79/F</td>
<td>MM</td>
<td>BGI</td>
<td>BGI × 2, trab, PPV, PCiol</td>
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<td>27</td>
<td>No patch, 1st stage BGI eroded</td>
<td>Pericardium</td>
<td>No</td>
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<tr>
<td>3/OD/83/F</td>
<td>MM</td>
<td>AVI</td>
<td>AVI, CPC, DSEK, PCiol</td>
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<td>29</td>
<td>SClaera</td>
<td>Cornia</td>
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</tr>
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<td>AVI</td>
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<td>11</td>
<td>SClaera</td>
<td>Cornia</td>
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<tr>
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<td>AVI</td>
<td>AVI, AV, Sutured IOL</td>
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<td>3</td>
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<td>POAG</td>
<td>BGI</td>
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<td>AVI</td>
<td>AVI, AV, PKP, PCiol</td>
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<td>Pericardium</td>
<td>Cornia</td>
<td>No</td>
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<tr>
<td>8/OS/76/F</td>
<td>NVG</td>
<td>AVI</td>
<td>EOR</td>
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<td>12</td>
<td>SClaera</td>
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<td>11/OS/83/F</td>
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<td>BGI</td>
<td>ECP, AV, PCiol</td>
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<td>BGI</td>
<td>PPV, AIOI, AV</td>
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<td>13/OD/60/M</td>
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<td>BGI</td>
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<td>BGI</td>
<td>BGI, PCP, PCiol, SCT, ASR</td>
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<td>15/OS/74/M</td>
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<td>120</td>
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</table>

Abbreviations: ACIOL, anterior chamber intraocular lens; ASR, anterior segment reconstruction; AV, anterior vitrectomy; AVI, Ahmed valve implant; BGI, Baerveldt glaucoma implant; CPC, cyclophotocoagulation; DSEK, Descemet-stripping endothelial keratoplasty; ECP, endocyclophotocoagulation; EOR, extensive orbital radiation; F, female; ICE, irido corneal endothelial syndrome; IG, inflammatory glaucoma; IOL, intraocular lens; M, male; MGI, Molteno glaucoma implant; MM, mix mechanism; NVG, neovascular glaucoma; OD, right eye; OS, left eye; PCiol, phacoemulsification with intraocular lens implant; PKP, penetrating keratoplasty; POAG, primary open-angle glaucoma; PPV, pars plana vitrectomy; PXF, pseudoexfoliation; SB, scleral buckle; SCT, stem cell transplant; STR, strabismus surgery; TAC, traumatic with acid burn to face and eyes; TR, tube erosion repair; Trab, trabeculectomy; TR, trauma due to BB gun injury.

TABLE 2. Additional Demographic and Clinical Course Characteristics of Study Subjects

<table>
<thead>
<tr>
<th>Case/Eye/ Age, y/Sex</th>
<th>Split Lid</th>
<th>HM or Worse in Fellow Eye</th>
<th>Preoperative Vision</th>
<th>Postoperative Vision</th>
<th>Change in Vision, Lines</th>
<th>Preoperative IOP</th>
<th>IOP at Last Follow-up</th>
<th>Change in IOP</th>
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<tr>
<td>1/OD/74/F</td>
<td>Yes</td>
<td>Yes</td>
<td>20/60</td>
<td>20/50</td>
<td>+1</td>
<td>19</td>
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<tr>
<td>2/OD/79/F</td>
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<td>No</td>
<td>20/400</td>
<td>20/400</td>
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<td>18</td>
<td>9</td>
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<tr>
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<td>Yes</td>
<td>20/100</td>
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<td>16</td>
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<tr>
<td>4/OS/79/F</td>
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<td>Yes</td>
<td>20/80</td>
<td>20/100</td>
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<tr>
<td>5/OS/83/F</td>
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<td>Yes</td>
<td>20/25</td>
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<td>24</td>
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<td>-9</td>
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<tr>
<td>6/OD/66/M</td>
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<td>9/OD/82/M</td>
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<tr>
<td>10/OS/56/F</td>
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<tr>
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<td>20/40</td>
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<td>Yes</td>
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<td>NLP</td>
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<td>No</td>
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<td>CF</td>
<td>0</td>
<td>15</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>

Abbreviations: CF, count fingers; F, female; HM, hand motion; IOP, intraocular pressure; KP, keratoprosthesis; LP, light perception; M, male; MM, mix mechanism; NA, nonapplicable; NLP, no light perception; OD, right eye; OS, left eye; SP, soft by palpation (IOP).
was limited, the eyelid was split vertically to the apex of the tarsus for access to the fornix, an improvement from our original experience (Figure 3A). A surgical pen was used to outline the pedicle flap in a 3:1 ratio of length to width. Lidocaine with epinephrine was injected beneath the outlined conjunctival flap to assist with dissection of the flap and hemostasis. When first learning this technique, it is best to err on making the flap larger to ensure sufficient tissue is available for adequate coverage. The conjunctival pedicle flap is interpolated onto the corneal patch and sewn to the limbus and surrounding conjunctiva with several interrupted polyglactin sutures (Figure 2B and Figure 3B). No sutures are necessary for the conjunctiva posterior to the exposed tube as these structures will heal by primary intent.

### POSTOPERATIVE VISITS

After surgery, all patients were prescribed a topical antibiotic ophthalmic drop for 1 week. Glaucoma medications and topical steroids were used at the discretion of the individual surgeon. Patients were evaluated at postoperative day 1, 7, and 30. Afterwards, they were followed up regularly on 3-month to 6-month intervals.

### OUTCOME MEASURES

The primary outcome measure was the recurrence of an erosion following the fornical conjunctival flap. Secondary outcomes were visual acuity and intraocular pressure control. A unique aspect of our tertiary referral practice is the nontransient nature of our patient population and the ability for long-term follow-up.

### RESULTS

All patients presented to the practice with tube erosions. Figure 4 demonstrates the typical appearance of patients in this case series (patient 7). Figure 4 demonstrates this patient’s uneventful postoperative course during the first 14 months.

A fornical conjunctival pedicle flap was successfully performed in all 15 cases. A corneal patch graft was used in 8 of the repairs and pericardium was used in 7 of the repairs. There were no intraoperative or postoperative complications. Three of the 15 cases required that the lid be surgically split to provide adequate exposure and access to the fornical conjunctiva. The lid incision in these 3 cases healed with minimal to no cosmetic morbidity.

The mean follow-up time after repair with the pedicle flap was 49
months (range, 3-156 months). Twelve eyes had at least 12 months of follow-up and 10 eyes had follow-up longer than 18 months. During the follow-up period, there were no recurrences of tube erosions and the conjunctival flap maintained a healthy appearance. Case 14 underwent several surgical procedures following a pedicle flap, including several corneal transplants and a keratoprosthesis. After 156 months of follow-up, this eye had very thin conjunctiva over the tube from the prior pedicle flap and was at very high risk for erosion. Although this patient has not had a repeat erosion, we are monitoring him closely to ensure one does not occur.

As seen in Table 1 and Table 2, there was no major difference between the following preoperative and postoperative values: visual acuity, intraocular pressure, and number of glaucoma medications. In case 8, the patient’s vision decreased from 20/200 to counting fingers; however, this was owing to issues not directly related to the erosion repair. The patient’s vision declined after undergoing a partial tarsorrhaphy, which was required to treat her exposure keratopathy from radiation orbitopathy. Table 1 and Table 2 summarize the clinical features of each patient as well as the follow-up course. During the follow-up period, no patients experienced diplopia or any other direct adverse events related to the pedicle flap.

### DISCUSSION

Tube erosions are an infrequent occurrence; however, when they occur, they are challenging to manage and may lead to endophthalmitis, device extrusion, and even epithelial downgrowth. Preoperatively, the conjunctiva should be inspected and, if the erosion is small and the surrounding conjunctiva appears healthy with redundancy, repair with a partial thickness corneal patch over the tube and direct conjunctival closure is indicated. However, most times, the surrounding conjunctiva is thin, scarred, scarce, and avascular owing to numerous previous surgical procedures (as noted in 80% of our cases). Preoperatively, one must also assess the eyelids. It is important to perform a simple distraction test on the eyelid overlying the exposed tube to determine lid laxity and assess availability and access to the conjunctival fornix. If the lid is very tight and immobile, one should be prepared to split the lid to access the fornix.

Pedicle flaps allow the importation of distal, vascularized tissue to an area lacking this essential ingre-
Pedicle flaps should have a 3:1 ratio, length to width. We have rotated flaps 60° to 120°, preferring to recruit them from the conjunctival fornix (while respecting and avoiding the lacrimal gland ducts when they are near the flap pedicle or base). When planning the flap, the base should be near, but not on, the drainage plate. Flaps from the lower fornix can be used to cover superior tube exposures and vice versa. Underlying Tenon tissue can be included in the proximal arm of the conjunctival flap to increase the distal flap’s vascularity and integrity. We generally advance and interpolate the flaps over conjunctiva surrounding the exposed tube rather than inlay the flap through surrounding conjunctiva. Although the conjunctiva originates from the fornix, we have not observed a symblepharon or other abnormal scar formation. Patients were examined at every visit to ensure proper healing of the pedicle flap. Patients who underwent the split-lid technique did not have traction placed on their upper lid until postoperative month 1. Despite their tight orbits, one could appreciate the health of the flap.

Given the complexity of these cases, it is best to have both the glaucoma and oculoplastic specialist involved in the surgical repair. Because flap harvesting requires a relatively wide exposure of conjunctiva, it is sometimes necessary to split the eyelid vertically near the exposed tube to gain adequate exposure to the fornical conjunctiva. In this case series, the lid-splitting technique was necessary for 3 of the 15 eyes. Primary closure of a surgical lid incision is routinely performed by oculoplastic specialists and can be performed predictably and reliably with no intraoperative or postoperative morbidity. In fact, in our case series, it was often difficult to detect which lids had in fact been split after 6 months of follow-up.

We have not had a single recurrence of a tube erosion after performing a conjunctival pedicle flap. Prior to the development of the fornical conjunctival pedicle flap, we often used an autologous conjunctival patch graft harvested from a different quadrant in the same eye or from the patient’s fellow eye. Because these free conjunctival grafts lacked adequate blood supply, they occasionally reeroded. Moreover, these free conjunctival grafts often came from quadrants that might need to be used for future glaucoma surgical procedures.

The goal of this study was to demonstrate the relative long-term safety and efficacy of the fornical conjunctival pedicle flap. This study had limitations typical of other retrospective medical record reviews. Given the relatively low frequency of tube erosions, even in a high-volume tertiary referral center, it is not feasible to perform a prospective randomized trial validating this technique.

In conclusion, tube erosions are a very challenging problem to manage, especially in eyes that have undergone several surgical interventions. As demonstrated by the retrospective review of our clinical data over the past 10 years, the fornical conjunctival pedicle flap is a safe, effective, and successful technique to solve this problem long-term. Moreover, it preserves the function of the previously placed tube and does not disturb adjacent quadrants, maintaining availability for future glaucoma surgery.

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Author Contributions: Study concept and design: Grover and Merritt. Acquisition of data: Grover and Merritt. Analysis and interpretation of data: All authors. Drafting of the manuscript: Grover and Merritt. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: Grover. Administrative, technical, and material support: All authors. Study supervision: Merritt. Conflict of Interest Disclosures: None reported.


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