• Investigation •

Trend of glaucoma internal filtration surgeries in a tertiary hospital in China

Yang Cao[1,2,3], Hai-Shuang Lin[1,2,3], Hui-Yan Mao[1,2,3], Yin Zhao[1,2,3], Yan-Qian Xie[1,2,3], Shao-Dan Zhang[1,2,3], Qi Zhang[1,2,3], Pei-Juan Wang[1,2,3], Guo-Xing Li[1,2,3], Ai-Wu Fang[1,2,3], Yuan-Bo Liang[1,2,3]

[1]The Eye Hospital, School of Ophthalmology and Optometry, Wenzhou Medical University, Wenzhou 325027, Zhejiang Province, China
[2]Glaucoma Research Institute, Wenzhou Medical University, Wenzhou 325027, Zhejiang Province, China
[3]National Clinical Research Center for Ocular Diseases, Wenzhou 325027, Zhejiang Province, China
Correspondence to: Yuan-Bo Liang. Eye Hospital and School of Ophthalmology and Optometry, Wenzhou Medical University, Wenzhou 325000, Zhejiang Province, China. yuanboliang@wmu.edu.cn
Received: 2022-08-29 Accepted: 2022-12-07

Abstract

● **AIM:** To evaluate the trend of glaucoma internal filtration surgeries for inpatients between 2015 and 2021 at the Eye Hospital of Wenzhou Medical University.

● **METHODS:** A review of the medical records of inpatients who had been diagnosed with glaucoma and received anti-glaucoma surgery between January 1, 2015 and December 31, 2021 was conducted. The glaucoma diagnosis in this study included primary open angle glaucoma, primary angle-closure glaucoma, secondary glaucoma, and paediatric glaucoma. The types of surgeries were categorised as internal filtration, external filtration, and cyclodestruction surgery based on the pathway of aqueous humor outflow. The trend of these glaucoma surgeries in the sample of patients with different types of glaucoma was then analysed.

● **RESULTS:** The number of patients hospitalised for glaucoma surgery increased yearly, from 752 in 2015 to 1373 in 2021, at the Eye Hospital of Wenzhou Medical University. Regarding the patients diagnosed with primary open angle glaucoma, internal filtration surgery increased from 27.40% of the sample to 54.40% of the sample, while external filtration surgery decreased from 71.50% to 44.20% between 2015 and 2021. For paediatric glaucoma, internal filtration surgery increased from 37.50% in 2015 to 88.20% in 2021. Whilst different types of surgeries were performed on the sample of patients with secondary glaucoma, the proportion of internal filtration surgery also showed an increase from 18.20% in 2015 to 40.90% in 2021. Meanwhile, internal filtration surgery in the patient sample with primary angle-closure glaucoma already accounted for over 70.00% in 2015, and showed a small increase by 2021.

● **CONCLUSION:** As surgical technology and surgical experience continue to elevate and improve, the range of glaucoma surgeries are correspondingly evolving. This study find that internal filtration surgeries accounted for an increasing proportion of treatments in the surgical management of glaucoma between 2015 and 2021.

● **KEYWORDS:** glaucoma; internal filtration surgery; inpatient; trend

DOI:10.18240/ijo.2023.02.12

Citation: Cao Y, Lin HS, Mao HY, Zhao Y, Xie YQ, Zhang SD, Zhang Q, Wang PJ, Li GX, Fang AW, Liang YB. Trend of glaucoma internal filtration surgeries in a tertiary hospital in China. *Int J Ophthalmol* 2023;16(2):251-259

INTRODUCTION

According to a report published by the Lancet Global Health Commission on Global Eye Health named Vision Beyond 2020, glaucoma is one of the leading causes of visual impairment in adults[1], as it accounts for 2% of visual impairment and 8% of blindness in the world[2]. Currently, the most effective treatment for glaucoma is reducing the intraocular pressure (IOP), as elevated IOP is a major risk factor for development and progression of glaucoma[3]. In terms of treatment, surgery is amongst the main options[4]. Trabeculectomy (Trab) and tube shunt surgery are two common, longstanding procedures that are successful in the treatment of glaucoma[5]. Whilst they can effectively reduce IOP, there remains a risk of potentially vision-threatening complications in 39% of Trab cases and in 22% of tube shunt cases; moreover, urgent postoperative interventions are necessary in 74% of Trab and 27% of tube shunts[6]. The bleb-related complications experienced by patients can be long-term, regardless of the IOP being controlled after surgery.

In recent years, there has been an increase in the treatment options available for patients with glaucoma, particularly as new surgical devices and techniques have been optimised and introduced. Phacoemulsification (Phaco) is a well-developed technique to extract cataracts and has also been performed to manage primary angle-closure glaucoma (PACG)[7]. Nevertheless, not all PACG patients in clinic are eligible for Phaco, especially those who have more than 180-degree angle closure. Therefore, goniosynechialysis (GSL) has been performed on patients with extensive angle closure who underwent Phaco, as this can lower the IOP by separating the anterior synechia from the trabecular meshwork[8-9]. Less invasive glaucoma procedures, collectively termed minimally invasive glaucoma surgery, can reduce the IOP with minimal tissue destruction, and also maintain a relatively high safety profile, short surgery time, the use of simple instrumentation, and rapid recovery for patients[10]. Non-penetrating glaucoma surgery options, such as canaloplasty and trabeculotomy, are a recent trend in clinical application[11]. These surgeries can reconstruct natural aqueous outflow channels by dilating Schlemm's canal, thus avoiding conjunctival scarring[12]. Penetrating canaloplasty (PCP) is a new bleb-independent surgery, and has the ability to reduce IOP with a particularly high success rate in PACG[13] and traumatic angle recession glaucoma[14].

Many countries have experienced changes in glaucoma surgery trends over recent years. In Australia, the percentage of primary filtering surgery declined by 68% between 1994 and 2014[15], whilst in Japan, external filtering surgery was the most common procedure for glaucoma prior to 2017, but this was overtaken by trabeculotomy from 2018 onwards[16]. Now, bleb-independent surgery has started to become the main interest of glaucoma surgeons. Wenzhou, an economically developed city in the southeast part of Zhejiang Province, has a population of over 9.5 million. The Eye Hospital of Wenzhou Medical University is one of the few tertiary hospitals in the region that specialises in ophthalmology, and has a high caseload of glaucoma inpatients. Therefore, this study in the Eye Hospital of Wenzhou Medical University analyse the trend of internal filtration surgeries between 2015 and 2021.

SUBJECTS AND METHODS

Ethical Approval This study adhered to the Declaration of Helsinki and the study protocol was approved by the Ethics Committee of the Wenzhou Medical University prior to study commencement (Number: 2022-111-K-85). Informed consent was not required, as data were collected in de-identified fashion.

Population and Procedures As this was a retrospective study, clinical records were obtained from the hospital's electronic medical record system (Thiseye, Eye Care System, Versions 2022.4.14.24461) for the period of January 1, 2015, until December 31, 2021.

The inclusion criteria of this study included patients who had been diagnosed with glaucoma and had received anti-glaucoma surgery during their hospitalisation. The exclusion criteria included patients who had received paracentesis, anterior chamber irrigation, air injection to the anterior chamber, glaucoma drainage device adjustment or extraction, injection of viscoelastic agent, intravitreal injection, iriplasty, scleral allograft or coreoplasty alone. Demographic information was also obtained, such as gender, age, the type of glaucoma, and the surgeries received.

Classification The types of glaucoma were classified as follows: 1) PACG: primary acute or chronic angle-closure glaucoma, primary angle closure; 2) primary open angle glaucoma (POAG): POAG and normal tension glaucoma; 3) paediatric glaucoma: congenital, childhood, and juvenile glaucoma; 4) secondary glaucoma: steroid-induced glaucoma, exfoliative glaucoma, angle recession glaucoma, pigmentary glaucoma, malignant glaucoma, neovascular glaucoma, Posner-Schlossman Syndrome, iridocorneal endothelial syndrome, nanophthalmic, Sturger-Weber syndrome, uveitis and other causes lead to the glaucoma[17]; 5) reoperation: patients who had previously undergone anti-glaucoma surgery and had now been readmitted for surgery; 6) others: where classification could not be determined based on the medical records.

The surgeries were classified as follows: 1) internal filtration surgery[18]: promoting aqueous humor outflow through physiological channels (including angle surgery and suprachoroidal drainage), which was independent of bleb, including trabeculotomy, Phaco, canaloplasty, goniotomy, peripheral iridectomy, GSL, PCP, cataract extraction combined with GSL/PCP, and other similar types; 2) external filtration surgery[19]: based on the Trab and glaucoma drainage implant (GDI), including non-penetrating trabecular surgery, Ahmed, Ex-Press, XEN implantation, cataract extraction combined with Trab/GDI and so on; 3) cyclodestruction surgery: cyclophotocoagulation, low dose laser cystoplasty, ultrasound cystoplasty; 4) bleb-management surgery that was present only in the reoperation group, including bleb revision, bleb separation, conjunctival suture.

Statistical Analysis The glaucoma types and surgical procedures were analysed using R (Version 4.1.2) and Prism 9 (Version 9.0.0, GraphPad Software Ink). Non-normal distribution variables were represented by the median and quartiles. The Cochrane-Armitage trend test was performed to determine the trend of glaucoma surgical procedures over a period of time. Statistical significance was denoted at $P<0.05$.

RESULTS

This study comprised 6543 (8435 eyes) patients with glaucoma who had received anti-glaucoma surgeries in the Glaucoma Department of the Eye Hospital of Wenzhou Medical

University. The median age of the sample was 63 years old, with a minimum value of 1mo and a maximum value of 95 years old. Of the total sample, 2749 patients were men and 3794 patients were women (42.01% *vs* 57.99%). These findings are shown in Table 1. The number of hospitalised patients in the Glaucoma Department exhibited an increase of 82.58% in 2021 from 2015.

Table 2 presented the number of surgeries for each type of glaucoma. PACG cases accounted for 54.00% of the hospitalised patients who received anti-glaucoma surgeries, followed by secondary glaucoma patients (15.05%), POAG patients (13.28%), and paediatric glaucoma patients (1.74%). Table 3 demonstrated the number of glaucoma surgeries performed at the Eye Hospital of Wenzhou Medical University between 2015 and 2021. The most common surgery was Phaco combined with GSL (Phaco-GSL), which accounted for 37.10% of glaucoma surgeries over the last seven years. The second most common surgery was Phaco or Phaco combined with intraocular lens implantation. Meanwhile, the proportion of GDI surgeries decreased from 7.88% in 2015 to 4.16% in 2021, while the proportion of PCP increased from 1.70% to 11.92% over this time period. The proportion of combined cataract extraction with PCP/goniotomy also increased from 0.85% to 2.81%, while combined cataract extraction with Trab/GDI witnessed a decrease in proportion from 15.34% to 9.72%. The proportion of Trab surgeries decreased between 2016-2018, but then increased slightly the following years. The proportion of cyclodestruction surgeries remained consistent over the entire time period.

The number and types of glaucoma surgeries for each type of glaucoma were shown in Table 4. The proportion of external filtration surgeries for PACG decreased from 26.10% to 15.40% from 2015 to 2021. However, the proportion of internal filtration surgeries fluctuated between 71.70% and 81.90% over this time. The angle-closure glaucoma group showed the highest proportion of internal filtration surgeries, accounting for over 70.00% of the total surgeries for this group, with a fairly consistent, statistically significant trend over the study time period (Z=2.46, P=0.014; Figure 1A). Meanwhile, the proportion of cyclodestruction surgeries remained stable without evident change between 2015 and 2021.

In 2015, the most common surgical procedure was external filtration (71.50%), while internal filtration surgery accounted for only 27.40% of surgeries in POAG patients. Yet, by 2021, this had increased to 54.40% of total surgeries for this group, whereas external filtration surgery decreased to 44.20%. The increase in internal filtration surgery over the seven-year period was found to be statistically significant (Z=6.41, P<0.001; Figure 1B).

Table 1 Age and gender for glaucoma patients undergoing anti-glaucoma surgery in the Eye Hospital of Wenzhou Medical University from 2015 to 2021

Year	*n*	Age		Gender, *n* (%)	
		Median	Range	Men	Women
2015	752	63 (54, 70)	6mo-91y	294 (39.10)	458 (60.90)
2016	766	63 (54, 70)	12mo-93y	285 (37.21)	481 (62.79)
2017	660	63 (56, 70)	3mo-90y	266 (40.30)	394 (59.70)
2018	840	64 (54, 71)	6mo-95y	363 (43.21)	477 (56.79)
2019	1135	64 (53, 71)	1mo-91y	492 (43.35)	643 (56.65)
2020	1017	63 (54, 71)	3mo-93y	442 (43.46)	575 (56.54)
2021	1373	63 (53, 71)	1mo-93y	607 (44.21)	766 (55.79)
Total	6543	63 (54, 71)	1mo-95y	2749 (42.01)	3794 (57.99)

The number of surgeries performed for secondary glaucoma cases was second to angle-closure glaucoma surgeries between 2015 and 2021. The proportion of internal filtration surgeries increased from 18.20% in 2015 to a peak prevalence in 2018 of 50.00%, before fluctuating for the remaining time period, as depicted in Figure 1C (Z=5.91, P<0.001). In contrast, external filtration surgeries exhibited the opposite trend, whereby the proportion decreased from 49.6% in 2015 to 39.00% in 2021. Cyclodestruction surgeries remained generally stable, accounting for 25.00% of total surgeries.

For paediatric glaucoma patients, the number of surgeries increased by 537.50% from 2015 to 2021, thus indicating a significant trend over this period. However, external filtration surgeries decreased from a peak proportion of 50.00% in 2015 to 9.80% in 2021, whilst the volume of internal filtration surgeries increased by 50.70%. This trend is displayed in Figure 1D (Z=5.17, P<0.001). In addition, there were too few cyclodestruction surgeries to determine a trend over the seven years.

In regard to reoperation, a stable trend was observed between 2015 and 2021, representing 11.29% of the total 939 ophthalmic procedures in glaucoma patients in 2015 and 16.30% of the 1779 cases in 2021. Of these procedures, internal filtration surgery was the most common, accounting for almost over 50.00%, followed by bleb-management surgery. However, the proportions of external filtration and cyclodestruction surgeries were lower, at 12.30% and 7.70% of surgeries, respectively. There is no evident trend in the proportion change for these surgeries over the study period, as there are only minor fluctuations, as depicted in Table 5.

DISCUSSION

A distinct increase in internal filtration surgeries for glaucoma patients was identified over the seven year study period, which corroborates the findings of previous studies[20-21]. However, this study also found that the proportions of the different glaucoma surgeries had distinct features over this time.

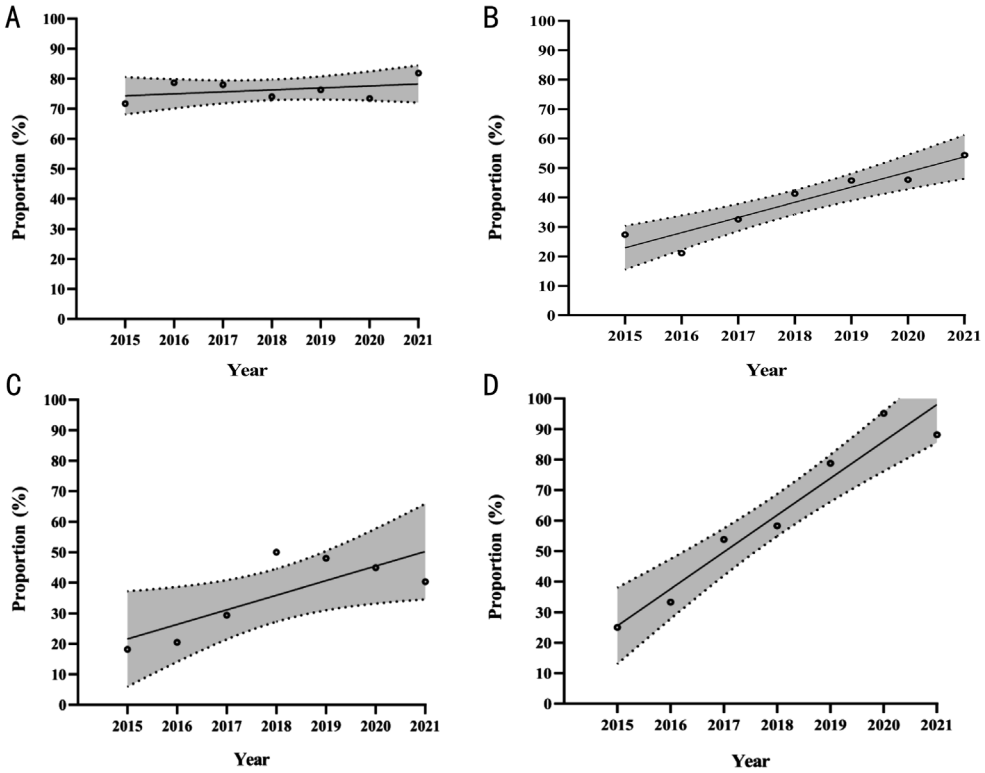

Figure 1 The trend of internal drainage surgery in different types of glaucoma A: The trend of internal drainage surgery in primary angle-closure glaucoma remined stable; B: The trend of internal drainage surgery in primary open angle glaucoma increased; C: The trend of internal drainage surgery in secondary glaucoma was upward; D: The internal drainage surgery in pediatric glaucoma presented the trend of escalation every year.

Table 2 The number of surgeries in different type of glaucoma in the Eye Hospital of Wenzhou Medical University from 2015 to 2021 *n* (%)

Year	*n*	POAG	PACG	SG	PG	Reoperation	Others
2015	939	95 (10.12)	579 (61.66)	143 (15.23)	8 (0.85)	106 (11.29)	8 (0.85)
2016	968	76 (7.85)	628 (64.88)	117 (12.09)	9 (0.93)	134 (13.84)	4 (0.41)
2017	867	86 (9.92)	549 (63.32)	109 (12.57)	13 (1.50)	102 (11.76)	8 (0.93)
2018	1089	162 (14.88)	589 (54.09)	154 (14.14)	12 (1.10)	164 (15.06)	8 (0.73)
2019	1506	227 (15.07)	761 (50.53)	223 (14.81)	33 (2.19)	251 (16.67)	11 (0.73)
2020	1287	187 (14.53)	625 (48.56)	205 (15.93)	21 (1.63)	242 (18.80)	7 (0.55)
2021	1779	287 (16.13)	824 (46.32)	318 (17.88)	51 (2.87)	290 (16.30)	9 (0.50)
Total	8435	1120 (13.28)	4555 (54.00)	1269 (15.05)	147 (1.74)	1289 (15.28)	55 (0.65)

POAG: Primary open angle glaucoma; PACG: Primary angle-closure glaucoma; SG: Secondary glaucoma; PG: Paediatric glaucoma.

External filtration surgeries were the main surgical approach for POAG patients in 2015. Although Trab is traditionally the most popular and flexible surgical method, especially in combination with detachable suture technology, argon laser suture release technology, and viscoelastic materials, issues such as postoperative ocular hypotony, shallow anterior chamber, and bleb-related complications (infection, leakage, scarring), have been troublesome and unavoidable[19,21-22]. Subsequently, postoperative IOP reduction and visual quality have not been optimal in many Trab cases. Furthermore, Trab can accelerate lens degeneration, and the failure rate of Trab can be increased if cataract surgery is conducted subsequently[23]. Therefore, this explains the observed decline in Trab-related surgeries found in this study. In contrast, the number of internal filtration surgeries showed a considerable increase, accounting for more than half of the surgeries in 2021. Research has evidenced positive results in POAG patients following internal filtration surgery[24]. Meanwhile, a comparison of the safety, efficacy, and postoperative management of canaloplasty versus Trab with mitomycin C in POAG cases showed that both canaloplasty and Trab are effective in lowering IOP. However, canaloplasty was more favourable due to the fewer follow-up visits and significantly fewer complications and interventions compared with Trab[25]. Several other studies have shown similar results[26-27]. Moreover, this study found that more POAG patients were undergoing PCP; a previous long-term

Table 3 The number of glaucoma surgeries in the Eye Hospital of Wenzhou Medical University from 2015 to 2021 *n* (%)

Year	*n*	Internal filtration surgery						External filtration surgery				Cyclodestruction surgery	Bleb-management surgery
		P or P+I	P+I+GSL	PCP	Canaplasty	Combined cataract extraction with PCP/goniotomy	Others[a]	Trab	GDI	Combined cataract extraction with Trab/GDI	Others[b]		
2015	939	177 (18.85)	327 (34.82)	16 (1.70)	4 (0.43)	8 (0.85)	8 (0.85)	94 (10.01)	74 (7.88)	144 (15.34)	0	72 (7.67)	15 (1.60)
2016	968	149 (15.39)	433 (44.73)	10 (1.03)	6 (0.62)	1 (0.10)	11 (1.14)	58 (6.00)	75 (7.75)	128 (13.22)	0	63 (6.51)	34 (3.51)
2017	867	113 (13.03)	396 (45.67)	35 (4.04)	7 (0.81)	4 (0.46)	9 (1.04)	56 (6.46)	56 (6.46)	118 (13.61)	0	59 (6.81)	14 (1.61)
2018	1089	110 (10.10)	424 (38.93)	105 (9.64)	10 (0.92)	15 (1.38)	33 (3.03)	104 (9.55)	20 (1.84)	157 (14.42)	11 (1.01)	67 (6.15)	33 (3.03)
2019	1506	197 (13.08)	513 (34.06)	178 (11.82)	28 (1.86)	23 (1.53)	49 (3.25)	200 (13.28)	1 (0.07)	145 (9.63)	4 (0.27)	110 (7.30)	58 (3.85)
2020	1287	131 (10.18)	436 (33.88)	132 (10.26)	17 (1.32)	26 (2.02)	63 (4.90)	182 (14.14)	1 (0.08)	143 (11.11)	3 (0.23)	95 (7.38)	58 (4.50)
2021	1779	239 (13.43)	600 (33.73)	212 (11.92)	2 (0.11)	50 (2.81)	47 (2.64)	185 (10.40)	74 (4.16)	173 (9.72)	0	126 (7.08)	71 (4.00)
Total	8435	1116 (13.23)	3129 (37.10)	688 (8.16)	74 (0.88)	127 (1.51)	220 (2.61)	879 (10.41)	301 (3.57)	1008 (11.95)	18 (0.21)	592 (7.02)	283 (3.35)

P: Phacoemulsification; GSL: Goniosynechialysis; I: Intraocular lens; Trab: Trabeculectomy; GDI: Glaucoma drainage implant; PCP: Penetrating canaloplasty; [a]Others include trabeculotomy, GSL, goniotomy, peripheral iridectomy, trabeculotomy combined with trabeculectomy and 360-degree trabeculectomy; [b]Others include non-penetrating trabecular surgery.

Table 4 Numbers and proportions of 3 types glaucoma surgery for various type of glaucoma in the Eye Hospital of Wenzhou Medical University from 2015 to 2021 *n* (%)

Year	POAG			PACG			PG			SG		
	Internal filtration surgery	External filtration surgery	Cyclodestruction surgery	Internal filtration surgery	External filtration surgery	Cyclodestruction surgery	Internal filtration surgery	External filtration surgery	Cyclodestruction surgery	Internal filtration surgery	External filtration surgery	Cyclodestruction surgery
2015	26 (27.40)	68 (71.50)	1 (1.10)	415 (71.70)	151 (26.10)	13 (2.20)	3 (37.50)	4 (50.00)	1 (12.50)	26 (18.20)	71 (49.60)	46 (32.20)
2016	16 (21.10)	58 (76.30)	2 (2.60)	494 (78.70)	114 (18.10)	20 (3.20)	3 (33.30)	6 (66.70)	0	25 (21.40)	61 (52.10)	31 (26.50)
2017	28 (32.60)	57 (66.30)	1 (1.10)	428 (78.00)	106 (19.30)	15 (2.70)	8 (61.50)	5 (38.50)	0	32 (29.30)	49 (45.00)	28 (25.70)
2018	67 (41.30)	94 (58.10)	1 (0.60)	436 (74.00)	137 (23.30)	16 (2.70)	7 (58.30)	4 (33.30)	1 (8.40)	77 (50.00)	41 (26.60)	36 (23.40)
2019	104 (45.80)	121 (53.30)	2 (0.90)	581 (76.30)	156 (20.50)	24 (3.20)	30 (90.91)	3 (9.09)	0	107 (48.00)	53 (23.70)	63 (28.30)
2020	86 (46.00)	100 (53.50)	1 (0.50)	459 (73.40)	146 (23.40)	20 (3.20)	21 (100.00)	0	0	93 (45.40)	58 (28.30)	54 (26.30)
2021	156 (54.40)	127 (44.20)	4 (1.40)	675 (81.90)	127 (15.40)	22 (2.70)	45 (88.20)	5 (9.80)	1 (2.00)	130 (40.90)	124 (39.00)	64 (20.10)
Total	483 (43.10)	625 (55.80)	12 (1.10)	3488 (76.50)	937 (20.60)	130 (2.90)	117 (79.60)	27 (18.40)	3 (2.00)	490 (38.60)	457 (36.00)	322 (25.40)
Z	6.41			2.46			5.17			5.91		
P	0.001[b]			0.014[a]			0.001[b]			0.001[b]		

POAG: Primary open angle glaucoma; PACG: Primary angle-closure glaucoma; SG: Secondary glaucoma; PG: Paediatric glaucoma [a]$P<0.05$; [b]$P<0.01$.

Int J Ophthalmol, Vol. 16, No. 2, Feb.18, 2023 www.ijo.cn
Tel: 8629-82245172 8629-82210956 Email: ijopress@163.com

Table 5 Numbers and proportions of 4 types of glaucoma surgery for reoperation in the Eye Hospital of Wenzhou Medical University from 2015 to 2021 *n* (%)

Year	Number	Internal filtration surgery	External filtration surgery	Cyclodestruction surgery	Bleb-manage ment surgery
2015	106	62 (58.50)	18 (17.00)	11 (10.40)	15 (14.10)
2016	134	68 (50.70)	22 (16.40)	10 (7.50)	34 (25.40)
2017	102	64 (62.75)	13 (12.75)	11 (10.80)	14 (13.70)
2018	164	100 (61.00)	16 (9.80)	15 (9.10)	33 (20.10)
2019	251	166 (66.10)	17 (6.80)	10 (4.00)	58 (23.10)
2020	242	146 (60.30)	25 (10.30)	13 (5.40)	58 (24.00)
2021	290	142 (49.00)	47 (16.20)	30 (10.30)	71 (24.50)
Total	1289	748 (58.00)	158 (12.30)	100 (7.70)	283 (22.00)

efficacy study identified the ability of PCP to sustain IOP reduction with a high complete success rate (81.3%) at 36 and 60mo postoperatively[28]. Compared with external filtration surgery, internal filtration surgery primarily aims to rebuild the function of the trabecular meshwork, and therefore, it is a more natural and physiological process to facilitate aqueous outflow. Internal filtration surgeries can be canal-based, whereby filtration is restored through Schlemm's canal; this procedure is designed to retain the normal anatomy as opposed to removing it, and to be conjunctival bleb free, as this minimises the risk of long-term endophthalmitis and ocular hypotony[19]. Due to this advantage of being bleb-independent, internal filtration surgery has the potential to be the future dominating surgical method for POAG.

The findings for paediatric glaucoma were similar to the trend of internal filtration surgery in POAG. The underlying mechanism of paediatric glaucoma involves maldevelopment of the trabecular meshwork and/or anterior chamber angle, resulting in reduced aqueous outflow, elevated IOP, enlarged corneal diameter, cupping of the optic disc, and a series of other clinical features[29]. Goniotomy or trabeculotomy *ab externo* are often the preferred initial treatment for this disease[30]. In primary congenital glaucoma, Trab (with or without mitomycin-C) is typically reserved as a second procedure if angle surgery fails, or it is used as part of a combined approach with Trab. Children, especially infants, have a superior healing response compared with adults, meaning the risk of scarring of the fistula or the conjunctiva is higher; thus, the surgical outcomes of Trab for children are worse than for adults[31]. Nonetheless, as surgical technologies have undergone innovation in recent times, the development of 360° trabeculotomy has produced more accurate positioning of Schlemm's canal and effective cutting of the trabecular meshwork. An extensive amount of literature has confirmed the superior results yielded by 360° trabeculotomy in terms of IOP control and success rates in paediatric glaucoma[30,32-33]. Cyclodestructive procedures are considered a last resort option in refractory paediatric glaucoma, including cyclocryotherapy (the use of freezing temperatures), transscleral cyclophotoco-agulation (the use of laser), or endoscopic cyclophotocoagulation (the use of laser with endoscope). This is because cyclodestructive methods can damage the ciliary body and reduce the formation of aqueous humor. In most parts of the world, most paediatric glaucoma patients undergo internal filtration surgery to restore physiological aqueous drainage pathways. In 2015, there were only eight cases of childhood glaucoma in the Eye Hospital of Wenzhou Medical University hospital; however, the limited treatment experience at the time meant that half of these patients underwent Trab. As the hospital's experience and number of patients in this situation have increased over time, more mainstream treatment methods have been implemented, especially internal filtration surgery.

PACG is more common in Asians than in Africans or Europeans[34]. This study showed that angle-closure glaucoma and secondary glaucoma were the most common types of glaucoma cases at the Eye Hospital of Wenzhou Medical University, which matched the findings of studies conducted in Shanghai[35], Tianjin[36], and Beijing[37]. In regard to angle-closure glaucoma, the proportion of internal filtration surgeries increased slightly from 2015 to 2021 to over 70% of patients. Of these patients, most underwent Phaco or Phaco-GSL. Patients with PACG have some specific anatomic abnormalities and are characterised by the thick lens and short axial length of their eyeballs, which can lead to pupillary block, narrowed anterior chamber, and subsequent increases in IOP[38-39]. Phaco is an appropriate surgical treatment because it can deepen the anterior chamber and eliminate the pupillary block by removing the lens. According to the fifth edition of the European Glaucoma Guidelines, Phaco is chiefly recommended for primary angle closure and PACG patients who are aged 50 years and older[4]. A study reported the qualified success after Phaco-GSL as being over 85%, with the follow-up period over 12mo[40]. In the Eye Hospital of Wenzhou Medical University,

Phaco-GSL was the most common antiglaucoma surgery prior to 2014[41]. However, internal filtration surgeries rebuilt access to Schlemm's canal for aqueous humor. The present study also found that cataract extraction combined with an anti-glaucoma procedure was the second most common surgical treatment for angle-closure glaucoma. These findings could be due to several reasons; PACG with concurrent cataracts is fairly typical for aging glaucoma patients, and Phaco has become more widely accessible to patients due to the rapid economic developments and continued medical education programs in China[21]. This study identified a small number of patients who had received PCP, which had good efficacy and safety profiles, and maximally maintained the physiological anatomy of the operated eyes and restored the aqueous humor outflow in a bleb-independent manner, irrespective of the extent of angle closure[13].

Secondary glaucoma is a complex condition that is caused by a variety of factors. Based on the specific cause of glaucoma in each patient, an appropriate surgical procedure is selected. Previous studies have highlighted that GDI and Trab in secondary open-angle glaucoma and neovascular glaucoma patients, respectively, produced unsatisfactory results[42-43]. In this study, PCP was performed for some of the patients with secondary glaucoma, such as traumatic angle recession glaucoma[14], steroid glaucoma[44], iridocorneal endothelial syndrome[45], satisfactory clinical outcomes were determined for these patients in terms of IOP control and avoidance of postoperative bleb-related complications. Therefore, internal filtration surgery for secondary glaucoma showed an increase in this hospital.

Whilst these are insightful findings, certain limitation must be acknowledged. The chosen surgical procedure is somewhat dependent on the experiences and preferences of the lead surgeon, thus, this sample had potential selection bias.

In conclusion, an increase in internal filtration surgeries based on physiological channels and non-bleb was identified in the surgical management of glaucoma in this study. The proportion of internal filtration surgeries accounted for over half of the total surgeries across a diverse range of types of glaucoma in the studied hospital. This anticipates internal filtration surgery as becoming the mainstream surgical procedure for glaucoma in the future. However, the trend does not mean the disappearance of external filtration surgeries, such as Trab or GDI, which are still the important surgical procedures for some type of glaucoma.

ACKNOWLEDGEMENTS

Authors' contributions: Study concept and design: Liang YB, Cao Y, Lin HS; data collection, analysis and interpretation: Cao Y, Lin HS, Mao HY, Zhao Y; manuscript writing: Cao Y; statistical analysis: Cao Y, Lin HS; technical or material support, and supervision: Xie YQ, Zhang SD, Zhang Q, Wang PJ, Li GX, Fang AW, Liang YB; critical revision of the manuscript for intellectual content: Liang YB, Lin HS. All authors approved the final version of the manuscript.

Foundations: Supported by the National Key Research and Development Project of China (No.2020YFC2008200); the Program for Zhejiang Leading Talent of S&T Innovation (No.2021R52012); Key Research and Development Projects of Zhejiang Province (No.2022C03112); the Zhejiang Provincial Program for the Cultivation of Leading Talents in Colleges and Universities (No.2020099).

Conflicts of Interest: Cao Y, None; **Lin HS,** None; **Mao HY,** None; **Zhao Y,** None; **Xie YQ,** None; **Zhang SD,** None; **Zhang Q,** None; **Wang PJ,** None; **Li GX,** None; **Fang AW,** None; **Liang YB,** None.

REFERENCES

1 Burton MJ, Ramke J, Marques AP, *et al*. The lancet global health commission on global eye health: vision beyond 2020. *Lancet Glob Health* 2021;9(4):e489-e551.

2 King A, Azuara-Blanco A, Tuulonen A. Glaucoma. *BMJ* 2013;346:f3518.

3 Oie S, Ishida K, Yamamoto T. Impact of intraocular pressure reduction on visual field progression in normal-tension glaucoma followed up over 15 years. *Jpn J Ophthalmol* 2017;61(4):314-323.

4 European Glaucoma Society Terminology and Guidelines for Glaucoma, 5th Edition. *Br J Ophthalmol* 2021;105(Suppl 1):1-169.

5 Kawabata K, Shobayashi K, Iwao K, Takahashi E, Tanihara H, Inoue T. Efficacy and safety of Ex-PRESS® mini shunt surgery versus trabeculectomy for neovascular glaucoma: a retrospective comparative study. *BMC Ophthalmol* 2019;19(1):75.

6 Gedde SJ, Herndon LW, Brandt JD, Budenz DL, Feuer WJ, Schiffman JC. Postoperative complications in the tube versus trabeculectomy (TVT) study during five years of follow-up. *Am J Ophthalmol* 2012;153(5):804-814.e1.

7 Liu Y, Li WJ, Jiu XD, Lei XW, Liu L, Yan CY, Li XJ. Systematic review and Meta-analysis of comparing phacoemulsification combined with goniosynechialysis to other mainstream procedures in treating patients with angle-closure glaucoma. *Medicine* 2019;98(42):e17654.

8 Campbell DG, Vela A. Modern goniosynechialysis for the treatment of synechial angle-closure glaucoma. *Ophthalmology* 1984;91(9): 1052-1060.

9 Teekhasaenee C, Ritch R. Combined phacoemulsification and goniosynechialysis for uncontrolled chronic angle-closure glaucoma after acute angle-closure glaucoma. *Ophthalmology* 1999;106(4):669-675.

10 Manasses DT, Au L. The new era of glaucoma micro-stent surgery. *Ophthalmol Ther* 2016;5(2):135-146.

11 Xiao JY, Liang AY, Wang YL, Cheng GW, Zhang MF. Efficacy and safety of non-penetrating glaucoma surgery with phacoemulsification versus non-penetrating glaucoma surgery: a Meta-analysis. *Int J Ophthalmol* 2021;14(12):1970-1978.

12 Gołaszewska K, Konopińska J, Obuchowska I. Evaluation of the efficacy and safety of canaloplasty and iStent bypass implantation in patients with open-angle glaucoma: a review of the literature. *J Clin Med* 2021;10(21):4881.

13 Zhang SD, Hu C, Cheng HH, Gu J, Samuel K, Lin HS, Deng YX, Xie YQ, Hu JJ, Le RR, Xu SX, Tham CC, Liang YB. Efficacy of bleb-independent penetrating canaloplasty in primary angle-closure glaucoma: one-year results. *Acta Ophthalmol* 2022;100(1):e213-e220.

14 Cheng HH, Ye WQ, Zhang SD, Xie YQ, Gu J, Le RR, Deng YX, Hu C, Zhao ZQ, Ke ZS, Liang YB. Clinical outcomes of penetrating canaloplasty in patients with traumatic angle recession glaucoma: a prospective interventional case series. *Br J Ophthalmol* 2022:bjophthalmol-bjophtha2021-320659.

15 Kerr NM, Kumar HK, Crowston JG, Walland MJ. Glaucoma laser and surgical procedure rates in Australia. *Br J Ophthalmol* 2016;100(12):1686-1691.

16 Fujita A, Hashimoto Y, Matsui H, Yasunaga H, Aihara M. Recent trends in glaucoma surgery: a nationwide database study in Japan, 2011-2019. *Jpn J Ophthalmol* 2022;66(2):183-192.

17 European Glaucoma Society Terminology and Guidelines for Glaucoma, 4th Edition - Chapter 3: Treatment principles and options Supported by the EGS Foundation: Part 1: Foreword; Introduction; Glossary; Chapter 3 Treatment principles and options. *Br J Ophthalmol* 2017;101(6):130-195.

18 Loewen NA, Schuman JS. There has to be a better way: evolution of internal filtration glaucoma surgeries. *Br J Ophthalmol* 2013;97(10): 1228-1229.

19 Coleman AL. Advances in glaucoma treatment and management: surgery. *Invest Ophthalmol Vis Sci* 2012;53(5):2491-2494.

20 Tian JX, Shi Y, Xin C. The analysis of glaucoma surgery method changes in the past 10 years based on clinical data of hospitalized patients. *Chin J Ophthalmol Med (Electronic Edition)* 2019;9(4):218-226.

21 Qiao CY, Zhang H, Cao K, Tian JX, Chung TY, Shan J, Han Y, Wang NL, Investigators for the Chinese Glaucoma Study Consortium. Changing trends in glaucoma surgery over the past 5 years in China. *J Glaucoma* 2022;31(5):329-334.

22 Tunç Y, Tetikoglu M, Kara N, Sagdık HM, Özarpaci S, Elçioğlu MN. Management of hypotony and flat anterior chamber associated with glaucoma filtration surgery. *Int J Ophthalmol* 2015;8(5):950-953.

23 Choy BNK. Comparison of surgical outcome of trabeculectomy and phacotrabeculectomy in Chinese glaucoma patients. *Int J Ophthalmol* 2017;10(12):1928-1930.

24 Khaimi MA. Canaloplasty: a minimally invasive and maximally effective glaucoma treatment. *J Ophthalmol* 2015;2015:485065.

25 Brüggemann A, Despouy JT, Wegent A, Müller M. Intraindividual comparison of Canaloplasty versus trabeculectomy with mitomycin C in a single-surgeon series. *J Glaucoma* 2013;22(7):577-583.

26 Vastardis I, Fili S, Perdikakis G, Gatzioufas Z, Kohlhaas M. Estimation of risk-benefit ratio and comparison of post-operative efficacy results between trabeculectomy and canaloplasty. *Eur J Ophthalmol* 2021;31(3):1405-1412.

27 Garris WJ, Le C, Zurakowski D, Ayyala RS. Comparison of surgical outcomes between canaloplasty and trabeculectomy with mitomycin C at 2-year follow-up: a longitudinal cohort study. *Indian J Ophthalmol* 2018;66(1):66-70.

28 Ye WQ, Gu J, Hu C, *et al*. The preliminary study on long-term efficacy of penetrating canaloplasty in glaucoma. *Ophthalmol CHN* 2022;30(1):14-19.

29 Liang Y, Yu QL, Ji FF, Sun H, Yuan ZL. Viscocanalostomy combined with nearly 360-degree suture trabeculotomy for the treatment of primary congenital glaucoma: a preliminary report of a novel technique for trabeculotomy. *Graefes Arch Clin Exp Ophthalmol* 2020;258(2):379-386.

30 Celea C, Dragosloveanu S, Pop M, Celea C. Comparison of 360-degree circumferential trabeculotomy and conventional trabeculotomy in primary pediatric glaucoma surgery: part 1. *J Pediatr Ophthalmol Strabismus* 2016;53(6):357-364.

31 Gagrani M, Garg I, Ghate D. Surgical interventions for primary congenital glaucoma. *Cochrane Database Syst Rev* 2020;8(8): CD008213.

32 Lim ME, Neely DE, Wang JY, Haider KM, Smith HA, Plager DA. Comparison of 360-degree versus traditional trabeculotomy in pediatric glaucoma. *J AAPOS* 2015;19(2):145-149.

33 Shi Y, Wang HZ, Yin J, Li M, Zhang XF, Xin C, Chen XY, Wang NL. Microcatheter-assisted trabeculotomy versus rigid probe trabeculotomy in childhood glaucoma. *Br J Ophthalmol* 2016;100(9):1257-1262.

34 Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. *Ophthalmology* 2014;121(11):2081-2090.

35 Zheng YY, Zhang YQ, Sun XH. Epidemiologic characteristics of 10 years hospitalized patients with glaucoma at Shanghai eye and ear, nose, and throat hospital. *Medicine* 2016;95(29):e4254.

36 Yang J, Qu Y, Li BA, Zhong ZL, Shi LK, Tian XF, Wang R, Xu D, Liu YF. Epidemiological characteristics of inpatients undergoing surgery for glaucoma at Tianjin eye hospital from 2013 to 2017. *J Ophthalmol* 2021;2021:3628481.

37 Liu T, Qiao CY, Xu XY, Li WH. The analysis of the change of the constitution of the admitted patients with glaucoma. *Zhonghua Yan Ke Za Zhi* 2017;53(8):610-615.

38 Young CEC, Seibold LK, Kahook MY. Cataract surgery and intraocular pressure in glaucoma. *Curr Opin Ophthalmol* 2020;31(1):15-22.

39 Zhang X, Wang JX, Li Y, Jiang B. Diagnostic test accuracy of Spot and Plusoptix photoscreeners in detecting amblyogenic risk factors in children: a systemic review and meta-analysis. *Ophthalmic Physiol Opt* 2019;39(4):260-271.

40 Wei LQ, Fu L, Nie L, Lian HL, Qian ZB, Liang YB, Pan WH. Efficacy of combined phacoemulsification and goniosynechialysis in primary angle closure disease with different degrees of peripheral anterior synechiae. *J Glaucoma* 2022;31(7):540-546.

41 Hu C, Xu J, Liang YB, Ye C, Wu HX, Feng KM, Xie YQ, Fang AW, Qu J. Changing patterns of surgical treatment for glaucoma in the Eye Hospital of Wenzhou Medical University during the past ten years. *Zhonghua Yan Ke Za Zhi* 2018;54(3):184-188.

42 Ibáñez-Muñoz A, Soto-Biforcos VS, Rodríguez-Vicente L, Ortega-Renedo I, Chacón-González M, Rúa-Galisteo O, Arrieta-Los Santos A, Lizuain-Abadía ME, Del Río Mayor JL. XEN implant in primary and secondary open-angle glaucoma: a 12-month retrospective study. *Eur J Ophthalmol* 2020;30(5):1034-1041.

43 Tokumo K, Komatsu K, Yuasa Y, Murakami Y, Okumichi H, Hirooka K, Nakakura S, Tabuchi H, Kiuchi Y. Treatment outcomes in the neovascular glaucoma tube versus trabeculectomy study. *Graefes Arch Clin Exp Ophthalmol* 2021;259(10):3067-3076.

44 Hu JJ, Lin HS, Zhang SD, Ye WQ, Gu J, Xie YQ, Tang YH, Liang YB. A new bleb-independent surgery namely penetrating canaloplasty for corticosteroid-induced glaucoma: a prospective case series. *Int J Ophthalmol* 2022;15(7):1077-1081.

45 Deng YX, Zhang SD, Ye WQ, Gu J, Lin HS, Cheng HH, Xie YQ, Le RR, Tao Y, Zhang W, Chen W, Tham CC, He MG, Wang NL, Liang YB. Achieving inner aqueous drain in glaucoma secondary to iridocorneal endothelial syndrome: one year results of penetrating canaloplasty. *Am J Ophthalmol* 2022;243:83-90.