A Case Series and Systematic Review: Results of Surgical Management of Glaucoma Drainage Device Tube Exposure

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ABSTRACT

Objective: To present a case series of patients who underwent surgical repair for glaucoma drainage device (GDD) tube exposure and conduct a systematic review to analyze results of various surgical techniques.

Materials and Methods: This study provides the details of GDD tube exposure repair at our hospital. Additionally, a systematic review was conducted using electronic databases including EMBASE, MEDLINE, and CENTRAL. Data extraction and analysis included demographic information, surgical techniques, results, and duration of follow-up.

Results: We reported nine cases of GDD tube exposure repair, with additional 109 cases from 24 previous studies. One of our challenging cases encountered multiple tube revision failures by the patch graft technique; the exposure issue was sustainably resolved by a hinge scleral flap with buccal mucosal graft technique. Of the 118 cases, various surgical techniques were used, including patch grafts, hinge scleral flaps, primary conjunctival closure and rerouting. Among the cases, 61.6% were classified as difficult cases. The overall first, fifth and thirteenth-year survival rate was 90.7%, 86.2% and 86.2%, respectively. Rerouting and scleral flap/tunnel techniques demonstrated the highest survival rate. No statistically significant differences in survival outcomes were observed among patch graft, scleral flap/tunnel and rerouting method (P = 0.129). The mean survival duration was 33.54 months. The duration of follow-up was 35.01 months.

Conclusion: Surgical management of GDD tube exposure yields favorable outcomes. A hinge scleral flap with buccal mucosal grafts can be a good option to treat challenging cases. The findings can shape an algorithm to manage GDD tube exposure.

Keywords: Glaucoma drainage device; glaucoma tube; glaucoma shunt; expose; treatment (Siriraj Med J 2024; 76: 865-875)

INTRODUCTION

Glaucoma is a prevalent chronic ocular disorder that affects a significant proportion of the global population. Among the various treatment modalities available for this condition, the implantation of a glaucoma drainage device (GDD) is a widely accepted and effective option. However, GDD-related complications such as tube exposure can occur, necessitating prompt and appropriate surgical management as the tube exposure can be the risk of ocular infection. The non-intact ocular barrier such as one caused by minor trauma can be associated with penetrating glaucoma surgery.[1] GDD tube exposure is a rare and sight-threatening complication of GDD implantation. The management of GDD tube exposure poses a significant challenge for ophthalmologists, as there is no consensus on the optimal surgical technique to repair the exposed tube. Several surgical strategies have been proposed, including primary conjunctival closure, repositioning the tube[2-4], covering the tube with a patch graft[5-21], scleral flap[22,23], scleral tunnel[24], and/or buccal mucosal graft.[19] However, there is no consensus on the optimal surgical technique.

To better understand the results of surgical treatment of GDD tube exposure, we present a case series of patients who underwent surgical repair of the exposed tube. In addition, we conduct a systematic review of the existing literature on the management of GDD tube exposure to provide a detailed analysis of the different surgical techniques and their respective results.

MATERIALS AND METHODS

This research was conducted in compliance with the principles of the Declaration of Helsinki. It received ethical approval from the Committee for the Protection of Human Participants in Research at the Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand. The research project has been registered in the Thai Clinical Trials Registry (TCTR20221004006).

We reported nine exposed GDD tubes repaired at the Department of Ophthalmology of the Faculty of Medicine of Siriraj Hospital, Mahidol University, Bangkok, Thailand. In this study, all cases of GDD tube exposure that required repair between October 2015 and March 2023 were included.

Also, we conduct a systematic review of GDD tube exposure repair. A comprehensive search of electronic databases was done, including EMBASE, MEDLINE, and CENTRAL, to identify all relevant studies. A search strategy was developed based on relevant keywords such as 'glaucoma drainage implant', 'glaucoma tube', 'glaucoma shunt', 'expose', 'erosion', and 'treatment' (Supplementary 1). The search was limited to studies published from January 1997 to April 2022. No restrictions on language and no filters were applied. All reports

of patients who had undergone GDD tube exposure repair were included. Studies were excluded if (1) they had insufficient data, (2) patients had GDD exposure concurrently with endophthalmitis, (3) they included patients with MIGS or other parts of GDD exposure, and (4) they were not a primary study.

The studies identified through the search underwent a two-step screening process. Two reviewers independently screened the titles and abstracts of all studies, and any discrepancies were resolved through discussion or by consulting a third reviewer. The interreviewer agreement to include an article for full-text review was strong (Cohen's kappa coefficient = 0.80). Full-text articles from potentially relevant studies were further screened using the same process. The reasons for excluding studies at each stage will be documented and reported according to the PRISMA 2020 Statement.[25]

The data extraction process included information on demographic data (sex, age, cause of glaucoma, type of GDD, time from GDD insertion to GDD tube exposure, previous ocular surgeries, previous tube exposure revision), the technique of tube exposure repair, survival time after repair and follow-up time. In one primary study, there was a lack of detailed information on the duration of survival for each individual case. The average survival duration was used to represent all the cases. Among the cases with sufficient available data, this study classified the cases as difficult cases if the patient met at least one of three criteria: (1) trauma-related glaucoma, (2) patients who had undergone at least one previous revision of tube exposure, or (3) patients who had undergone at least four previous ocular surgeries.

The quality of the included studies was independently evaluated by two reviewers using the tool proposed by Murad and colleagues[26], which was appropriate for the study design and assessed the risk of bias in the study, reported as high, moderate, or low. Any discrepancies will be resolved through discussion or by consulting a third reviewer.

All data analyzes were performed with SPSS Statistics version 18 (SPSS, Inc.). The data extracted from a systematic review and our reported cases were analyzed together. Continuous data were reported as mean in normally distributed data or median (IQR) in nonnormally distributed data. Categorical data were reported as numbers and percentages based on available data. Wilcoxon's signed rank test was used to compare postoperative and preoperative data. Kaplan-Meier analysis with a log-rank test showed survival function after tube exposure repair. Cox proportional hazards regression was used to assess the strength of association between surgical techniques with the respective 95% confidence interval (CI). $P<0.05$ indicated statistical significance.

Surgical technique

Tube coverage: Hinge scleral flap

As shown in Supplementary 2. After dissecting conjunctiva and Tenon's capsule (A), the scleral incision was made parallel to the tube approximately 1-2 mm from the tube with a depth of half the scleral thickness. From the incision, a half-thickness scleral tunnel was created using a crescent knife (B). The length of the flap was intended to cover 75-80 % of the entire length of the tube on the sclera. When the desired length of the flap was achieved, the Westcott tenotomy scissors were used to cut at each end of the tunnel to create a flap (C, D). Cover the tube with the flap and suture each corner of the flap with 10-0 nylon suture and then buried the knot (E, F).

Conjunctival substitute: Buccal mucosal graft

Prior to harvesting the graft, the patient should rinse their mouth with mouthwash three times. The buccal mucosa was painted with povidone-iodine. After measuring the size, the area was marked accordingly. The buccal mucosa was outlined with a sharp dissection using a 15-scalpel blade, and the graft was subsequently dissected with Westcott scissors. The buccal mucosal graft was placed to cover the GDD tube.

The important point is to reduce the wound tension by undermining the surrounding tissue until there is no tension between the graft and the surrounding tissue when the wounds are attached. The size of the graft should be larger than the defect because wound contraction can be powerful enough to cause wound dehiscence later. The bed of the graft is another thing to address, tenon tissue should be pulled and sewed to provide a nourishing bed for the oral mucosal graft. The favorable sign is tiny vessels that grow beyond the edge of the graft, thus the graft will start to get pinkish in color not pale.

RESULTS

Nine consecutive GDD tube exposures were repaired over a period of seven years. The baseline demographics and clinical characteristics of the patients are presented in Table 1. Of the nine patients, five were men (56%). The median age (IQR) was 51 (38, 76) years. Five different diagnoses of glaucoma were identified, uveitis being the most common. The Baerveldt implant was the most commonly used GDD implant and five GDDs were located superotemporal (56%). The median interval (IQR) between GDD insertion and tube exposure was 25.9 (5.9, 84.1) months. The patient had multiple previous

TABLE 1. Demographic and clinical characteristics of this current study.

Patient number	Age/Sex/ Eye	Glaucoma diagnosis	GDD model	Exposure quadrant	Time to exposure (month)	No. prior ocular surgery	Difficult case	IOP		BCVA		No. glaucoma medication	
								Pre-op	Post-op	Pre-op	Post-op	Pre-op	Post-op
2	36/F/R	Post PKP	Baerveldt	Superotemporal	58.5	6	Yes	Not tense	Not tense	0.56	0.5	2	2
3	74/M/L	Uveitis	Baerveldt	Superonasal	18.8	3	No	8	Not tense	0.3	0.34	0	0
4	40/F/L	Uveitis	Baerveldt	Superonasal	1	4	Yes	4	4	2.3	2.3	0	0
7	52/F/R	Uveitis	Baerveldt	Superotemporal	109.7	5	Yes	8	10	1.6	2	0	0
8	77/M/L	POAG	Ahmed	Superotemporal	10.4	2	No	14	10	0.6	0.8	3	2
9	85/F/R	Uveitis	Malteno	Inferotemporal	223.7	6	Yes	4	2	2	2	0	0
1	8/M/R	Congenital	Baerveldt	Superonasal	27.3	5	Yes	13	19	2	2	3	1
5	48/M/L	Blast injury	Baerveldt	Superotemporal	1.3	5	Yes	0	4	2.6	0.62	0	0
6	51/M/R	Blast injury	Baerveldt	Superotemporal	25.9	6	Yes	9	8	2	2.3	0	0
Median (IQR)	51 (38, 75.5)				25.9 (5.9, 84.1)	5 (4, 6)		8 (4, 12)	8 (4, 10)	2 (0.58, 2.15)	2 (0.56, 2.15)	0 (0, 2.50)	0 (0, 1.5)
P-value[#]								0.689		0.689		0.5	

[#]Wilcoxon signed rank test

Abbreviations: GDD = glaucoma drainage device; PKP = penetrating keratoplasty; POAG = primary open-angle glaucoma

ocular surgeries with a median (IQR) of 5 (4, 6) times. Various repair techniques were utilized to repair the nine consecutive GDD tube exposures. These included five patch grafts, one patch graft with buccal mucosal graft, two hinge scleral flaps, and one primary closure with a viable former patch graft. Seven out of nine cases (77.8%) were categorized as difficult cases. No statistically significant differences were observed in the pre and post repair values of IOP, BCVA, or the number of glaucoma medications used. The median follow-up time (IQR) after the first repair was 16.4 (5.5, 41.5) months. Surgical outcomes are presented in Table 2. Six cases were successfully repaired until the latest follow-up visit. No intraoperative complications were found. However, three cases required additional surgeries due to reexposure of the GDD tube. Further details regarding these failure cases are described below.

In case No. 1, an 8-year-old boy underwent a Baerveldt shunt implantation two years prior due to congenital glaucoma. The surgical procedure involved the use of a scleral flap and a corneoscleral patch graft to cover the tube. However, the patient experienced two instances of tube exposure, the first of which was repaired using a corneoscleral patch graft with a primary conjunctival closure technique. Nine days later, a second tube exposure occurred, which was repaired using a corneoscleral patch graft with a buccal mucosal graft. The tube remained covered for six months, but the patient later presented with a third exposure along with eye discharge and discharge inside the lumen of the tube. No vitritis was detected. The shunt was subsequently removed along with a subconjunctival antibiotic injection and there were no subsequent occurrences of endophthalmitis.

Case No. 5, a 48-year-old man with a firecracker injury to his left eye. A Baerveldt shunt implantation was performed using a patch graft covering the tube. Poor conjunctival integrity was noted intraoperatively with a few button holes. The buccal mucosal graft was used to cover the holes. A month later, the wound was dehisced with tube exposure and bleb leakage. The former patch graft was still in place, so primary conjunctival closure was performed. Nevertheless, the conjunctiva dehisced multiple times, necessitating two buccal mucosal grafts and one resuture. Later, a reexposure occurred with early signs of endophthalmitis. The shunt was removed and intravitreal antibiotics were injected. Endophthalmitis resolved. The patient received endoscopic cyclophotocoagulation to lower the IOP.

Case No. 6, a 51-year-old male, a victim of a gas explosion. He had multiple concurrent eye injuries including a ruptured globe, retinal detachment, rejection of the graft after penetrating keratoplasty surgery, and occlusion of the central retinal vein. The patient underwent multiple surgeries, received multiple intravitreal injections, and was on prolonged steroid therapy. Two years after the Baerveldt shunt implantation, the first tube exposure occurred. A corneal button graft with conjunctival autograft was used to cover the tube. Subsequently, several tiny tube reexposures (about 0.1 millimeters) with concurrent corneal graft rejection and persistent corneal epithelial defects were detected. The patient received 11 patches of the amniotic membrane covering both the persistent corneal epithelial defect and tube exposure. After stabilizing the corneal disease, tube exposure repair was performed using a corneal patch graft with primary conjunctival closure. Two weeks later, the reexposure occurred. The split-thickness hinge scleral flap with a buccal mucosal graft was used to cover the tube. The tube remains covered until the last follow-up visit, which was 3.3 years after the last repair.

Until April 2022, a total of 109 cases of GDD tube exposure were identified, originating from 24 primary research studies (Supplementary 3), apart from 9 cases from the current study.[2-24,27] The comprehensive results of the search are presented in PRISMA flow diagram (Supplementary 4). Demographic information for the 118 cases is presented in Table 3, although some data were not available. The average age of the participants was 61 years, with a nearly equal gender distribution of 51% male and 49% female. The common causes of glaucoma were primary open-angle glaucoma (POAG; 22.9%), uveitis (13.6%), and trauma (11%). There were some undetermined secondary causes in which further details were unavailable from the primary study. Other secondary causes (mentioned in Table 3) included post-encircling, corneal ulcers, multiple surgery, and steroid-induced glaucoma. The most commonly implanted type of GDD was the Ahmed model (59.3%). The patients had undergone a mean of 3.78 previous ocular surgeries and most of them (86%) had not received any previous repair for tube exposure. Tube erosion occurred after GDD implantation in a mean of 3 years. Among patients with sufficient data available (n = 86), 53 individuals (61.6%) met the criteria for difficult cases.

Of all 118 cases, the reexposure of GDD tubes occurred in 12 cases (10.2%). The average duration of follow-up after repair was 35.01 months. The mean survival duration after repair was 33.54 months. A cumulative survival rate was shown in the Kaplan-Meier curve (Fig 1). The first-year survival rate was 90.7%. Although the survival rates for the second to fourth year remained at 89.1%. Then it dropped to 86.2% in the fifth to thirteenth year.

TABLE 2. Details of operation techniques and repair outcomes.

Patient number	First repair method	First repair outcome	First repair survival duration (month)	No. total repair	For failure case			Follow-up time after the first repair (month)
					Final major repair method	Final outcome	Cause of GDD removal	
2	Patch graft	Success	54.7	1				54.7
3	Patch graft + buccal mucosal graft	Success	24.4	1				24.4
4	Hinge scleral flap + buccal mucosal graft	Success	28.3	1				28.3
7	Hinge scleral flap + patch graft + rerouting	Success	9	1				9
8	Patch graft	Success	3.1	1				3.1
9	Patch graft	Success	2.6	1				2.6
1	Patch graft	Failure	0.3	2	Patch + buccal mucosal graft	Removed	Sign of early infection	16.4
5	Primary closure	Failure	0.7	3 Major 1 Minor*	Buccal mucosal graft	Removed	Endophthalmitis	7.8
6	Patch graft	Failure	3.5	3 Major 11 Minor*	Hinge scleral flap + buccal mucosal graft	Success		59.3
Median (IQR)			3.5 (1.7, 26.4)					16.4 (5.5, 41.5)

*Minor procedure including resuture and amniotic membrane patching

TABLE 3. Baseline characteristics of all cases.

Characteristics	Value
Mean age (year)	61.15
Sex (M: F)	51:49
Glaucoma diagnosis; n (%)	
POAG	27 (22.9)
Uveitis	16 (13.6)
NVG	9 (7.6)
Trauma	13 (11)
Congenital	6 (5.1)
Post PKP	6 (5.1)
Post PPV	4 (3.4)
PACG	4 (3.4)
JOAG	3 (2.5)
PXG	2 (1.7)
ICE	2 (1.7)
Mix mechanism	7 (5.9)
Other secondary causes	5 (4.2)
Undetermined secondary cause	14 (11.9)
GDD type; n (%)	
Ahmed	70 (59.3)
Baerveldt	46 (39)
Molteno	2 (1.7)
Mean number of previous ocular surgery	3.78
Number of previous tube expose repair; n (%)	
0	98 (86)
1	11 (9.6)
2	4 (3.5)
3	1 (0.9)
Mean time from GDD insertion to tube erosion (month)	35.84
Difficult case; n (%)	53 (61.6)

Abbreviations: GDD = glaucoma drainage device; ICE = iridocorneal endothelial syndrome; JOAG = juvenile open angle glaucoma; NVG = neovascular glaucoma; PACG = primary angle-closure glaucoma; PKP = penetrating keratoplasty; POAG = primary open-angle glaucoma; PPV = pars plana vitrectomy; PXG = pseudoexfoliative glaucoma

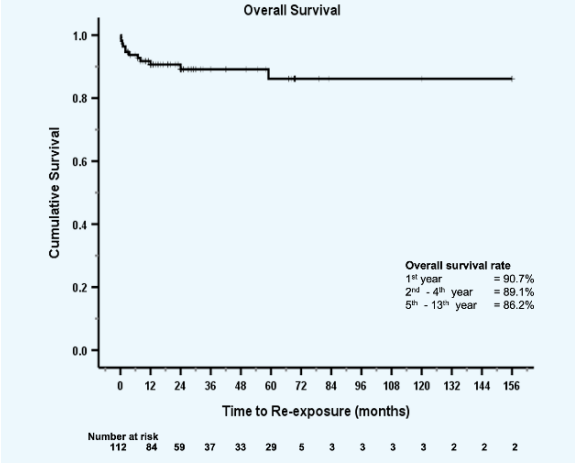

Fig 1. Kaplan-Meier survival analysis of the overall GDD tube-exposure repair.

Various surgical methods were performed for the repair of GDD tube exposure (Table 4). In 84 eyes, the repair involved the use of a novel patch graft placed on the exposed tube. This approach was applied in 24 cases with additional buccal mucosal grafts layered on top, while in 60 cases other conjunctival substitutes were used instead. Patch grafts consisted of 45 corneas, 20 pericardia, 7 scleras, 5 corneoscleras, 4 tenon capsules, 2 Ologen® collagen matrix and 1 perichondrium. In 15 eyes, the tubes were rerouted to a new location, either into the vitreous cavity or positioned above a new area of the sclera. Among these cases, 12 received supplementary patch grafts on top, while 3 did not. In 18 eyes, hinge scleral flaps or scleral tunnels were created to provide cover for the tubes. Among these, 14 cases used supplementary patch grafts, while 4 did not. Only one case was repaired by primary conjunctival closure without any additional patch graft or flap, noting that the former patch graft that had been placed during initial implantation of GDD still covered the tube.

Based on various surgical repair methods, the rate of reexposure, the follow-up time and the number of difficult cases are shown in Table 4. Repair techniques involving rerouting and scleral flap or scleral tunnel methods did not demonstrate instances of reexposure during the average follow-up periods of 26.7 and 14.2 months, respectively. Within these respective groups, 6 cases (54.5%) and 7 cases (38.9%) were classified as difficult cases. In a single difficult case that underwent primary conjunctival closure repair, reexposure was observed on the 21st day following the repair. Among the 24 cases using the patch graft method with buccal mucosal graft, 3 instances of reexposure (12.5%) occurred 1, 2, and 59 months after the repair, with an average follow-up duration of 67.4 months. The complexity of the cases within this particular group could not be determined due to inadequate data. Out of 60 cases in which patch grafts were employed with other conjunctival substitutes, eight cases (13.3%) exhibited reexposure. The reexposure occurred at 0.3, 0.3, 2, 3.5, 7, 8, 12, and 24 months after repair. This group exhibited the highest proportion of difficult cases, comprising 39 cases (71%).

The subgroup analysis of a survival probability is shown in Fig 2. Among the different methods used for tube exposure repair (Fig 2A), rerouting and scleral flap/tunnel techniques demonstrated the highest survival rate, followed by the patch graft with the buccal mucosal graft method, which demonstrated a higher survival rate compared to the patch graft with other conjunctival substitutes method. However, the primary conjunctival closure method was not shown in the graph. It exhibited the lowest survival rate. The first-year survival rates for these methods were 100%, 91.7%, 86.6%, and 0%, respectively. No statistically significant differences were observed among all the methods shown in Fig. 2A (P=0.129). Furthermore, the patch graft with other

TABLE 4. Methods of GDD tube exposure repair and outcomes.

Methods of GDD tube exposure repair	n	Reexposure n (%)	1st year survival	Mean follow-up time (month)	Difficult case n (%)
Total	118	12 (10.2)	90.7%	35.01	53 (61.6)
Patch graft	84	11 (13.1)	88.4%	41.3	39 (70.9)
With buccal mucosal graft	24	3 (12.5)	91.70%	67.4	Unidentified
With other conjunctival substitutes	60	8 (13.3)	86.60%	31.8	39 (70.9)
Rerouting	15	0	100%	26.7	6 (54.5)
With patch graft	12			26.8	3 (37.5)
Without patch graft	3			26.7	3 (100)
Scleral flap/tunnel	18	0	100%	14.2	7 (38.9)
With patch graft	14			13.8	6 (42.9)
Without patch graft	4			15.6	1 (25)
Conjunctival closure only (no patch graft/flap)	1	1 (100)	0%	7.8	1 (100)
Missing data (n)	0	0	6	9	32

Abbreviation: GDD = glaucoma drainage device

conjunctival substitutes group exhibited a higher risk of reexposure compared to the patch graft with buccal mucosal graft group, as indicated by a hazard ratio of 1.52 (95% CI 0.39-6.00). However, this difference did not reach statistical significance (P = 0.547). In terms of case complexity (Fig 2B), it was observed that difficult cases exhibited a lower survival rate and a higher risk of reexposure compared to nondifficult cases, with a first-year survival rate of 86.2% and 96.4%, respectively. The hazard ratio was 4.76 (95% CI 0.59-38.11) without statistical significance (P = 0.142).

DISCUSSION

Since there are various methods to manage tube exposure, choosing the right one for each patient can be challenging. To our knowledge, this study is the complete review of the literature according to the methods of managing tube exposure to this day. In this study, we found that rerouting and hinge scleral flap are the most successful method. The split-thickness hinge scleral flap technique has been proposed by Lee et al.[23] Furthermore, from our case report there was one patient who suffered a blast injury with multiple failures from the patch graft technique. Finally, the exposure was successfully ended with a hinged scleral flap together with a buccal mucosal graft.

Lack of guideline and high-quality RCTs due to the rarity of the disease and various surgical options, we attempt to complete the review with the idea that there is not only one best solution for all patients. However, there should be more sophisticated techniques for more challenging cases. Therefore, we classified the cases into difficult cases which are the cases that are more challenging from a surgical point of view to resolve the exposure of the tube. Recurrent tube exposure, widespread conjunctival damage caused by trauma, and multiple previous surgeries are criteria in this study where the patient can be classified as difficult cases if they meet at least one of these criteria.

Basically, when encountering a tube eroded, the causes needed to be identified. First, if the problem is with mechanical tube rubbing against the conjunctiva, then the tube should be secured firmly to the sclera. Second, if the problem is about patch graft dissolution, then proper tube coverage is mandatory. Third, if conjunctival health is a problem, one should search for appropriate conjunctival substitutes. Finally, other modifiable factors such as medications and some systemic conditions that were believed to have a negative impact on wound healing should be addressed. For example, changing the eye drop of steroids to other immune suppressors can help accelerate wound healing.[28,29]

Among a number of causes underlying the exposure of the GDD tube, patch graft melting has been widely discussed. Smith et al. had studied 64 eyes after GDD implantation with various types of patch graft, including donor sclera, dura mater, and pericardium. The result was similar in terms of percentage of graft melting during 2 years of follow-up.[30] The pathophysiology of graft dissolution is not fully understood, but it could be related to an immune-mediated process.[30] The hinge scleral flap is presumed to have some benefit over the other patch grafts due to its biocompatibility and demonstrates its own vascular supply. Therefore, it could be more resistant to melt. It has been confirmed by a comprehensive review comparing tube covering materials done by Silva et al.

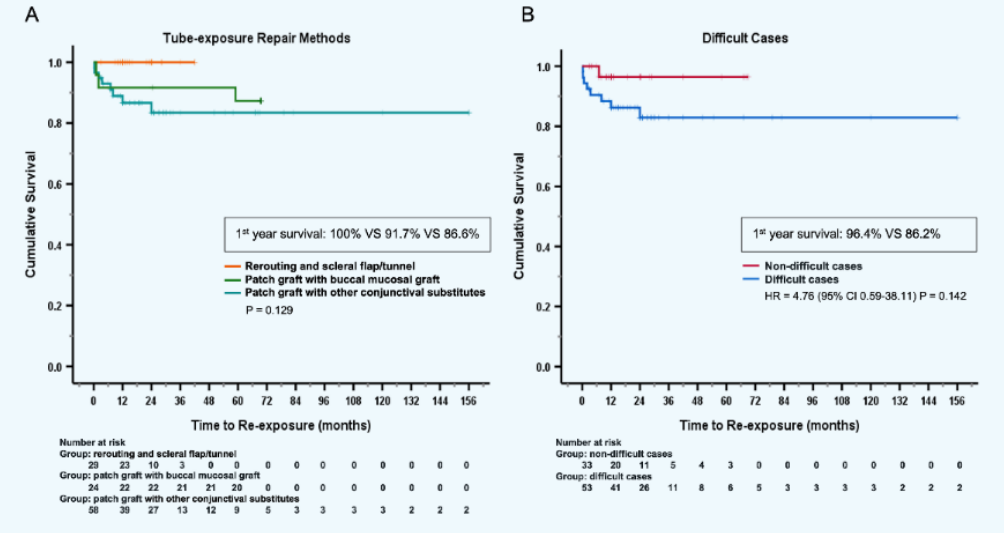

Fig 2. Kaplan-Meier survival analysis of GDD tube-exposure repair in different subgroups. (A) Survival rates corresponding to the use of different repair methods. (B) Survival rates for cases classified as difficult and nondifficult.

that scleral flap provides a low rate of tube exposure.[31] This might explain why hinge scleral flap have a higher success rate than patch grafts and could successfully close the defect of a patient in our series who had failed from multiple patch graft repair.

However, the patch graft group has a longer follow-up time with a more difficult case percentage compared to the rerouting and hinge scleral flap technique. Therefore, the interpretation must be done with care. Rerouting is another interesting technique that can be used with refractory cases. Theoretically, it eliminates all the problems of unhealthy conjunctiva and the localized wound healing problem by moving the tube to a more healthy area. Using this technique sometimes requires special instruments such as tube extender[3], vitrectomy tools, pars plana tube[4], etc. Compared to rerouting, hinge scleral flap requires simple technique and tools. However, the patient with thin sclera is not a good candidate for this method.

Not only tube coverage, but conjunctival replacement is another point to be concerned with. Especially in the case with scar, thin, and friable conjunctiva, severe ocular surface problem, and re-exposed tube where the defect tends to get bigger when the previous repair attempt had failed. The surgical options must be tailored. Both fresh and preserved human amniotic membranes have been widely used. These membranes consist of a dense basement membrane that facilitates epithelial healing, while also modulating inflammation and reducing scar formation.[32] However, when considering coverage for the exposed GDD tube, the oral mucosa is superior to the amniotic membrane because it is thicker and more stable.[33] Not only its durability but also the presentation of epithelial stem cells in the oral mucosa.[33] Compared to nasal mucosa, although oral mucosa has no goblet cells, it is easier to access the tissue, so the glaucoma specialist can do it herself. Furthermore, the grafts are not different in terms of durability.[33]

There are several limitations in this study. The first is the limited number of cases due to the rarity of this condition. Second, we have a variety of methods being used to manage the condition. Comparing between all the methods was difficult and made the number in each group smaller; then we grouped them into 3 groups to get some idea of how each group of methods performs. Third, most of the literature was case series and was reported retrospectively, so it lacks some information with different demographic data of patients. However, we present characteristics of the reports and evaluate the risk of bias to each paper. Most of the reports show a low risk of bias.

In conclusion, this study is the first complete systematic review to date regarding tube exposure repair with mostly low risk of bias literature was gathered and analyzed. Together with our case series, they can shape the algorithm managing tube exposure. The hinged scleral flap with oral mucosal graft can be a good choice to deal with more challenging cases. It could also be a guide for repairing tube erosion in a stepwise manner. No single method suits all, but this more sophisticated technique could be reserved for more difficult cases.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

Author Contributions

S.P., N.N. and T.P. designed the study, collected data, recruit articles and extract data from articles. N.N. and S.P. interpreted the results. N.N. wrote the manuscript with support from S.P., N.R, P.P., D.S., N.K. and A.J. All authors provided critical feedback and helped shape the research.

Use of artificial intelligence

Artificial Intelligence tool was not used in this manuscript.

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