Original Article

Prognostic factors affecting the surgical success of gonioscopy-assisted transluminal trabeculotomy

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Purpose: To investigate the prognostic factors affecting gonioscopy-assisted transluminal trabeculotomy (GATT) surgical success. **Methods:** Fifty-three eyes were retrospectively enrolled. Open-angle glaucoma patients with at least 6-month follow-up were included. At baseline, demographic characteristics, intraocular pressure (IOP), number of anti-glaucomatous medications (AG), and glaucoma type were recorded. Postoperatively, IOP, complications, and number of AG were noted. The effects of these parameters on surgical success were investigated. **Results:** The median follow-up time was 13.7 months. The mean IOP decreased from 25.6 ± 6.2 mm Hg at baseline to 14.6 ± 3.5 mm Hg at final, and the number of AG decreased from 3.2 ± 0.78 to 1.2 ± 1.3. When target IOP was considered as 18 mm Hg and 15 mm Hg, surgical success rates were 81.1% and 60.4%, respectively. When target IOP was considered as 18 mm Hg, a positive effect of the combination with cataract surgery and a negative effect of postoperative macrohyphema on success rates were observed. Other factors did not show any association with the success rates for both target IOP values when analyzed by the Cox proportional hazards regression analysis. **Conclusion:** Postoperative macrohyphema may affect surgical success rates negatively. The contribution of the combination with cataract surgery is controversial. Glaucoma stage does not seem to affect surgical success.

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In recent years, minimally invasive glaucoma surgeries (MIGS) have increasingly been performed for the surgical treatment of glaucoma. The high incidence of the complications with trabeculectomy and valve surgeries has been the main reason for choosing MIGS. Various MIGS techniques have been described respectively since the beginning of the 2000s.[1] Goniotomy-assisted transluminal trabeculotomy (GATT) was first introduced in 2014 by Grover *et al*. They reported that GATT led to a significant decrease in both IOP and anti-glaucoma medications in patients with open-angle glaucoma.[2] Despite the fact that the effectiveness and reliability of the GATT have been shown in many studies, there are not enough studies on prognostic factors affecting its surgical success.[2-6] In addition, any studies about prognostic factors affecting surgical outcomes of GATT in advanced stage glaucoma patients have not been reported yet. This study was conducted in order to report the results of the patients who underwent GATT surgery and to investigate prognostic factors affecting GATT surgical success.

Methods

Patients with open-angle glaucoma who underwent the GATT surgery between 2015 and 2018, and had a follow-up of at least 6 months were retrospectively enrolled. GATT surgery was indicated when an IOP was higher than 21 mm Hg or a progression was detected despite maximum medical therapy which refers to three or more classes of anti-glaucomatous medication. Moreover, GATT was performed in one eye with anti-glaucomatous drop allergy, although the IOP was 14 mm Hg. Preoperative demographic characteristics, previous intraocular surgeries, ophthalmologic examination findings, intraocular pressure (IOP), number of preoperative anti-glaucoma medications, visual field (VF) data from the Humphrey Field Analyzer II (HFA; Carl Zeiss Meditec, Inc., Dublin, CA, USA), retinal nerve fiber layer (RNFL) thickness data from the Spectralis HRA +OCT (Heidelberg Engineering, Heidelberg, Germany), glaucoma type, postoperative IOP, number of postoperative anti-glaucoma medications, and complications were recorded. Severity of glaucoma was graded according to the mean deviation (MD) value in VF test. For mild disease, MD ≥ -6 dB; for moderate disease, –12 dB ≤ MD < –6 dB; and for severe disease MD < –12 dB values were considered. The effects of these parameters on surgical success were investigated. Postoperative IOP spike is defined as an IOP of more than 25 mm Hg in postoperative 1-month period. Any hyphema filling more than half of the anterior chamber was considered as macrohyphema.

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GATT was performed with thermal suture modification technique described by Grover DS *et al*.[7] In patients with coexisting cataract and open-angle glaucoma, GATT was performed first and then cataract was removed using phacoemulsification. A partial trabeculotomy could be performed in some cases due to the inability to cannulate the Schlemm's canal circumferentially. In these cases, a second cannulation was attempted in the opposite direction as suggested by Grover *et al*.[7] Consequently, 360-degree trabeculotomy could be achieved in all eyes. Postoperatively, topical antibiotics and steroids were initiated. Previous anti-glaucoma medications were discontinued.

The data from first day, first week, first month, third month, sixth month, first year, and second year were recorded. The two different postoperative IOP threshold values for surgical success were determined as IOP ≤15 mm Hg and ≤18 mm Hg. If postoperative IOP was measured higher than 21 mm Hg or further glaucoma progression was detected, anti-glaucoma medication was initiated. The need for further glaucoma surgery was considered as surgical failure.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics version 17.0 software (IBM Corporation, Armonk, New York). Whether the distributions of continuous variables were normally or not being determined Kolmogorov–Smirnov test. Descriptive statistics for continuous variables were expressed as mean ± SD or median (25^{th} – 75^{th}) percentiles, where appropriate. Number of cases and percentages were used for categorical data. While the mean differences between groups were compared Student's *t* test, otherwise the Mann Whitney U test was applied for the comparisons of not normally distributed data. Categorical data were evaluated Continuity corrected χ^2 or Fisher exact test, where applicable. Whether the differences in IOP and number of medications between pre- and postop were statistically significant or not were examined Paired *t* test and Wilcoxon Sign Rank test, respectively. The Kaplan–Meier survival curves were used in order to examine cumulative success rate throughout the follow-up. Univariate Cox's proportional hazard regression models were performed to identify factors associated with success. The results were considered statistically significant for $P < 0.05$.

Results

A total of 53 eyes of 53 patients were enrolled in the study. Glaucoma types, demographic information, and clinical data are shown in Table 1. Sixty percent of the eyes had VF data, and 92% of the eyes had RNFL thickness data. Mean VF MD was –18.48 ± 9.20 db (range: –1.90 to –33.80), mean pattern standard deviation was 7.79 ± 3.26 db (range 1.80 to 12.58) and mean RNFL thickness was 59.27 ± 20.91μ (range: 30 to109).

The average IOP was 25.6 ± 6.2 mm Hg (14-40) at baseline, 13.3 ± 3.0 mm Hg at postoperative sixth month, and 15 ± 3.8 mm Hg at postoperative first year. The average IOP decrease was 11.0 ± 6.7 mm Hg at last visit. Preoperative and postoperative IOP values were illustrated in a scatter plot [Fig. 1]. The average IOP decreases were 48.0%, 43.6%, 42.9% at sixth month, first year, and final visit, respectively. The average duration of pre-operative anti-glaucomatous treatment was 4.0 ± 1.5 (1-6) years. The average number of anti-glaucoma medications decreased from 3.2 ± 0.8 to 1.2 ± 1.3. The differences in IOP and number of medications were statistically significant (both $P < 0.001$).

Table 1: Demographic and Clinical Data

	n=53
Age (year)	59.5±19.3
Age range (year)	12-86
Glaucoma Types	
POAG	26 (49.1%)
PXF	20 (37.7%)
Inflammation Related Glaucoma	3 (5.6%)
Juvenile and Congenital Glaucoma	3 (5.6%)
Silicone Oil Glaucoma	1 (1.8%)
Previous Intraocular Surgery Except P-IOL	7 (13.2%)
Previous Glaucoma Surgery	4 (7.5%)
Severity of Glaucoma	
Mild	7 (13.2%)
Moderate	7 (13.2%)
Severe	39 (73.6%)
Preoperative median C/D	0.80 (0.60-0.90)
Postoperative IOP Spike	16 (30.2%)
Additional Glaucoma Surgery	5 (9.4%)
Combination with P-IOL	15 (28.3%)
Hyphema in Postoperative 1st Day	
Microhyphema	48 (90.6%)
Macrohyphema	5 (9.4%)
Follow-up (month)	13.7 (6-24)

POAG: Primay open-angle glaucoma, PXF: Pseudoexfoliative glaucoma, C/D: Cup-to-disc ratio, P-IOL: Phacoemulsification with intraocular lens implantation, IOP: Intraocular pressure

The surgical success rate was 81.1% when the target IOP was considered as 18 mm Hg. All the effects of the demographic and clinical data on surgical success were investigated. There was a significant positive effect of the combination with cataract surgery and a negative effect of postoperative macrohyphema development on the surgical success rate ($P = 0.046$, $P = 0.041$, respectively, Table 2). The surgical success rate was 60.3% when the target IOP was considered as 15 mm Hg. None of the other parameters was found to be associated with the surgical success rate [Table 2].

When the effects of these parameters on the surgical success rates were analyzed through the Cox proportional hazards regression analysis, it was found that none of the factors affected the success rates for both target IOP values [Table 3]. The Kaplan-Meier survival curves are shown in Figs. 2 and 3.

In fifteen eyes, cataract surgery was performed following GATT surgery. The preoperative IOP was 23.0 ± 6.9 mm Hg and the postoperative was 13.7 ± 2.6 mm Hg in this combined surgery sub-group. The preoperative and postoperative IOP's were 26.7 ± 5.6 and 15.0 ± 3.8 mm Hg in 38 eyes in which GATT was performed alone. No significant difference was found between the groups regarding the IOP change ($P = 0.253$, Student's t-test).

Surgical complications

Microhyphema was observed in 48 (90.6%) of the eyes, while macrohyphema in 5 (9.4%) of the eyes. Hyphema was transient and cleared spontaneously in all but two eyes which required anterior chamber washing. Toxic anterior segment syndrome was observed in one eye, and successfully settled by increasing the dose of corticosteroid drop. No serious complications such as endophthalmitis or hypotony were encountered.

Discussion

High rates of the serious complications with traditional glaucoma surgeries have been well-known for many years and have also been reported in the TVT study.[8] These complications have prompted glaucoma surgeons to perform MIGS more frequently in recent years.[1] GATT is a newly described ab interno trabeculotomy procedure. Successful surgical outcomes of GATT with low complication rates were reported by numerous authors, especially by Grover, in the last 5 years.[2-7]

The researchers found that visual field progression was significantly worse when IOP was greater than 17.5 mm Hg in the AGIS study; however, they observed no progression when IOP was lower than 14 mm Hg.[9] Considering 73.6% of the all eyes have advanced-stage glaucoma in the present study, two different surgical success criteria, target IOP ≤18 mm Hg and ≤15 mm Hg, were defined. The surgical success rate was 81.1% for target IOP less than 18 mm Hg and 60.3% for less than 15 mm Hg. The average decreases in IOP were 48%, 43.6% at month 6, month 12, and the average number of anti-glaucoma medication decreased from 3.1 to 1.2 in the study. It ranged between 30% and 52.7% at month 6, 39.8% and

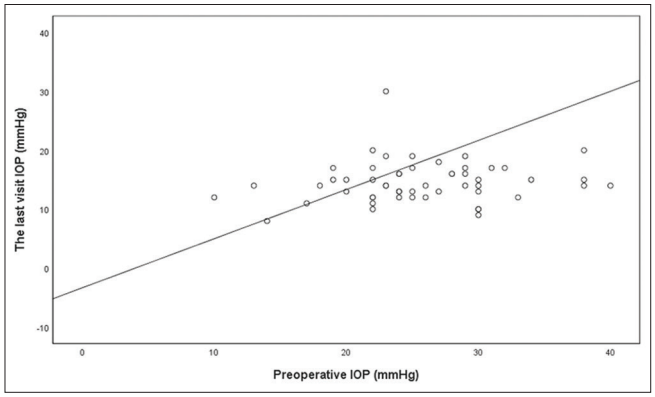

Figure 1: The scatter plot which represent the preoperative and postoperative IOP values

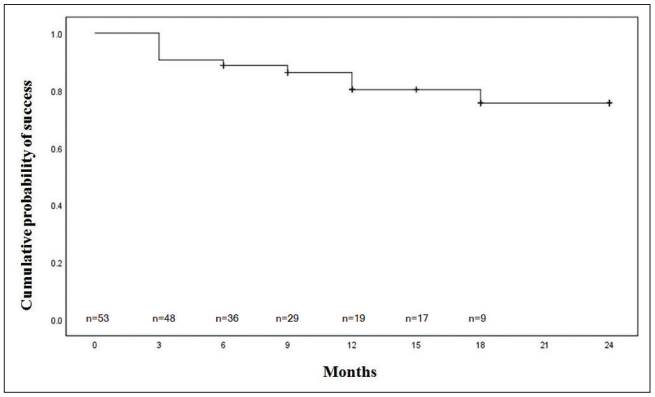

Figure 2: The Kaplan-Meier survival curves (IOP≤18 mm Hg) open-angle

Table 2: Surgical success rates and statistical analysis results according to demographic and clinical data when the target IOP was 18 mm Hg and 15 mm Hg

Target IOP	18 mm Hg			15 mm Hg		
	US (*n*=10)	S (*n*=43)	*P*	US (*n*=21)	S (*n*=32)	*P*
Age (year)	53.6±22.7	60.9±18.4	0.288†	52.1±20.9	64.3±16.8	0.023†
Glaucoma Type						
POAG	4 (40.0%)	22 (51.2%)	0.728‡	12 (57.1%)	14 (43.8%)	0.501¥
PFX	4 (40.0%)	16 (37.2%)	>0.999‡	5 (23.8%)	15 (46.9%)	0.160¥
Other	2 (20.0%)	5 (11.6%)	0.604‡	4 (19.0%)	3 (9.4%)	0.415‡
Previous Intraocular Surgery Except P-IOL	0 (0.0%)	7 (16.3%)	0.323‡	3 (14.3%)	4 (12.5%)	>0.999‡
Previous Glaucoma Surgery	0 (0.0%)	4 (9.3%)	>0.999‡	2 (9.5%)	2 (6.3%)	>0.999‡
Preoperative IOP	24.6±5.6	25.9±6.4	0.567†	25.7±4.8	25.6±7.0	0.967†
Preoperative C/D	0.8 (0.5-0.9)	0.8 (0.7-0.9)	0.699¶	0.8 (0.8-0.9)	0.8 (0.6-0.9)	0.642¶
Postoperative IOP Spike	3 (30.0%)	13 (30.2%)	>0.999‡	6 (28.6%)	10 (31.3%)	>0.999¥
Combination with P-IOL	0 (0.0%)	15 (34.9%)	0.046‡	3 (14.3%)	12 (37.5%)	0.128¥
1st Day Macrohyphema	3 (30.0%)	2 (4.7%)	0.041‡	4 (19.0%)	1 (3.1%)	0.074‡
Number of Postoperative Medications	6 (60.0%)	23 (53.5%)	>0.999‡	12 (57.1%)	17 (53.1%)	0.996¥
RNFL	51.1±14.8	60.8±21.7	0.232†	54.4±19.7	62.1±21.4	0.217†
MD	-19.2±9.8	-18.3±9.2	0.827†	-18.6±10.1	-18.4±8.8	0.950†
PSD	7.8±3.5	7.8±3.3	0.988†	7.0±3.3	8.3±3.2	0.318†

† Student's *t* test, ‡ Fisher exact test, ¶ Mann Whitney U test, ¥ Continuity corrected χ^2 test. US: Unsuccessful, S: Successful, POAG: Primay open-angle glaucoma, PXF: Pseudoexfoliative glaucoma, C/D: Cup-to-disc ratio, P-IOL: Phacoemulsification with intraocular lens implantation, IOP: Intraocular pressure, RNFL: Retinal nerve fiber layer, MD: Mean deviation, PSD: Pattern standard deviation

Table 3: The analysis of the effects of the parameters on the surgical success rates through the cox proportional hazards regression analysis

Target IOP	18 mm Hg			15 mm Hg		
	HR	%95 CI	*P*	HR	%95 CI	*P*
Age (year)	1.005	0.990-1.019	0.547	1.006	0.988-1.025	0.494
Glaucoma type						
POAG	Reference	-	-	Reference	-	-
PFX	1.205	0.631-2.302	0.572	1.493	0.714-3.119	0.287
Other	0.778	0.294-2.062	0.614	0.940	0.269-3.282	0.923
Previous Intraocular Surgery Except P-IOL	0.891	0.396-2.005	0.780	0.811	0.284-2.136	0.695
Previous Glaucoma Surgery	0.831	0.297-2.329	0.725	0.894	0.210-3.814	0.880
Preoperative IOP	1.008	0.957-1.061	0.768	1.013	0.956-1.072	0.671
Preoperative C/D	1.357	0.228-8.078	0.737	1.023	0.156-6.726	0.981
Postoperative IOP Spike	1.183	0.615-2.275	0.614	1.220	0.573-2.597	0.606
Combination P-IOL	0.840	0.446-1.581	0.589	0.913	0.442-1.883	0.804
1st Day Macrohyphema	0.507	0.121-2.121	0.353	0.427	0.058-3.168	0.405
RNFL	0.991	0.976-1.006	0.253	0.990	0.972-1.009	0.312
MD	1.001	0.951-1.053	0.978	0.993	0.933-1.057	0.829
PSD	0.900	0.778-1.042	0.158	0.900	0.751-1.079	0.256

HR: Hazard ratio, CI: Confidence interval, POAG: Primay open-angle glaucoma, PXF: Pseudoexfoliative glaucoma, C/D: Cup-to-disc ratio, P-IOL: Phacoemulsification with intraocular lens implantation, IOP: Intraocular pressure, RNFL: Retinal nerve fiber layer, MD: Mean deviation, PSD: Pattern standard deviation

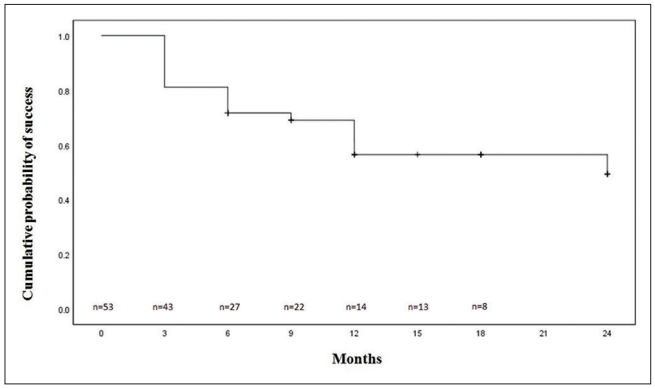

Figure 3: The Kaplan-Meier survival curves (IOP≤15 mm Hg)

56.8% at month 12, and 37.3% and 49.8% at month 24 among the primary and secondary open-angle glaucoma groups in the studies of Grover *et al*.[2,5] Rahmatnejad *et al*. reported that the success of GATT was 63% and the average decrease in IOP was 44%.[3] Grover *et al*. reported that the average decrease in glaucoma drops ranged from 1.0 to 2.1 at month 24.[5] Rahmatnejad *et al*. reported that the number of anti-glaucoma medication needed was decreased from 3.1 to 1.2, similar to in the present study.[3] In another study conducted in our clinic, it was reported that the surgical success rate of GATT was 83.7%, mean IOP decreased from 25.0 mm Hg to 15.9 mm Hg, and the number of anti-glaucomatous medications decreased from 3.4 to 1.2.[10] Given these outcomes, the GATT surgery seems to be an effective technique in reducing high IOP and decreasing number of medications in patients with open-angle glaucoma.

Trabeculectomy is the most frequently preferred surgical technique in the treatment of glaucoma for years.[11] Numerous studies showed that satisfactory surgical success rates were achieved after trabeculectomy in the advanced stage glaucoma.[12-14] Failure rates after trabeculectomy were 10% at year 2, 20% at year 5 and 30% at year 10 in the AGIS.[15] In the present study, there was no significant relationship between surgical success rates and parameters associated with glaucoma severity. Taking these results and safety profile of GATT together, GATT can be considered as the first choice for surgical treatment in all stages of open-angle glaucoma.

When the target IOP was 18 mm Hg, it was found that the combination with phacoemulsification and postoperative macrohyphema had significant positive and negative effects on the surgical success rates in the present study, respectively. The effect of the combination with cataract surgery is controversial in the literature. There is no clear data about the effect of GATT combined with cataract surgery. Furthermore, several authors also reported different results related to the success of ab interno trabeculectomy (Trabectome) combined with phacoemulsification or as a standalone procedure.[16,17]

Regarding the effect of complications on the surgical success, it was found that the cases with macrohyphema had statistically significant unsuccessful results when the IOP limit was 18 mm Hg, not 15 mm Hg. We think the different results between 18 and 15 mm Hg IOP limits can be explained due to statistics as the number of successful cases is different. As there was no data about the association of hyphema degree and surgical success rate in the literature, it is not possible to explain the underlying mechanism of surgical failure in patients exhibiting macrohyphema after the GATT surgery. However, the possible explanation for surgical failure is that macrohyphema may lead to secondary changes in the iridocorneal angle, increasing inflammatory response.

When the success rates were investigated according to the glaucoma type, it was seen that the success rates were comparable in PFX and the POAG groups for a target IOP of 18 mm Hg (ratios: 16/20 and 22/26 respectively). Although it was not statistically significant, the success rate of the PFX group is greater than that of the POAG group for a target IOP of 15 mm Hg (ratios: 15/20 and 14/26, respectively). Therefore, it could be stated that lower IOP values can be achieved with the GATT surgery in PFX patients. Considering the fact that there was no progression in cases with an IOP lower than 14 mm Hg in AGIS, GATT might be a good surgical option for the advanced stage of PFX glaucoma cases necessitating lower target IOPs.[9] Although there is no data about GATT in the literature, it has been reported in several studies that surgeons achieved a high surgical success rates with ab interno trabeculectomy in PFX when compared with POAG cases.[17,18]

The limitations of this study include the small patient population and its retrospective nature. Although patients with mostly advanced stage glaucoma were included in the study, visual field and RNFL data scattered over a wide range and missing visual field data about almost 40% of the cases due to unreliable results are another important limitations. Progression data of the cases needs clarifying if this surgical technique is really appropriate for those cases with advanced glaucoma or not especially in the long-term.

Conclusion

In conclusion, the GATT surgery seems to be a promising, successful and safe option at least in the short period of the present study, even for advanced glaucoma. A positive effect of the combination with cataract surgery and a negative effect of postoperative macrohyphema on surgical success rates are worth noting. As it is controversial for PFX glaucoma, further prospective studies are needed.

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Conflicts of interest

There are no conflicts of interest.

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