TABLE 1. Patients With Steroid-Induced Glaucoma and Primary Open-Angle Glaucoma who Underwent Trabeculotomy

	SIG-LOT, n (%) (n = 121)	SIG-LET, n (%) (n = 42)	*P* Value	POAG-LOT, n (%) (n = 108)	*P* Value
Female	62 (51.2)	26 (61.9)	.232[a]	38 (35.2)	.014[a]
Right eye	62 (51.2)	22 (52.4)	.899[a]	50 (46.3)	.455[a]
Age (years), mean ± SD	38.4 ± 17.6	42.3 ± 17.9	.153[b]	45.2 ± 15.0	.001[b]
Preoperative IOP (mm Hg), mean ± SD	38.1 ± 10.0	35.6 ± 8.3	.169[b]	28.9 ± 8.4	<.001[b]
Combined sinusotomy	20 (16.5)	—	—	33 (30.6)	.012[a]
Previous cataract surgery	17 (14.0)	4 (9.5)	.626[c]	5 (4.6)	.029[c]
Previous vitrectomy	6 (5.0)	0 (0.0)	.320[c]	0 (0.0)	.054[c]
Diabetic mellitus	13 (10.7)	6 (14.3)	.736[c]	10 (9.3)	.709[a]
Hypertension	18 (14.9)	8 (19.0)	.695[c]	15 (13.9)	.832[a]
Cause of corticosteroid use					
Atopic dermatitis	21 (17.4)	4 (9.5)	.335[c]		
Uveitis	25 (20.7)	11 (26.2)	.457[a]		
Collagen disease	37 (30.6)	17 (40.5)	.240[a]		
Route of administration					
Ocular instillation only	17 (14.0)	12 (28.6)	.591[a]		
Posterior sub-Tenon's injection of TA	13 (10.7)	1 (2.4)	.178[c]		
Intravitreal injection of TA	10 (8.3)	0 (0.0)	.121[c]		
Oral administration	72 (59.5)	26 (61.9)	.784[a]		
Intravenous administration	3 (2.5)	2 (4.8)	.826[c]		
Corticosteroid administration for more than 3 months after surgery	68 (56.2)	25 (59.5)	.708[a]		

IOP = intraocular pressure; POAG-LOT = primary open-angle glaucoma patients who underwent trabeculotomy; SD = standard deviation; SIG-LET = steroid-induced glaucoma patients who underwent trabeculectomy with mitomycin C; SIG-LOT = steroid-induced glaucoma patients who underwent trabeculotomy; TA = triamcinolone acetonide.

[a]*P* values are based on the χ^2 for independence test.

[b]*P* values are based on Mann-Whitney *U* test.

[c]*P* values are based on the χ^2 for independence test with Yates' correction.

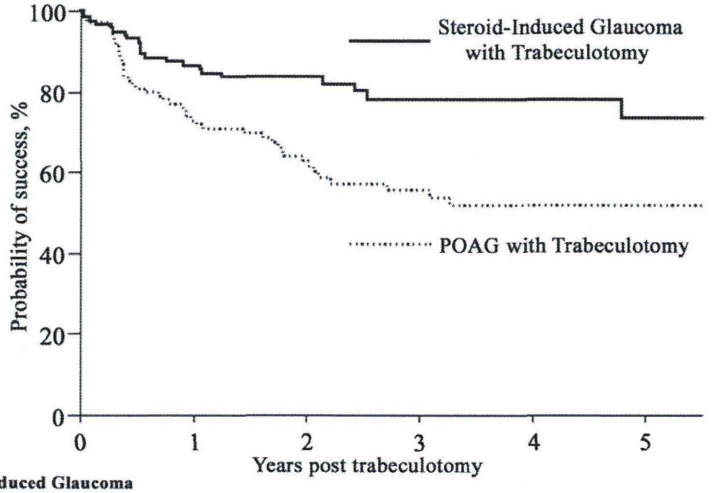
glaucoma, we retrospectively reviewed clinical charts at 17 clinical centers in Japan.

METHODS

• PATIENT SELECTION AND SURGICAL PROCEDURES: We retrospectively reviewed the medical records of patients with steroid-induced glaucoma who underwent trabeculotomy or trabeculectomy with MMC and those with POAG who underwent trabeculotomy between January 1, 1997, and December 31, 2006, at the following 17 clinical centers in Japan: Kumamoto University Hospital (Kumamoto), Niigata University Medical and Dental Hospital (Niigata), University of Tokyo Hospital (Tokyo), Kanazawa University Hospital (Kanazawa), Gifu University Hospital (Gifu), Kagawa University Hospital (Miki), University of Yamanashi Hospital (Chuo), Tohoku University Hospital (Sendai), Ryukyu University Hospital (Nishihara), Kyoto Prefectural University Hospital (Kyoto), Kagoshima University Medical and Dental Hospital (Kagoshima), Kyoto University Hospital (Kyoto), Nagoya City University Hospital (Nagoya), Saga University Hospital (Saga), Kobe University Hospital (Kobe), Hiroshima University Hospital (Hiroshima), and NTT West Kyushu Hospital (Kumamoto).

Eyes that presented with an IOP ≥22 mm Hg while on ocular hypotensive medications before surgery were included in this study. Steroid-induced glaucoma eyes were defined as open-angle eyes with an IOP elevation ≥22 mm Hg after the administration of corticosteroid. If both eyes underwent glaucoma surgeries, the eye that was treated first was investigated. Exclusion criteria were as follows: eyes with a history of previous glaucoma surgery, eyes that had undergone intraocular surgery up to 3 months before trabeculotomy or trabeculectomy, steroid-induced glaucoma eyes in the active phase of uveitis, eyes associated with IOP ≥22 mm Hg before corticosteroid administration in the medical records, and eyes that underwent combined glaucoma and cataract surgeries.

The technique of trabeculotomy performed in this study has been described previously.[19] In brief, after conjunctival incision, a 4 × 4-mm square or triangular scleral flap at four-fifths thickness was created at the corneal limbus. After identification of the Schlemm's canal, its outer wall was cut with a razor blade and excised with fine scissors. U-shaped probes were then inserted into both ends of the opened canal and rotated 90 degrees against the trabecular



Steroid-Induced Glaucoma											
No. at risk	121	121	100	89	77	63	42	32	26	22	20
Failure	0	8	7	3	0	2	1	0	0	0	1
Censored	0	13	4	9	14	19	9	6	4	2	5
POAG											
No. at risk	108	108	84	72	67	47	38	32	26	25	18
Failure	0	20	8	3	6	4	1	2	0	0	0
Censored	0	4	4	2	14	5	5	4	1	7	3

FIGURE 1. Criterion A–based Kaplan-Meier survival curves of surgical outcomes in patients with steroid-induced glaucoma (solid line) vs primary open-angle glaucoma (POAG; dotted line) that underwent trabeculotomy. The steroid-induced glaucoma eyes had a significantly higher cumulative probability of success than the POAG eyes ($P = .0008$).

meshwork. Rotation of these probes achieved 120-degree opening of the trabecular meshwork. The scleral flap was closed with 1 to 7 10-0 nylon sutures until the wound became watertight.

During trabeculotomy, some cases were combined with a sinusotomy, based upon the procedure of Mizoguchi and associates,[21] which made 1 or 2 sites of 1-mm-diameter sclerotomy with a punch through the scleral flap before closure with 10-0 nylon sutures. Trabeculectomy was performed according to a modification of the technique developed by Cairns.[22] Conjunctiva incisions included limbal-based and fornix-based procedures. After the creation of a scleral flap, sponges soaked with MMC (0.4 mg/mL) were applied to the posterior surface of the conjunctiva, Tenon's capsule, the adjacent episcleral tissue, and the scleral flap for 2 to 5 minutes, followed by irrigation with balanced salt solution. A trabecular block was excised to create a fistula in the anterior chamber, and peripheral iridectomy was then performed. The scleral flap was closed with 10-0 nylon sutures while the conjunctival flap was sutured with 10-0 nylon or 7-0 silk. All patients were required to sign informed consent forms before surgery.

• MAIN OUTCOME MEASURE: The main outcome measure was the probability of success in the Kaplan-Meier survival-curve analysis. Before data analysis, surgical failure was defined by the following IOP levels, with or without ocular hypotensive medications, which were verified at the next visit: criterion A, IOP ≥21 mm Hg; criterion B, IOP ≥18 mm Hg. IOP data that were examined using a Goldmann applanation tonometer were collected from patients' medical records. IOPs that corresponded to criteria A and B up to 3 months after surgery were not considered a surgical failure because of the occurrence of postoperative IOP fluctuations after trabeculotomy.[19] If additional glaucoma surgery was performed, or visual acuity deteriorated to an absence of light perception, the eye was regarded as a surgical failure for both criteria.

We compared the surgical outcomes between the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group, and between the steroid-induced glaucoma with trabeculotomy group and the steroid-induced glaucoma with trabeculectomy group. To determine potential risk factors for surgical failure of steroid-induced glaucoma after trabeculotomy, the following variables were assessed: gender, age, pseudophakia, previous vitrectomy, route of corticosteroid administration (ocular instillation, intravitreal injection, posterior sub-Tenon's injection, or systemic administration), duration of corticosteroid administration after glaucoma surgery, reason for corticosteroid use (collagen disease, atopic dermatitis, or uveitis), sinusotomy, previous cataract surgery, and baseline IOP. These factors were analyzed statistically in the steroid-induced glaucoma with trabeculotomy group with criteria A and B. Data on postoperative complications were also collected from the medical records.

• STATISTICAL ANALYSIS: Data analysis was performed using the JMP version 8 statistical package program (SAS

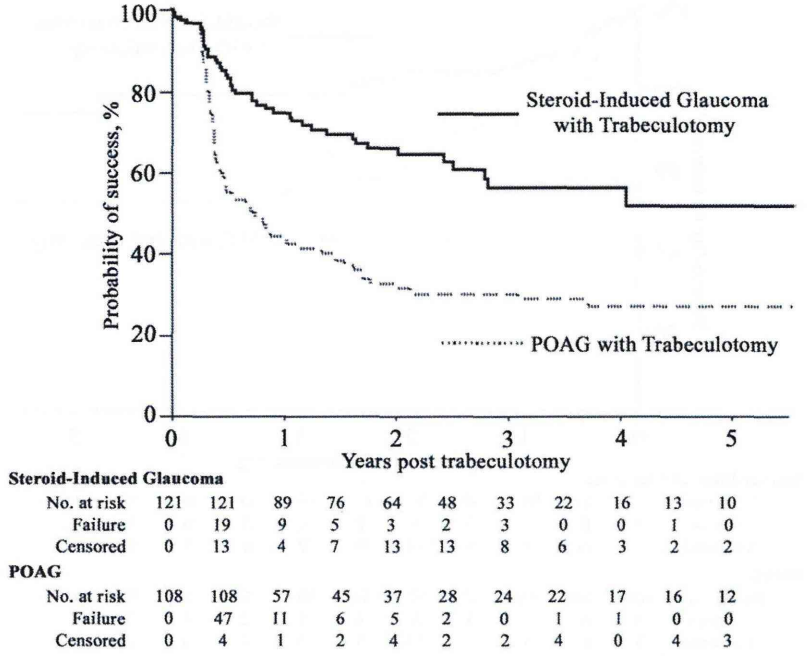


FIGURE 2. Criterion B–based Kaplan-Meier survival curves of surgical outcomes in patients with steroid-induced glaucoma (solid line) vs primary open-angle glaucoma (POAG; dotted line) that underwent trabeculotomy. The steroid-induced glaucoma eyes had a significantly higher cumulative probability of success than the POAG eyes ($P < .0001$).

TABLE 2. Cox Proportional Hazards Model Determining Likelihood of Surgical Outcomes for Patients With Steroid-Induced Glaucoma and Primary Open-Angle Glaucoma who Underwent Trabeculotomy

	Criterion A			Criterion B		
Variable	RR	95% CI	*P* Value	RR	95% CI	*P* Value
Steroid-induced glaucoma	0.409	0.223–0.735	.0027	0.451	0.286–0.706	.0005
Age (per year)	0.999	0.982–1.015	.8917	1.007	0.995–1.019	.2408
Preoperative IOP (per mm Hg)	1.004	0.977–1.029	.7557	0.993	0.972–1.013	.5115
Female	0.761	0.451–1.260	.2911	0.695	0.468–1.021	.0639
Previous cataract surgery	2.105	0.823–4.681	.1132	1.627	0.784–3.084	.1804
Combined sinusotomy	1.054	0.575–1.847	.8600	0.839	0.526–1.300	.4399

CI = confidence interval; IOP = intraocular pressure; RR = relative risk.

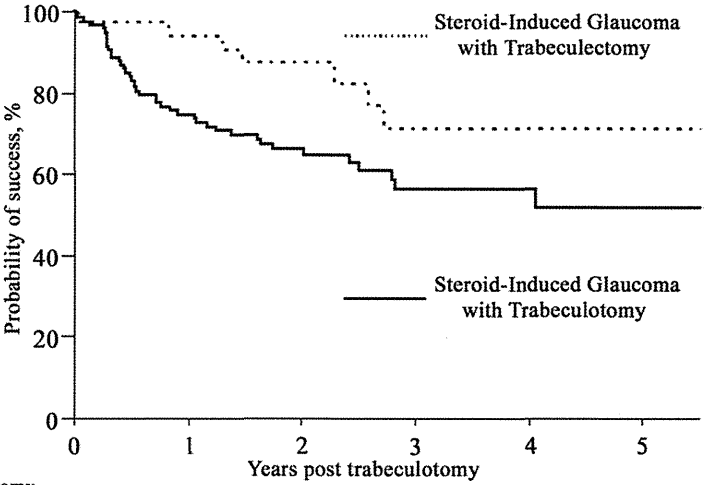
Institute, Cary, North Carolina, USA). Comparisons of the outcomes between the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group, as well as between the steroid-induced glaucoma with trabeculotomy group and the steroid-induced glaucoma with trabeculectomy group, were analyzed by the Kaplan-Meier survival curve and the log-rank test. To assess prognostic factors of steroid-induced glaucoma with trabeculotomy in univariate analysis, Kaplan-Meier survival-curve analysis and the log-rank test were used. To confirm the effects of prognostic factors and to identify the relative risk (RR) of surgical failure, multivariate prognostic factor analysis was performed with the Cox proportional hazards model. Multivariate factors were selected from variants with a probability (*P*) value of less than .15 shown by univariate analysis. A *P* value less than .05 was considered statistically significant.

RESULTS

• PATIENT CHARACTERISTICS: In total, 163 patients (163 eyes) with steroid-induced glaucoma and 108 patients (108 eyes) with POAG satisfied the study criteria. All eligible patients were Japanese. Of the 163 eyes with steroid-induced glaucoma, 121 were included in the steroid-induced glaucoma with trabeculotomy group and 42 were included in the steroid-induced glaucoma with trabeculectomy group. Table 1 lists the characteristics of the enrolled patients.

Trabeculotomy											
No. at risk	121	121	100	89	77	63	42	32	26	22	20
Failure	0	8	7	3	0	2	1	0	0	0	1
Censored	0	13	4	9	14	19	9	6	4	2	5
Trabeculectomy											
No. at risk	42	42	32	31	28	23	17	14	11	10	8
Failure	0	1	0	1	0	1	1	0	0	1	0
Censored	0	9	1	2	5	5	3	3	1	1	2

FIGURE 3. Criterion A–based Kaplan-Meier survival curves of surgical outcomes in eyes with trabeculotomy (solid line) vs trabeculectomy (dotted line) for steroid-induced glaucoma. There was no significant difference in the cumulative probability of success between the eyes with trabeculotomy and trabeculectomy ($P = .3636$).



Trabeculotomy											
No. at risk	121	121	89	76	64	48	33	22	16	13	10
Failure	0	19	9	5	3	2	3	0	0	1	0
Censored	0	13	4	7	13	13	8	6	3	2	2
Trabeculectomy											
No. at risk	42	42	32	30	26	21	15	11	9	8	7
Failure	0	1	1	2	0	1	2	0	0	0	0
Censored	0	9	1	2	5	5	2	2	1	1	1

FIGURE 4. Criterion B–based Kaplan-Meier survival curves of surgical outcomes in eyes with trabeculotomy (solid line) vs trabeculectomy (dotted line) for steroid-induced glaucoma. The trabeculectomy group showed a significantly higher cumulative probability of success than the trabeculotomy group ($P = .0352$).

The steroid-induced glaucoma with trabeculotomy group was significantly younger ($P = .001$) and had a higher preoperative IOP ($P < .001$), a higher number of female patients ($P = .014$), a higher number of previous cataract surgeries ($P = .029$), and a lower number of combined sinusotomies ($P = .012$) than the POAG with

TABLE 3. Influence of Prognostic Factors on Survival Time of Steroid-Induced Glaucoma Patients who Underwent Trabeculotomy

Variable	Number of Patients	Criterion A 80% Survival Time (Days)	Criterion A *P* Value[a]	Criterion B 80% Survival Time (Days)	Criterion B *P* Value[a]
Gender			.1779		.0422
Female	62	>3850		305	
Male	59	385		146	
Age (years)			.9040		.2458
<30	51	852		206	
≥30	70	916		181	
Preoperative IOP (mm Hg)			.7443		.4387
<40	79	181		181	
≥40	42	840		200	
Diabetes mellitus			.1936		.0848
Yes	13	146		96	
No	108	816		291	
Hypertension			.9394		.9915
Yes	18	>2148		291	
No	103	852		195	
Combined sinusotomy			.2416		.9270
Yes	20	146		120	
No	101	916		260	
Previous cataract surgery			.0055		.1829
Yes	17	49		49	
No	104	1732		272	
Previous vitrectomy			<0.0001		.0050
Yes	6	10		10	
No	115	1742		260	
Cause of corticosteroid use					
Collagen disease			.3397		.9248
Yes	37	750		195	
No	84	1732		200	
Atopic dermatitis			.9929		.2449
Yes	21	278		162	
No	100	852		195	
Uveitis			.4674		.7942
Yes	25	>2519		177	
No	96	840		200	
Route of steroid administration					
Ocular instillation only			.6968		.1204
Yes	17	1732		1286	
No	104	852		181	
Posterior sub-Tenon's injection of TA			.9546		.3239
Yes	13	>1339		>1339	
No	108	916		200	
Intravitreal injection of TA			.1843		.4379
Yes	10	49		49	
No	111	916		206	
Oral administration			.7412		.6920
Yes	72	840		181	
No	49	1732		272	
Intravenous administration			.4050		.1883
Yes	3	>1580		>1580	
No	118	852		195	

Continued on next page

TABLE 3. Influence of Prognostic Factors on Survival Time of Steroid-Induced Glaucoma Patients who Underwent Trabeculotomy *(Continued)*

Variable	Number of Patients	Criterion A: 80% Survival Time (Days)	Criterion A: *P* Value[a]	Criterion B: 80% Survival Time (Days)	Criterion B: *P* Value[a]
Postoperative corticosteroid administration			.1987		.7335
>3 months	68	<3850		195	
≤3 months	53	372		200	

IOP = intraocular pressure; TA = triamcinolone acetonide.
[a]The *P* values are based on the log-rank test.

trabeculotomy group. However, there were no significant differences in patient characteristics between the steroid-induced glaucoma with trabeculotomy group and the steroid-induced glaucoma with trabeculectomy group.

• STEROID-INDUCED GLAUCOMA VS POAG: The mean follow-up periods were 38.4 ± 28.7 months in the steroid-induced glaucoma with trabeculotomy group and 49.8 ± 37.2 months in the POAG with trabeculotomy group (P = 0.010). Kaplan-Meier survival-curve analyses of the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group for criteria A and B are presented in Figures 1 and 2, respectively. The steroid-induced glaucoma with trabeculotomy group had a significantly higher cumulative probability of success for criteria A (P = .0008) and B (P < .0001). For criterion A, the probabilities of success 1, 2, 3, and 5 years after trabeculotomy in the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group were as follows: 86.5% vs 73.2%, 83.5% vs 63.0%, 78.1% vs 55.8%, and 73.5% vs 52.2%, respectively. For criterion B, the probabilities of success 1, 2, 3, and 5 years after trabeculotomy in the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group were as follows: 74.6% vs 44.7%, 66.1% vs 33.0%, 56.4% vs 30.6%, and 51.7% vs 27.5%, respectively. The number of eyes classified as surgical failures in the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group were 22/121 (18.2%) vs 45/108 (41.7%) for criterion A and 42/121 (34.7%) vs 73/108 (67.6%) for criterion B, respectively.

Since there were significant differences between the preoperative data of the steroid-induced glaucoma with trabeculotomy group and the POAG with trabeculotomy group, a Cox proportional hazards model including age, preoperative IOP, gender, previous cataract surgery, and combined sinusotomy was performed (Table 2). The multivariate model suggested that trabeculotomy in steroid-induced glaucoma eyes was independently associated with a better prognosis when compared with the same procedure in POAG eyes, even after adjusting for confounding factors (criterion A, RR = 0.409, P = .0027; criterion B, RR = 0.451, P = .0005).

• TRABECULOTOMY VS TRABECULECTOMY: The mean follow-up period in the steroid-induced glaucoma with trabeculectomy group was 37.1 ± 31.8 months (38.4 ± 28.7 months in the steroid-induced glaucoma with trabeculotomy group, P = .808). The Kaplan-Meier survival-curve analysis between the steroid-induced glaucoma with trabeculotomy group and the steroid-induced glaucoma with trabeculectomy group for criteria A and B are presented in Figures 3 and 4, respectively. No significant difference was found between the 2 groups for criterion A (P = .3636). The probabilities of success 1, 2, 3, and 5 years after surgery in the steroid-induced glaucoma with trabeculectomy group for criterion A were 97.6%, 94.3%, 83.8%, and 74.5%, respectively. The number of eyes classified as surgical failures in the steroid-induced glaucoma with trabeculectomy group was 5 (11.9%) for criterion A. However, the steroid-induced glaucoma with trabeculectomy group showed a significantly higher cumulative probability of success for criterion B (P = .0352). The probabilities of success 1, 2, 3, and 5 years after surgery in the steroid-induced glaucoma with trabeculectomy group for criterion B were 94.5%, 87.7%, 71.6%, and 71.6%, respectively. The number of eyes classified as surgical failures in the steroid-induced glaucoma with trabeculectomy group was 7 (16.7%) for criterion B.

• PROGNOSTIC FACTORS FOR FAILURE OF TRABECULOTOMY FOR STEROID-INDUCED GLAUCOMA EYES: The potential prognostic factors influencing survival time are listed in Table 3. Univariate analysis showed previous cataract surgery (P = .0055) and previous vitrectomy (P < .0001) to be significant prognostic factors for criterion A, and male gender (P = .0422) and previous vitrectomy (P = .0050) for criterion B. Diabetes mellitus (P = .0848) and ocular instillation of corticosteroid (P = .1204) were the factors with a P value of less than .15 for criterion B. The Cox proportional hazards model including these variables revealed that prognostic factors for surgical failure were

TABLE 4. Cox Proportional Hazards Model on Criteria A and B, Determining Likelihood of Surgical Outcomes for All 121 Patients With Steroid-Induced Glaucoma who Underwent Trabeculotomy

	Criterion A			Criterion B		
Variable	RR	95% CI	*P* Value	RR	95% CI	*P* Value
Previous cataract surgery	1.614	0.255–5.688	.5488		—	
Previous vitrectomy	5.340	1.037–38.655	.0452	3.898	1.108–10.688	.0360
Male		—		1.783	0.938–3.414	.0774
Diabetes mellitus		—		1.871	0.754–4.018	.1632
Corticosteroid administration other than ocular instillation		—		2.752	1.065–9.426	.0352

CI = confidence interval; IOP = intraocular pressure; RR = relative risk.

previous vitrectomy (RR = 5.340, P = .0452 for criterion A; RR = 3.898, P = .0360 for criterion B) and corticosteroid administration other than ocular instillation (RR = 2.752, P = .0352 for criterion B) (Table 4).

• POSTOPERATIVE COMPLICATIONS: In the steroid-induced glaucoma with trabeculectomy group, choroidal detachment occurred in 2 eyes (4.8%), flat anterior chamber requiring anterior chamber reformation occurred in 1 eye (2.4%), and hypotony maculopathy occurred in 7 eyes (16.7%). None of these complications occurred in either the steroid-induced glaucoma with trabeculotomy group or the POAG with trabeculotomy group. The progression of postoperative cataracts was observed in 9 eyes (7.4%) of the steroid-induced glaucoma with trabeculotomy group, 1 eye (0.9%) of the POAG with trabeculotomy group, and 4 eyes (9.5%) of the steroid-induced glaucoma with trabeculectomy group. No eyes encountered postoperative infectious blebitis or endophthalmitis.

DISCUSSION

THIS STUDY COMPARED THE SUCCESS RATES OF TRABECULOTOMY for steroid-induced glaucomatous eyes with those for trabeculectomy for steroid-induced glaucoma eyes, and for trabeculotomy for POAG eyes. Trabeculotomy showed a significantly higher cumulative probability of success in steroid-induced glaucoma patients than POAG patients for both criterion A (P = .0008) and criterion B (P < .0001). The probability of success in steroid-induced glaucoma eyes treated with trabeculotomy was comparable to that in steroid-induced glaucoma eyes treated with MMC trabeculectomy for criterion A (P = .3636), but was significantly lower for criterion B (P = .0352). Significant prognostic factors for surgical failure of trabeculotomy in steroid-induced glaucoma patients were previous vitrectomy for criteria A (RR = 5.340, P = .0452) and B (RR = 3.898, P = .0360), and corticosteroid treatment other than ocular instillation for criterion B (RR = 2.752, P = .0352).

Several studies have demonstrated surgical results for steroid-induced glaucoma patients.[10,11,13–15,17,23–27] For example, Sihota and associates[10] reported that 9 eyes with steroid-induced glaucoma that required trabeculectomy with MMC showed normal IOP levels after surgery. Several reports[11,23–27] demonstrated that filtering surgery was successful for IOP management in steroid-induced glaucomatous eyes after intravitreal injection of triamcinolone acetonide. Krishnan and associates[13] found that all of 3 eyes with triamcinolone-induced IOP elevation were successfully treated with viscocanalostomy. For laser trabeculoplasty, Ricci and associates[14] and Viola and associates[15] reported that argon laser trabeculoplasty was effective in all cases in their studies, and selective laser trabeculoplasty was shown to lower IOP in 5 of 7 eyes.[17] However, these reports on surgical treatment for steroid-induced glaucoma included only a small number of cases and lacked control groups and details of long-term prognosis. Our previous study lacked control groups but showed that trabeculotomy reduced IOPs to 21 mm Hg or less in 14 eyes with steroid-induced glaucoma.[12] To our knowledge, our present multicenter study reports on the largest number of steroid-induced glaucoma patients.

Trabeculotomy showed a better prognosis in steroid-induced glaucoma eyes than POAG eyes in the present study. The accumulation of extracellular matrices in trabecular meshwork has been believed to cause increased outflow resistance of the aqueous humor in steroid-induced glaucoma patients. This is because histochemical data demonstrate abnormally accumulated extracellular matrices such as type IV collagen, heparin sulfate, proteoglycan, and fibronectin in the trabecular meshwork of steroid-induced glaucoma patients.[9] Because the main target of trabeculotomy for IOP reduction is the relief of outflow resistance in the trabecular meshwork, the consistency between the surgical target and the pathologic lesion might explain the effectiveness of surgery for steroid-induced glaucoma eyes.

The surgical success of trabeculotomy for steroid-induced glaucoma was comparable to the success of MMC trabeculectomy for steroid-induced glaucoma for criterion

A. Trabeculectomy has a potential risk of late-onset infection of the filtering bleb.[28–31] A previous multicenter case-control study suggested that the use of systemic corticosteroid and juvenile-onset glaucoma should be included among the risk factors for late-onset infection after filtering surgery.[32] Moreover, younger patients are more susceptible to steroid-induced IOP elevation.[4,33,34] Trabeculotomy might be more beneficial for younger patients with steroid-induced glaucoma, from the viewpoint of late-onset infection, than trabeculectomy because of the nonfiltering surgery.

Trabeculectomy had a significantly higher probability of success than trabeculotomy using criterion B in the present study. Thus, many steroid-induced glaucoma eyes treated with trabeculotomy had postoperative IOPs of 18 to 20 mm Hg, which might be too high to prevent progressive visual field changes for glaucomatous eyes with advanced progressive visual field defects. The Advanced Glaucoma Intervention Study[35] found that visual field loss in eyes with advanced open-angle glaucoma progresses further if postoperative IOP of 18 mm Hg or higher is more frequent. These findings imply that trabeculectomy rather than trabeculotomy is more favorable for controlling IOP in steroid-induced glaucoma eyes with advanced visual field loss.

Even when other types of glaucoma are included, the prognostic factors for the surgical failure of trabeculotomy have not been sufficiently identified. Our previous report indicated that higher preoperative IOP results in poorer prognosis in eyes with POAG or exfoliative glaucoma.[19] Higher preoperative IOP might reflect the severity of glaucoma, resulting in a poorer response to reduce IOP. The present study showed that higher preoperative IOP was not a prognostic factor for surgical failure of trabeculotomy for steroid-induced glaucoma, while corticosteroid administration other than ocular instillation was shown to be a prognostic factor in criterion B. These data might reflect the fact that the severity of steroid-induced glaucoma depends on the route of corticosteroid administration rather than the preoperative IOP levels. In addition, previous vitrectomy was a prognostic factor for surgical failure for both criteria. Although we have no conclusive explanation, it is conceivable that vitrectomy causes the elevation of inflammatory factors or growth factors in the aqueous humor. Vitrectomized eyes might lead to recurrent fibrosis in the outflow pathway of the trabecular meshwork that was created by the trabeculotomy.

This study had some limitations caused by the retrospective design. First, the selection bias of the type of surgery performed for steroid-induced glaucoma eyes might have affected the surgical result. In fact, all 6 vitrectomized eyes were treated with trabeculotomy. Because of conjunctival scarring after vitrectomy, trabeculotomy rather than trabeculectomy might have been the surgery of choice for vitrectomized eyes. Second, as higher IOP is a prognostic factor for failure of trabeculotomy for POAG eyes,[19] POAG patients with higher IOP might have been treated with trabeculectomy rather than trabeculotomy; this might have increased the cumulative probability of success in POAG with trabeculotomy.

In conclusion, this study demonstrates that trabeculotomy might be more effective for steroid-induced glaucoma eyes than POAG eyes. Moreover, the surgical success in steroid-induced glaucoma eyes is comparable to the outcome of trabeculectomy unless more substantial IOP reduction is necessary, in which case trabeculectomy would be a better option. IOP reduction of steroid-induced glaucoma patients with previous vitrectomy or with corticosteroid administration other than ocular instillation might be more resistant to trabeculotomy. Trabeculotomy should be considered as an option for the surgical management of steroid-induced glaucoma, although future prospective studies are necessary to validate our findings.

PUBLICATION OF THIS ARTICLE WAS SUPPORTED, IN PART, BY GRANTS-IN-AID FOR SCIENTIFIC RESEARCH FROM THE Ministry of Education, Culture, Sports, Science and Technology (MEXT), Tokyo, Japan, and the Suda Memorial Glaucoma Treatment Research Foundation, Tokyo, Japan. The authors indicate no financial conflict of interest. Involved in design and conduct of the study (K.I., M.I., H.T.); collection and management of the data (all authors); analysis (K.I., M.I); interpretation of the data (all authors); preparation of the first draft of the manuscript (K.I., M.I); and review and approval of the manuscript (all authors). All procedures conformed to the Declaration of Helsinki and informed consent was obtained from each of the patients participating in the study. The multicenter retrospective study protocol was approved by the Institutional Review Board of Kumamoto University Hospital, Kumamoto City, Japan.

Members of the Japanese Steroid-Induced Glaucoma Multicenter Study Group: *Kumamoto University Graduate School of Medical Sciences, Kumamoto, Japan:* Keiichiro Iwao, Masaru Inatani, and Hidenobu Tanihara. *Saga University Faculty of Medicine, Saga, Japan:* Keiichiro Iwao, Shinichiro Ishikawa, and Satoshi Okinami. *Graduate School of Medical and Dental Sciences, Niigata University, Niigata, Japan:* Takayuki Tanaka and Takeo Fukuchi. *University of Tokyo, Graduate School of Medicine, Tokyo, Japan:* Makiko Ito and Toshikatsu Kaburaki. *Kanazawa University Graduate School of Medical Science, Kanazawa, Japan:* Eiji Murotani and Tomomi Higashide. *Gifu University Graduate School of Medicine, Gifu, Japan:* Kyoko Ishida and Tetsuya Yamamoto. *Kagawa University Faculty of Medicine, Kagawa, Japan:* Kazuyuki Hirooka and Fumio Shiraga. *Faculty of Medicine, University of Yamanashi, Yamanashi, Japan:* Kiyotaka Ishijima and Kenji Kashiwagi. *Tohoku Graduate School of Medicine, Sendai, Japan:* Toru Nakazawa and Nobuo Fuse. *Ryukyu University School of Medicine, Okinawa, Japan:* Eriko Tomoyose and Hiroshi Sakai. *Kyoto Prefectural University of Medicine, Kyoto, Japan:* Yoko Ikeda and Kazuhiko Mori. *Kagoshima University Graduate School of Medical and Dental Sciences, Kagoshima, Japan:* Takehiro Yamashita and Taiji Sakamoto. *Kyoto University Graduate School of Medicine, Kyoto, Japan:* Fumitaka Hirose and Masanori Hangai. *Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan:* Miho Nozaki and Yuichiro Ogura. *Kobe University Graduate School of Medicine, Hyogo, Japan:* Maiko Naka and Akira Negi. *Graduate School of Biomedical Sciences, Hiroshima University, Japan:* Mina Mizukami and Takashi Kanamoto. *NTT West Kyusyu Hospital, Kumamoto, Japan:* Ryusuke Futa.

REFERENCES

1. Lewis JM, Priddy T, Judd J, et al. Intraocular pressure response to topical dexamethasone as a predictor for the development of primary open-angle glaucoma. Am J Ophthalmol 1988;106(5):607–612.
2. Jonas JB, Kreissig I, Degenring R. Secondary chronic open-angle glaucoma after intravitreal triamcinolone acetonide. Arch Ophthalmol 2003;121(5):729–730.
3. Smithen LM, Ober MD, Maranan L, Spaide RF. Intravitreal triamcinolone acetonide and intraocular pressure. Am J Ophthalmol 2004;138(5):740–743.
4. Iwao K, Inatani M, Kawaji T, Koga T, Mawatari Y, Tanihara H. Frequency and risk factors for intraocular pressure elevation after posterior sub-Tenon capsule triamcinolone acetonide injection. J Glaucoma 2007;16(2):251–256.
5. Opatowsky I, Feldman RM, Gross R, Feldman ST. Intraocular pressure elevation associated with inhalation and nasal corticosteroids. Ophthalmology 1995;102(2):177–179.
6. Becker B, Mills D. Corticosteroids and intraocular pressure. Arch Ophthalmol 1963;70(4):500–507.
7. Rohen JW, Linner E, Witmer R. Electron microscopic studies on the trabecular meshwork in two cases of corticosteroid-glaucoma. Exp Eye Res 1973;17(1):19–31.
8. Johnson D, Gottanka J, Flugel C, Hoffmann F, Futa R, Lutjen-Drecoll E. Ultrastructural changes in the trabecular meshwork of human eyes treated with corticosteroids. Arch Ophthalmol 1997;115(3):375–383.
9. Tawara A, Tou N, Kubota T, Harada Y, Yokota K. Immunohistochemical evaluation of the extracellular matrix in trabecular meshwork in steroid-induced glaucoma. Graefes Arch Clin Exp Ophthalmol 2008;246(7):1021–1028.
10. Sihota R, Konkal VL, Dada T, Agarwal HC, Singh R. Prospective, long-term evaluation of steroid-induced glaucoma. Eye (Lond) 2008;22(1):26–30.
11. Jonas JB, Degenring RF, Kamppeter BA. Outcome of eyes undergoing trabeculectomy after intravitreal injections of triamcinolone acetonide. J Glaucoma 2004;13(3):261.
12. Honjo M, Tanihara H, Inatani M, Honda Y. External trabeculotomy for the treatment of steroid-induced glaucoma. J Glaucoma 2000;9(6):483–485.
13. Krishnan R, Kumar N, Wishart PK. Viscocanalostomy for refractory glaucoma secondary to intravitreal triamcinolone acetonide injection. Arch Ophthalmol 2007;125(9):1284–1286.
14. Ricci F, Missiroli F, Parravano M. Argon laser trabeculoplasty in triamcinolone acetonide induced ocular hypertension refractory to maximal medical treatment. Eur J Ophthalmol 2006;16(5):756–757.
15. Viola F, Morescalchi F, Staurenghi G. Argon laser trabeculoplasty for intractable glaucoma following intravitreal triamcinolone. Arch Ophthalmol 2006;124(1):133–134.
16. Pizzimenti JJ, Nickerson MM, Pizzimenti CE, Kasten-Aker AG. Selective laser trabeculoplasty for intraocular pressure elevation after intravitreal triamcinolone acetonide injection. Optom Vis Sci 2006;83(7):421–425.
17. Rubin B, Taglienti A, Rothman RF, Marcus CH, Serle JB. The effect of selective laser trabeculoplasty on intraocular pressure in patients with intravitreal steroid-induced elevated intraocular pressure. J Glaucoma 2008;17(4):287–292.
18. Baser E, Seymenoglu R. Selective laser trabeculoplasty for the treatment of intraocular pressure elevation after intravitreal triamcinolone injection. Can J Ophthalmol 2009;44(3):e21.
19. Tanihara H, Negi A, Akimoto M, et al. Surgical effects of trabeculotomy ab externo on adult eyes with primary open angle glaucoma and pseudoexfoliation syndrome. Arch Ophthalmol 1993;111(12):1653–1661.
20. Sugimoto-Takeuchi R, Kuwayama Y, Shiga S, Takagi T. Trabeculotomy for steroid glaucoma. Atarashii Ganka (Journal of the Eye) 1992;9(7):1181–1183.
21. Mizoguchi T, Nagata M, Matsumura M, Kuroda S, Terauchi H, Tanihara H. Surgical effects of combined trabeculotomy and sinusotomy compared to trabeculotomy alone. Acta Ophthalmol Scand 2000;78(2):191–195.
22. Cairns JE. Trabeculectomy. Preliminary report of a new method. Am J Ophthalmol 1968;66(4):673–679.
23. Park HY, Yi K, Kim HK. Intraocular pressure elevation after intravitreal triamcinolone acetonide injection. Korean J Ophthalmol 2005;19(2):122–127.
24. Quiram PA, Gonzales CR, Schwartz SD. Severe steroid-induced glaucoma following intravitreal injection of triamcinolone acetonide. Am J Ophthalmol 2006;141(3):580–582.
25. Kubota T, Okabe H, Hisatomi T, Yamakiri K, Sakamoto T, Tawara A. Ultrastructure of the trabecular meshwork in secondary glaucoma eyes after intravitreal triamcinolone acetonide. J Glaucoma 2006;15(2):117–119.
26. Kaushik S, Gupta V, Gupta A, Dogra MR, Singh R. Intractable glaucoma following intravitreal triamcinolone in central retinal vein occlusion. Am J Ophthalmol 2004;137(4):758–760.
27. Singh IP, Ahmad SI, Yeh D, et al. Early rapid rise in intraocular pressure after intravitreal triamcinolone acetonide injection. Am J Ophthalmol 2004;138(2):286–287.
28. Lobue TD, Deutsch TA, Stein RM. Moraxella nonliquefaciens endophthalmitis after trabeculectomy. Am J Ophthalmol 1985;99(3):343–345.
29. Freedman J, Gupta M, Bunke A. Endophthalmitis after trabeculectomy. Arch Ophthalmol 1978;96(6):1017–1018.
30. Higginbotham EJ, Stevens RK, Musch DC, et al. Bleb-related endophthalmitis after trabeculectomy with mitomycin C. Ophthalmology 1996;103(4):650–656.
31. Wolner B, Liebmann JM, Sassani JW, Ritch R, Speaker M, Marmor M. Late bleb-related endophthalmitis after trabeculectomy with adjunctive 5-fluorouracil. Ophthalmology 1991;98(7):1053–1060.
32. Jampel HD, Quigley HA, Kerrigan-Baumrind LA, Melia BM, Friedman D, Barron Y. Risk factors for late-onset infection following glaucoma filtration surgery. Arch Ophthalmol 2001;119(7):1001–1008.
33. Inatani M, Iwao K, Kawaji T, et al. Intraocular pressure elevation after injection of triamcinolone acetonide: a multicenter retrospective case-control study. Am J Ophthalmol 2008;145(4):676–681.
34. Ohji M, Kinoshita S, Ohmi E, Kuwayama Y. Marked intraocular pressure response to instillation of corticosteroids in children. Am J Ophthalmol 1991;112(4):450–454.
35. The Advanced Glaucoma Intervention Study (AGIS): 7. The relationship between control of intraocular pressure and visual field deterioration. The AGIS Investigators. Am J Ophthalmol 2000;130(4):429-440.

Biosketch

Keiichiro Iwao, MD, PhD, received his doctorate from Saga University's Graduate School of Medicine, Saga, Japan, in 2009, which was based on mouse models of developmental glaucoma. He is currently assistant professor in the Department of Ophthalmology, Saga University Faculty of Medicine. He has been recognized by the Association for Research in Vision and Ophthalmology and was a recipient of the 2009 Kowa Travel Grant Award. His interests include glaucoma surgery and regeneration of the optic nerve.