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Changing Trends in Glaucoma Surgery Over the Past 5 Years in China

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on Behalf of the Investigators for the Chinese Glaucoma Study Consortium

Purpose: To analyze the trends of glaucoma surgery procedures over the past 5 years among hospitals across major provinces in China.

Materials and Methods: This was a retrospective observational study based on medical records. We obtained the annual numbers of commonly performed glaucoma incisional surgeries from 57 hospitals of 30 provincial regions in the Chinese Glaucoma Study Consortium (CGSC) from January 2015 to September 2019. The trend of glaucoma surgery was analyzed by Cochrane-Armitage trend test.

Results: Trabeculectomy, cataract extraction combined with goniosynechialysis, cataract extraction combined with trabeculectomy, and surgical peripheral iridotomy (SPI) were the top 4 surgical procedures percentages of which have the most substantial change over the course of 2015 to 2019 (all $P_{\text{trend}} < 0.001$). Numbers of trabeculectomies decreased significantly from 47.59% in 2015 to 31.21% in 2019; cataract extraction combined with goniosynechialysis increased from 12.12% to 28.48%; cataract extraction combined with trabeculectomy increased from 13.11% to 15.97%; and SPI decreased from 9.03% to 6.34%. The proportion of internal drainage surgery increased from 24.31% in 2015 to 39.29% in 2019 while external drainage surgery decreased from 69.20% to 54.64% (All $P_{\text{trend}} < 0.001$). The microinvasive glaucoma surgeries including AB-interno Canaloplasty, gonioscopy-assisted transluminal trabeculectomy, and Trabectome, increased from 0.62% to 1.40% ($P_{\text{trend}} < 0.001$). Across all study hospitals, the trends were similar, except for the Tibet Autonomous Region Eye Center, where SPI and trabeculectomy remained the most common anti-glaucoma surgeries.

Conclusion: In the past 5 years, we observed substantial reduction in trabeculectomy, and increase in combination cataract-glaucoma procedures across major hospitals in China. The proportion of internal drainage surgery increased, while external drainage surgery decreased significantly. Detailed understanding of shifting trends in glaucoma surgeries can facilitate better health care resource allocation and training of glaucoma subspecialists in China.

Key Words: glaucoma incisional surgery, cataract extraction combined anti-glaucoma surgery, internal drainage surgery, micro-invasive glaucoma surgeries

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Glaucoma is the leading cause of irreversible blindness.¹ The global prevalence of glaucoma for population aged 40 to 80 years is 3.54% (95% CrI, 2.09–5.82). The number of people (aged 40 to 80 y) with glaucoma worldwide was estimated to be 76.0 million in 2020, and will increase to 111.8 million in 2040.²

Based on several previous epidemiological studies from China, the prevalence of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) were estimated to range from 0.71% to 2.57%, and 0.76% to 1.74%, respectively.^{3–10} At present, intraocular pressure (IOP) lowering medications, laser and surgeries remain the main treatment options for glaucoma.¹¹

Due to China's large population and area, the treatment choice for glaucoma depends not only on the safety and efficacy of the treatment method, but also on the doctors as well as patients' personal preferences, which can vary widely based on geographic locations and economic situations. High quality clinical trials and new surgical techniques have had a significant impact on the choice of glaucoma therapy. For example, for angle-closure glaucoma, surgical management has gradually shifted toward lens extraction¹²; for open-angle glaucoma and developmental glaucoma, minimally invasive glaucoma surgeries (MIGS) have gained increasing favor as a method of choice.^{13,14} There are many continued medical education meetings/courses as well as surgical skill development programs to help doctors develop new and improve existing surgical skills in China. A clear understanding of shifting trends in glaucoma surgeries can help direct these training programs and further optimize the allocation of limited health care resources.

To study this unknown area, we collected annual number of glaucoma surgical procedures from Chinese Glaucoma Study Consortium (CGSC) from January 2015 to September 2019 and analyze the trends of glaucoma surgeries in China. The objective of this study was to elucidate current trends in glaucoma surgeries and analyze how these trends have evolved over the past 5 years across major hospitals in China.

MATERIALS AND METHODS

General Information

This was a cross-sectional survey and a retrospective observational study. The study was conducted in accordance

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TABLE 1. Numbers and Proportions of Glaucoma Surgeries of Hospitalized Patients From 2015 to 2019 in China [n (%)]

Surgery	2015	2016	2017	2018	2019	<i>P</i> _{trend}
Trabeculectomy	19,648 (47.59)	19,690 (43.92)	19,246 (39.65)	18,183 (35.74)	13,743 (31.21)	<0.001
P+I+GSL	5003 (12.12)	7121 (15.89)	9235 (19.02)	11,489 (22.58)	12,540 (28.48)	<0.001
P+I+Trab	5412 (13.11)	5947 (13.27)	7421 (15.29)	8595 (16.89)	7033 (15.97)	<0.001
SPI	3726 (9.03)	3826 (8.54)	3941 (8.12)	3564 (7.00)	2,792 (6.34)	<0.001
Cyclophotocoagulation	2680 (6.49)	2922 (6.52)	3294 (6.79)	3678 (7.23)	2674 (6.07)	<0.001
GDI	1879 (4.55)	1986 (4.43)	1959 (4.04)	2003 (3.94)	1777 (4.04)	<0.001
Trabeculectomy+Trabeculotomy	1070 (2.59)	1140 (2.54)	1200 (2.47)	1177 (2.31)	1035 (2.35)	0.055
Trabeculotomy	736 (1.78)	688 (1.53)	723 (1.49)	602 (1.18)	440 (1.00)	<0.001
Ex_PRESS implant	559 (1.35)	787 (1.76)	593 (1.22)	510 (1.00)	468 (1.06)	<0.001
Canaloplasty	150 (0.36)	124 (0.28)	197 (0.41)	95 (0.19)	139 (0.32)	0.23
ABiC	150 (0.36)	208 (0.46)	228 (0.47)	257 (0.51)	242 (0.55)	<0.001
External 360 degrees trabeculotomy	100 (0.24)	166 (0.37)	243 (0.5)	333 (0.65)	424 (0.96)	<0.001
NPGS	63 (0.15)	129 (0.29)	120 (0.25)	157 (0.31)	349 (0.79)	<0.001
Trabectome	63 (0.15)	47 (0.10)	68 (0.14)	101 (0.20)	221 (0.50)	<0.001
GATT	44 (0.11)	46 (0.10)	75 (0.15)	137 (0.27)	153 (0.35)	<0.001

ABiC indicates AB-interno Canaloplasty; GATT, gonioscopy-assisted transluminal trabeculectomy; GDIs, glaucoma drainage implants; NPGS, non-penetrating glaucoma surgery; P+I+GSL, phacoemulsification combined with intraocular lens implantation with goniosynechialysis; P+I+Trab, phacoemulsification combined with intraocular lens implantation with trabeculectomy; SPI, surgical peripheral iridotomy.

with the Declaration of Helsinki. Subject data were drawn from the Chinese Glaucoma Study Consortium (CGSC), a nation-wide glaucoma registry in mainland China. The CGSC included 111 sites in 67 cities which geographically cover all 23 provinces, 4 municipalities, and 5 autonomous regions in mainland China.¹⁵

Since nearly all patients who receive glaucoma surgery are admitted into hospital in China, we obtained the annual numbers of the commonly performed glaucoma surgeries from hospitalization medical records in CGSC from January 2015 to September 2019. We only chose representative tertiary medical centers with glaucoma-fellowship trained surgeons in this study.

Types of surgeries analyzed in this study included trabeculectomy (Trab), cataract extraction with intraocular lens implantation (CEIOL), CEIOL combined with goniosynechialysis (CEIOL+GSL), or combined with trabeculectomy

(CEIOL+trab), surgical peripheral iridotomy (SPI), glaucoma drainage implants (GDIs), Ex-PRESS implant, trabeculectomy, combined trabeculectomy-trabeculotomy, nonpenetrating glaucoma surgery (NPGS), canaloplasty (CP), AB-interno Canaloplasty (ABiC), gonioscopy-assisted transluminal trabeculectomy (GATT), external 360 degrees trabeculectomy, Trabectome, cyclophotocoagulation. Of note, the only GDI available in mainland China is the Ahmed valve.

All surgeries were classified by external drainage surgery, internal drainage surgery, and cyclophotocoagulation. External drainage surgery includes trabeculectomy, Ex-PRESS, GDIs, cataract extraction combined with Trab/GDIs, and combined trabeculectomy-trabeculotomy. Internal drainage surgery consists of CEIOL+GSL, SPI, trabeculectomy, canaloplasty, NPGS, GATT, ABiC, and Trabectome.

In this evaluation, 57 urban hospitals of 30 provincial regions from the CGSC were included. Details of

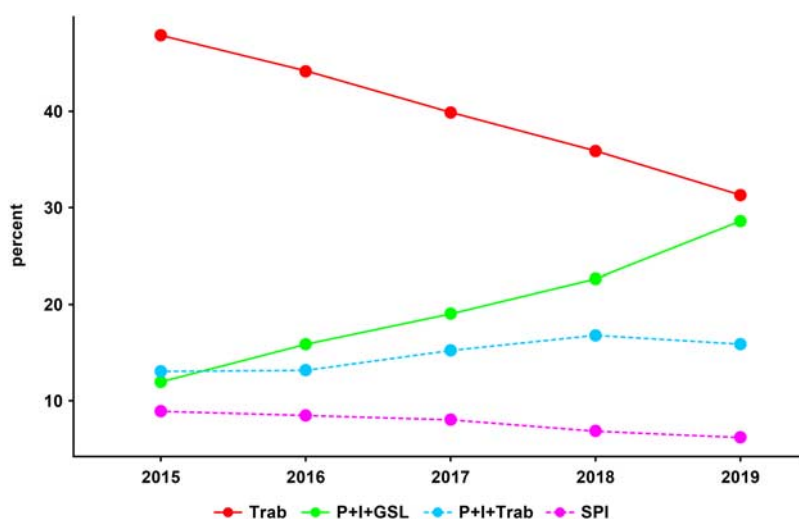


FIGURE 1. The trend of the top 4 surgical procedures (Trabeculectomy, P+I+GSL, P+I+Trab, and SPI) changed the most from 2015 to 2019. It indicated the significant and steady changes in decreased trabeculectomy and in increased P+I+GSL. P+I+GSL indicates phacoemulsification combined with intraocular lens implantation with goniosynechialysis; P+I+Trab, phacoemulsification combined with intraocular lens implantation with trabeculectomy; SPI, surgical peripheral iridotomy; Trab, trabeculectomy. Figure 1 can be viewed in color online at www.glaucomajournal.com.

TABLE 2. Numbers and Proportions of 3 Types Glaucoma Procedures From Year 2015 to 2019 [n (%)]

	2015	2016	2017	2018	2019	P_{trend}
Cyclophotocoagulation	2680 (6.49)	2922 (6.52)	3294 (6.79)	3678 (7.23)	2674 (6.07)	<0.001
Internal drainage surgery*	10,035 (24.31)	12,355 (27.56)	14,830 (30.55)	16,735 (32.89)	17,300 (39.29)	<0.001
External drainage surgery†	28,568 (69.2)	29,550 (65.92)	30,419 (62.66)	30,468 (59.88)	24,056 (54.64)	<0.001

*Internal drainage surgery refers to P+I+GSL, SPI, trabeculotomy, canaloplasty, nonpenetrating glaucoma surgery, gonioscopy-assisted transluminal trabeculotomy, AB-interno Canaloplasty, and trabectome in this evaluation.

†External drainage surgery refers to bleb forming procedures such as Trab, aqueous shunts of Ex-PRESS and GDIs implantation, P+I+Trab/GDIs, and combined trabeculectomy-trabeculotomy.

participating hospitals were described in Supplementary Table 1 (Supplemental Digital Content 1, <http://links.lww.com/IJG/A599>).

Statistical Analysis

Frequency and percentage were applied for categorical data. The trend of glaucoma surgeries from January 2015 to September 2019 was analyzed by Cochran-Armitage trend test. The significance level was 0.05, 2-tailed. All data analyses were done using an open source R program (Version 3.6.1).

RESULTS

The rates of each type of glaucoma surgeries from year 2015 to 2019 are shown in Table 1. Trabeculectomy, CEIOL+GSL/Trab, SPI, cyclophotocoagulation, and GDIs were the most commonly performed glaucoma surgeries in China during this time, collectively totaling >92% of all glaucoma surgeries performed in CGSC.

Trabeculectomy, CEIOL+GSL, CEIOL+Trab, and SPI were the top 4 surgical procedures that underwent the most substantial changes in numbers performed over the course of 2015 to 2019 (all $P_{\text{trend}} < 0.001$). Trabeculectomy decreased from 47.59% in 2015 to 31.21% in 2019, CEIOL+GSL increased from 12.12% in 2015 to 28.48% in 2019, CEIOL+Trab increased from 13.11% in 2015 to 15.97% in 2019 and SPI decreased from 9.03% in 2015 to 6.34% in 2019 (Fig. 1).

Over the past 5 years, most glaucoma surgeries exhibited statistically significant changes in the rates of surgeries

performed (all $P_{\text{trend}} < 0.001$). Notable exceptions were canaloplasty and combined trabeculectomy-trabeculotomy ($P_{\text{trend}} > 0.05$). CEIOL+GSL, CEIOL+Trab, external 360 degrees trabeculotomy, GATT, ABiC, and trabectome all increased year by year, while other surgical methods decreased gradually over the same study period. For example, GDIs decreased from 4.55% in 2015 to 4.04% in 2019, Ex-PRESS implant decreased from 1.35% in 2015 to 1.06% in 2019.

External drainage surgery decreased year by year, from 69.2% in 2015 to 54.64% in 2019 ($P_{\text{trend}} < 0.001$), while internal drainage surgery dramatically increased from 24.31% in 2015 to 39.29% in 2019. The proportion of cyclophotocoagulation remained relatively stable during the study period: 6.49% in 2015 and 6.07% in 2019 (Table 2, Fig. 2).

MIGS included GATT, ABiC, and Trabectome in this evaluation. The data showed ABiC increased from 0.36% in 2015 to 0.55% in 2019; GATT increased from 0.11% in 2015 to 0.35% in 2019; Trabectome increased from 0.15% in 2015 to 0.50% in 2019. Although the annual number and proportion of MIGS in total glaucoma surgery were small, it increased steadily from 0.62% in 2015 to 1.40% in 2019 ($P_{\text{trend}} < 0.001$) (Table 3, Fig. 3).

The trends for each hospital also were analyzed. Although larger hospitals contributed more cases, similar trends were observed across all hospitals, with the single exception of Tibet Autonomous Region Eye Center (Table 4).

In Tibet Autonomous Region Eye Center, SPI was the most common surgery and decreased from 87.93% in 2015 to 48.99% in 2019 ($P_{\text{trend}} < 0.001$). Trabeculectomy was the

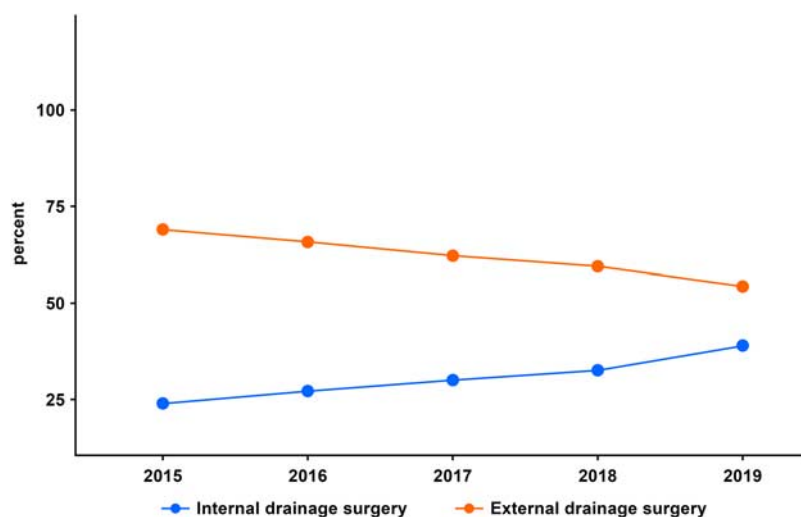


FIGURE 2. Showed the annual trend of the external and internal drainage surgery from 2015 to 2019. External drainage surgery decreased year by year, while internal drainage surgery dramatically increased. Figure 2 can be viewed in color online at www.glaucomajournal.com.

TABLE 3. Numbers and Proportions of MIGS From Year 2015 to 2019 [n (%)]

Year	MIGS*	Non-MIG†
2015	257 (0.62)	41,026 (99.38)
2016	301 (0.66)	44,526 (99.34)
2017	371 (0.76)	48,172 (99.24)
2018	495 (0.98)	50,386 (99.02)
2019	616 (1.40)	43,414 (98.60)

*MIGS included gonioscopy-assisted transluminal trabeculotomy, AB-interno Canaloplasty, and Trabectome in this evaluation.

†Other glaucoma surgery procedures were non-MIGS.

MIGS indicates minimally invasive glaucoma surgeries.

secondary most common procedure and increased from 6.90% in 2015 to 30.61% in 2019 ($P_{\text{trend}} < 0.001$). Meanwhile, the annual number of CEIOL+GSL and CEIOL+Trab were <10, but did increase minutely over the study period. CEIOL+trab, in particular, exhibited a statistically significant increase ($P_{\text{trend}} = 0.004$).

DISCUSSION

Surgical treatment is the main management for glaucoma in China. This preference for procedures has endured despite recent introductions of various new topical medications and laser therapies, all exhibiting good clinical efficacy in controlling IOP. With the advent of innovative and potentially safer surgical techniques and implants, there now exist a myriad of good surgical options for glaucoma management. Trabeculectomy is commonly used in surgical management of glaucoma,^{16–18} but it is accompanied by different kinds of complications and require more postoperative aftercare. In recent years, a series of studies have highlighted the effectiveness of lens extraction in treating PACG. Results have been promising with most studies demonstrating that extraction has been beneficial in lowering IOP and reducing reliance on glaucoma medications postoperatively.¹⁹ These results have subsequently led to changes in the management of PACG in China, with widespread adoption of cataract extraction for PACG, in lieu of traditional glaucoma surgeries. It is not possible within the scope of this report to

estimate the utilization of clear lens extraction or cataract extraction specifically for management of PACG, but it is important to highlight that cataract extraction alone (without recording goniosynechiolysis) will be utilized extensively as a glaucoma procedure, either as a standalone approach to reduce intraocular pressure or as a staged process in advance of a trabeculectomy. This represents a significant shift in the paradigm of glaucoma management in China since PACG is the main type of glaucoma in Chinese hospitalized patients.²⁰ The changing management of PACG is a major contributor to the overall trend shifts in glaucoma surgeries in China.

Our study found that cataract extraction combined with anti-glaucoma procedure (CEIOL+GSL/Trab) replaced trabeculectomy as the most common surgical treatment starting in 2018 (39.47% vs. 35.74% in 2018; 44.45% vs. 31.21% in 2019). This decrease in trabeculectomy rates is consistent with findings from previous studies.^{21–29} Another major finding of our survey is the increase in the rate of cataract extraction combined with anti-glaucoma procedure. Some factors may explain this change: Firstly, PACG with concurrent cataract is common for aging glaucoma patients. Secondly, phacoemulsification as a surgical technique has become more widely accessible thanks to rapid economic developments and continued medical education programs in China. More ophthalmologists have become proficient in phacoemulsification in recent years. Various high quality clinical trials,^{12,18} the Chinese glaucoma guideline and expert consensus promoted these changes. Together, these factors have shifted the practice pattern toward increased use of cataract extraction with or without anti-glaucoma procedure for PACG surgical treatment in China.

We found SPI gradually decreased year by year. This is likely due to the increased use of laser peripheral iridotomy (LPI). LPI is the current standard for initial treatment in PACG.³⁰ LPI is usually carried out in outpatient department, is more convenient and has lower risks of complication than SPI.

In our national survey, the rate of GDIs and Ex_PRESS implant slightly decreased. Our results are different from previous Canada and UK studies that showed a significant increase in aqueous shunt surgery.^{29,31} In China, GDIs are usually used in refractory glaucoma, seldomly used as the

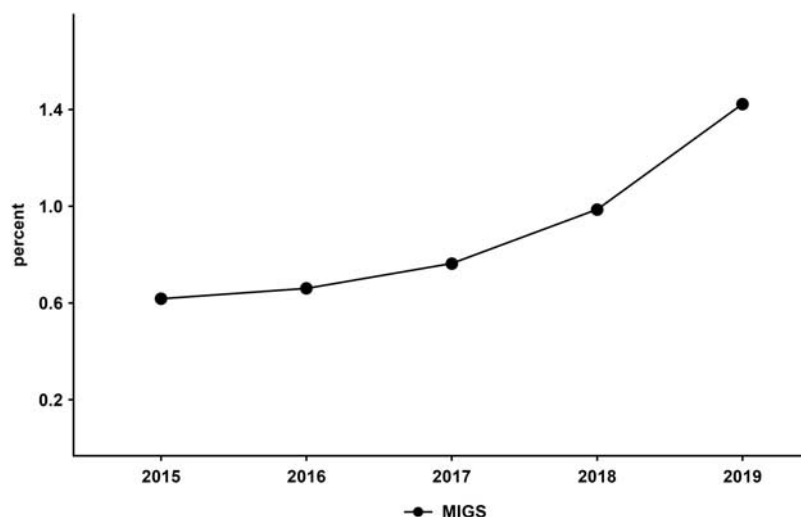


FIGURE 3. Showed the steadily increased trend of minimally invasive glaucomasurgery (MIGS) rates annually from 2015 to 2019. The annual number and proportion of MIGS in total glaucoma surgery were small, but it increased steadily.

TABLE 4. Numbers and Proportions of Each Glaucoma Surgery in Tibet Autonomous Region Eye Center From Year 2015 to 2019 [n (%)]

Year	Trabeculectomy	P+I+GSL	P+I+Trab	SPI	Trabeculectomy+Trabeculotomy
2015	4 (6.90)	0 (0.00)	0 (0.00)	51 (87.93)	3 (5.17)
2016	13 (15.29)	7 (8.24)	0 (0.00)	60 (70.59)	5 (5.88)
2017	45 (43.27)	6 (5.77)	4 (3.85)	45 (43.26)	4 (3.85)
2018	41 (32.80)	6 (4.80)	5 (4.00)	67 (53.60)	6 (4.80)
2019	30 (30.61)	9 (9.18)	7 (7.14)	48 (48.99)	4 (4.08)
<i>P</i> _{trend}	<0.001	0.142	0.004	<0.001	0.662

P+I+GSL indicates phacoemulsification combined with intraocular lens implantation with goniosynechialysis; P+I+Trab, phacoemulsification combined with intraocular lens implantation with trabeculectomy; SPI, surgical peripheral iridotomy.

primary surgery. Although studies from 1 Chinese hospital found Ex-PRESS and GDIs have increased during the past 10 years,³² our nation-wide survey suggest aqueous shunts are not common glaucoma procedures, and have no projected increased use in China.

External drainage surgery is also called bleb-forming procedure with conjunctival filtration bleb as the main method of reducing IOP. Internal drainage surgery promotes drainage of aqueous humor through physiological pathways. Our data showed that traditional external drainage surgery, mainly Trab, is still the most common procedure in China, although a decrease of 14.56% was noted from 2015 to 2019. By contrast, internal drainage surgery increased rapidly and steadily. This is consistent with the result of Beijing Tongren Hospital study, which found that the surgical methods of angle-closure glaucoma, open-angle glaucoma, and developmental glaucoma have all changed from external drainage to internal drainage procedures.³³

MIGS could provide a conjunctival-sparing, ab-interno approach in lowering both IOP and glaucoma medications, in addition to being safer than traditional incisional glaucoma surgery. MIGS seem effective in the reduction of IOP and glaucoma medication dependence.³⁴ MIGS included GATT, ABiC, and Trabectome in our study. Other MIGS procedure, such as iStent, Hydrus, Xen, etc., are not currently available in mainland China. Although the proportion of MIGS in total glaucoma surgery is small, only 1.4% in 2019, it was noted to increase throughout the duration of our study. Because POAG and congenital glaucoma are not common types of glaucoma in China, the ratio of MIGS in our study was understandably low; this, however, should not detract from the increasing usage of MIGS. In fact, our findings are consistent with a previous study, which also reported that MIGS such as canaloplasty, GATT, ABiC, external 360 degrees trabeculotomy, and Trabectome have remarkably increased in the treatment of POAG and development glaucoma.³³

Most participating hospitals had similar trends in glaucoma management during our study period; the notable exception is Tibet Autonomous Region Eye Center. This may be due to technical gaps driven by socioeconomic differences between the more underdeveloped rural and the more affluent city areas. We recommend additional training and sources to support our colleagues in such resource-scarce regions.

In summary, our study showed that glaucoma surgeries have evolved towards less invasive options that leverage more physiological pathways of aqueous drainage. The changing trends provided insights on the future directions of glaucoma surgery in China, which can additionally help to

allocate limited health care resources and train future generations of ophthalmologists.

Study Limitations

Our data was obtained only from patients admitted to the participating hospitals. Most surgical patients require hospitalization in China. Therefore, we expect that the small portion of outpatient cases would have minimal influence on the overall trends observed in this study.

Only the highest ranking hospitals from each participating region in China were included in the Consortium. Therefore, our study results are representative of only the major hospitals in each provincial regions, were not representative of the country as a whole, and it is unclear how these findings extrapolate to more resource-scarce and rural areas.

CONCLUSION

The data of the present study showed that surgical management patterns in glaucoma evolved significantly from 2015 to 2019. Trabeculectomy has decreased while cataract extraction related anti-glaucoma surgeries and MIGS have increased over our study period in China. The proportion of internal drainage surgery increased and external drainage surgery decreased significantly. Detailed understanding of these shifting trends in glaucoma procedures will aid in the planning of health care resource allocations and training of doctors in China.

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