Research Square

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Bent Ab Interno Needle Goniotomy combined with phacoemulsification compared with phacoemulsification alone for mild to moderate glaucoma

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Abstract

Background

Bent Ab Interno Needle Goniotomy (BANG) is a low-cost goniotomy technique. Previous studies of BANG combined with phacoemulsification have treated 30 to 100 degrees of trabecular meshwork. This study compares the reduction in intraocular pressure (IOP) and topical glaucoma medications (TGMs) after phacoemulsification combined with 120 degrees of BANG, and after phacoemulsification alone.

Methods

A total of 80 eyes of 42 patients were included in this retrospective case-control study. Twenty-six eyes with primary open angle glaucoma, normal tension glaucoma, or ocular hypertension underwent BANG combined with phacoemulsification, and 54 non-glaucomatous control eyes underwent standard phacoemulsification surgery.

Results

At 12 months, the average intraocular pressure of the Phaco + BANG group remained stable (17.5 ± 5.1mmHg vs 17.8 ± 4.1mmHg, $p = 0.86$), while the average number of topical glaucoma medications was reduced (1.4 ± 1.2 vs 0.3 ± 0.6, $p < 0.001$). For the Phaco-only group, there was a modest decrease in the average intraocular pressure (14.7 ± 3.8mmHg vs 11.9 ± 2.2mmHg, $p < 0.001$). In the Phaco + BANG group, all eyes that were on no topical glaucoma medications, remained on no drops, and the average intraocular pressure reduced (22.8 ± 3.0mmHg vs 16.4 ± 2.0mmHg, $p = 0.011$). This reduction was not significantly greater than in the Phaco-only group ($p = 0.11$). Eyes with baseline IOP above the median (16.5mmHg) had a reduction in IOP at 12 months, while eyes below the median had an increase. At 3 months, no topical glaucoma medications were required for 76.9% of eyes (20 of 26). At 1-day, 73.5% of eyes had a small hyphaema, all of which resolved spontaneously.

Conclusions

In eyes with glaucoma, combining BANG with standard phacoemulsification was associated with a reduction in topical medication burden, with IOP stable over 12 months, without substantial additional cost. Future research should include a glaucomatous control group that was not available for this study.

Background

Primary open-angle glaucoma (POAG) and normal-tension glaucoma (NTG) are progressive optic neuropathies characterized by degeneration of retinal ganglion cells and corresponding visual field loss. [1] Although the exact pathophysiology is multifactorial and not completely understood, elevated

intraocular pressure (IOP) is the most well-established and modifiable risk factor for disease progression, even in NTG, where IOP remains within the normal range.[2] Lowering IOP has conclusively been shown to reduce the rate of visual field deterioration and preserve visual function, regardless of the baseline IOP.[2, 3]

Treatment strategies aimed at lowering IOP include topical medications, laser therapies, minimally invasive glaucoma surgeries (MIGS), and more invasive filtration procedures such as trabeculectomy. While MIGS is a promising alternative to trabeculectomy due to its improved safety profile, many MIGS procedures involve implantable devices such as the iStent inject®, Hydrus® Microstent, or XEN® Gel Stent, which can be costly and demonstrate variable success rates.[4, 5]

Goniotomy is a MIGS technique that involves the removal of a segment of the trabecular meshwork (TM) to facilitate aqueous humor outflow from the anterior chamber into Schlemm's canal. This procedure can be performed using various single-use devices such as the Kahook Dual Blade® (New World Medical, Rancho Cucamonga, USA), TrabEx™ device (Microsurgical Technology, Redmond, USA), or the Trabectome® device (MicroSurgical Technology, Redmond, USA). Bent Ab Interno Needle Goniotomy (BANG) is a low-cost alternative that can be performed without the need for specialist equipment.[6] When combined with phacoemulsification cataract surgery, the only additional equipment required is a 25-gauge needle, making it particularly beneficial in resource-limited settings.

This study aims to compare the efficacy of phacoemulsification combined with BANG versus phacoemulsification alone for lowering IOP. Previous studies have treated 30 to 100 degrees of trabecular meshwork [10–13], while this study treated 120 degrees. Given that phacoemulsification alone is known to result in a slight reduction in IOP, we aim to determine the additional effect of BANG over a 12-month postoperative period.

Methods

This was a retrospective case-control study of 26 eyes with POAG, NTG, or ocular hypertension (OHT) that underwent phacoemulsification combined with BANG, and 54 eyes without glaucoma who underwent phacoemulsification alone. This study was approved by the Royal Australian and New Zealand College of Ophthalmologists Human Research Ethics Committee and was conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from each patient prior to enrolment.

For the BANG group, eyes were considered to have POAG based on structural loss detected on optical coherence tomography (OCT) imaging and/or functional loss on computerised perimetry, as well as documented IOP of ≥ 23mmHg prior to any IOP lowering treatment. NTG was defined as structural loss detected on OCT and/or functional loss on computerised perimetry with IOP of < 23mmHg, and OHT based on an IOP of ≥ 23mmHg prior to any IOP lowering treatment with no structural or functional loss detected. Eyes were excluded if they had severe glaucoma (retinal nerve fibre layer (RNFL) <60μm, MD <-12 dB), secondary glaucoma, Previous glaucoma surgery (including MIGS, trabeculectomy, or laser

trabeculoplasty), or concurrent ocular disease. Non-glaucomatous controls all had visually significant cataracts but no evidence of glaucoma and preoperative IOP of < 23mmHg. Control eyes were not on any TGM before or after surgery.

Preoperative testing included habitual distance visual acuity (and pinhole if 0.2 logMAR or worse), ocular biometry using the IOLMaster 700 (Car Zeiss Meditec, Germany), macula and optic nerve head OCT imaging using the Cirrus-HD-OCT (Carl Zeiss Meditec, Germany), corneal tomography using the Pentacam (Oculus, Germany), and IOP using the ICare ic100 rebound tonometer (Tiolat Oy, Finland). The ICare tonometer takes six consecutive measurements and displays the mean value, excluding any outliers. If the standard deviation of measurements is high, then the measurements were repeated.

All surgeries were performed by a single surgeon. Under conscious sedation, the eye was prepped and draped and an eyelid speculum was placed. Following standard phacoemulsification, the operating microscope and the patient's head were tilted for better visualization of the nasal angle. A disposable 25-gauge hypodermic needle was bent to 90° at the tip towards the bevel with a pair of needle holders and attached to a syringe. This needle was inserted through the main phaco incision (2.2mm) and a gonioprism was used to view the nasal angle. The needle was used to excise 120° of the nasal, superonasal, and inferonasal TM. The viscoelastic was evacuated with a standard irrigation aspiration handpiece. Postoperatively, topical dexamethasone 0.1% was prescribed four times per day, and topical nepafenac 0.3% once per day for 28 days. For patients that were on topical glaucoma medications (TGMs) prior to surgery, these were reduced or stopped at either 1 day or 1 month postoperatively, if their measured IOP was below 20mmHg.

All statistical analyses were conducted using SPSS version 30.0 (SPSS Inc., IBM). The Shapiro-Wilk test was used to determine normality of each parameter. Comparisons between preoperative and postoperative measures were made using linear mixed models accounting for inter-eye correlation, with between-group comparisons of IOP change adjusted for baseline IOP, and a p value of < 0.05 was considered significant. Topical medication use was recorded preoperatively and at 3 months postoperatively and compared using the Wilcoxon signed-rank test. Baseline IOP subgroups were defined by a median split (16.5mmHg) within the Phaco + BANG group, and the group-by-subgroup interaction was tested. All variables are expressed as mean ± standard deviation.

Results

A total of 80 eyes of 42 patients were included in the study. All patients were aged between 50 and 80 years. The preoperative characteristics and comparisons between the treatment and control group are presented in Table 1. There was no significant difference in age, sex distribution, central corneal thickness (CCT), IOP, or axial length (AL) between the two groups. The average RNFL thickness of the Phaco + BANG group was significantly thinner than the Phaco-only group ($p = 0.008$). The average number of preoperative TGMs per eye was 1.4. No eye from the Phaco-only group was on any TGM either preoperatively or postoperatively.

Table 1
Preoperative patient characteristics, diagnosis, and topical glaucoma medications (RNFL; retinal nerve fibre layer)

Parameter	Phaco + BANG (n = 26)	Phaco-only (n = 54)	p
Age (years)	71.7 ± 5.3	68.5 ± 7.2	0.150
Female sex, n (%)	10 (66.7%)	16 (59.3%)	0.636
Preop medications	1.3 ± 1.2	0	< 0.001
Central corneal thickness (μm)	542 ± 53	544 ± 30	0.745
Axial length (mm)	23.8 ± 1.1	23.9 ± 0.9	0.813
Average RNFL (μm)	82.2 ± 12.0	92.9 ± 8.4	0.008
Intraocular pressure (mmHg)	16.8 ± 4.9	14.7 ± 3.8	0.176
Diagnosis			
No glaucoma	0	54 (100%)	
Primary open-angle	18 (69.2%)	0	
Ocular hypertension	5 (19.2%)	0	
Normal tension	3 (11.5%)	0	
Preoperative topical glaucoma medications			
0	6 (23.1%)	54 (100%)	
1	12 (46.2%)	0	
2	3 (11.5%)	0	
3	3 (11.5%)	0	
4	2 (7.7%)	0	

Data are mean ± SD unless stated otherwise.

The change in IOP at each postoperative visit are presented in Fig. 1. The average IOP of the Phaco + BANG group remained stable at 17.5 ± 5.1mmHg preoperatively, and 17.8 ± 4.1mmHg at 12 months ($p = 0.86$), while the average number of TGM dropped from 1.4 ± 1.2 to 0.3 ± 0.6 at 3 months ($p < 0.001$). All TGMs remained the same at the 12-month visit. For the Phaco-only group, the average IOP decreased from 14.7 ± 3.8mmHg to 11.9 ± 2.2mmHg at 12 months ($p < 0.001$), a 19.0% reduction.

In the Phaco + BANG group, all eyes that were on no TGMs, remained on no drops, and the average IOP reduced from 22.8 ± 3.0mmHg to 16.4 ± 2.0mmHg at 12 months ($p = 0.011$), a 28.1% reduction. The reduction in IOP for eyes on no TGMs in the Phaco + BANG group was not significantly greater than eyes

in the Phaco-only group (-6.4 ± 3.2 vs. -2.8 ± 3.0; p = 0.11). There was a slight increase in IOP for eyes in the Phaco + BANG group that reduced their number of TGMs surgery (n = 15), from 15.7 ± 4.4mmHg to 18.2 ± 4.6mmHg (p = 0.033). When eyes were stratified by baseline IOP (median 16.5mmHg), eyes above the median had a reduction in IOP at 12 months (-3.4 ± 4.7mmHg, p = 0.040), while eyes below the median had an increase at 12 months (+ 4.7 ± 4.6mmHg, p = 0.016).

The average reduction in TGMs was 1.0 ± 0.7 and no eye had an increase in the number of TGMs. Of the 20 eyes using TGMs before surgery, all reduced their use, and 14 (70.0%) were medication-free at 3 months. All 12 eyes that were on one drop, went off all drops and for these eyes (10 with 12-month IOP data) there was no significant change in IOP (+ 1.0 ± 5.1 mmHg, p = 0.55).

At day 1, 25 eyes (73.5%) had a small hyphaema, all of which resolved spontaneously without sequellae. No other intraoperative or postoperative complications occurred.

Discussion

This study investigated the efficacy of phacoemulsification combined with BANG compared to phacoemulsification alone in the management of IOP and TGM burden in patients with glaucoma. The findings suggest that adding BANG to standard phacoemulsification reduces the requirement for TGMs in glaucomatous eyes, and is associated with a greater reduction in IOP than phacoemulsification alone in eyes not previously on TGMs, while maintaining low cost to the patient and a low risk profile. However, because the control group consisted of non-glaucomatous eyes, this comparison cannot isolate the additional effect of BANG.

We report an average reduction in IOP in the Phaco-only group of 2.8mmHg (19.0%). This is consistent with existing literature of non-glaucomatous eyes undergoing phacoemulsification where values range from 1 to 3mmHg.[7–9] Comparatively, there was a reduction in IOP of 28.1% for eyes that underwent Phaco + BANG that were on no TGMs prior to surgery. This aligns with previous studies that report reductions of 24% to 32% for eyes undergoing Phaco combined with BANG.[10–13] However, IOP reduction after cataract surgery is greater in eyes with glaucoma and higher baseline IOP [41], so the greater IOP reduction in the Phaco + BANG group may reflect baseline differences rather than the effect of BANG alone. Due to the clinical nature of this study, no glaucomatous control group was available as treating a glaucomatous eye with standard phacoemulsification was not considered appropriate clinical management.

We report an average reduction in TGMs of 1.0 at 3 months, with most eyes (76.9%) not requiring any TGMs at 3 months. Results from other studies of Phaco + BANG showed a reduction in TGMs of between 0.4 and 0.9.[10–12] One issue with comparing previously published results of Phaco + BANG, is that the amount of TM that is removed differs between studies. Bukke et al[10] treated 30 degrees, Eslami et al[12] treated 90 degrees, DeVience et al[11] and Schute et al[13] treated 100 degrees, and in the current study, 120 degrees were treated. While we hypothesise that treatment of a greater amount of the TM would result in a greater reduction in IOP, a direct comparative study is needed.

For those on preoperative TGMs, the number of drops reduced while maintaining stable IOP. There are numerous benefits to reducing or eliminating TGMs including reducing ocular surface toxicity, reversing prostaglandin-associated periorbitopathy,[14] and eliminating systemic side effects of the drugs,[15] resulting in a significant improvement in quality-of-life.

One alternative low cost MIGS option is excisional goniotomy using Kahook dual blade, a single-use ophthalmic knife designed to excise TM while reducing damage to adjacent sclera. When performed in combination with phacoemulsification, this technique results in a reduction in IOP of between 12% and 39%, and a reduction in the number of TGMs between 0.4 and 1.2.[16–23] Direct comparison studies are needed to analyse differences in success rates between the Kahook dual blade and BANG.

The findings of this study align favourably with established efficacy profiles of commonly utilized MIGS microstents in conjunction with cataract surgery. Specifically, our observed IOP reduction falls within the reported ranges for the three of the most commonly implanted devices, the iStent (8.0% to 39%), Hydrus (6.7% to 31%), and XEN Gel stent (20.6% to 55.9%).[24–33] Similarly, our TGM reduction of 1.1 is consistent with the reported ranges for iStent (0.3 to 1.7 TGMs), Hydrus (0.8 to 1.8 TGMs), and the XEN Gel stent (0.4 to 2.8 TGMs).[24–33] What is not known, however, is the long term IOP control of BANG compared to implantable devices, which needs to be explored.

While it appears that BANG has similar efficacy to MIGS microstents, there is a significant cost differential that is an important consideration. The cost of the 25-gauge hypodermic needle required for a goniotomy is less than $1 AUD in Australia, while the average out-of-pocket cost for privately insured patients undergoing combined cataract and glaucoma stent surgery in Australia is approximately $570 AUD, with a reported range of $150 AUD to $2,100 AUD.[34] Such costs may represent a considerable barrier to accessing MIGS for many patients, a factor particularly important in developing countries and healthcare systems with limited resources, where the economic burden on individuals and the public health system is a critical consideration for broader adoption and equitable access to these sight-preserving technologies.

A significant limitation when comparing the efficacy of MIGS across different studies stems from the inherent variability in patients response to treatment. Glaucoma is a heterogeneous disease, with differing etiologies, stages of progression, and baseline IOP. The impact of these factors on surgical outcomes can be substantial; for instance, a greater percentage reduction in IOP may be observed in patients with higher baseline pressures, potentially skewing comparative data if cohorts are not rigorously matched. Furthermore, patient-specific factors such as age, comorbidities, and adherence to postoperative medication regimens can influence the long-term success and medication reduction achieved with MIGS. This subjective nature of treatment response introduces considerable heterogeneity that complicates direct cross-study comparisons.

The most common postoperative complication for goniotomy procedures is transient hyphaema. This is an expected physiological response to opening the outflow pathway rather than a true adverse event. A postoperative hyphaema indicates patent outflow channels and is often viewed as a sign of successful

aqueous humor egress into Schlemm's canal. While this occurred in 73.5% of eyes in the current study and up to 76.2% of eyes in previous studies,[10–12, 16] it is self-limiting and has no effect on the longer-term surgical outcome. Other complications of phacoemulsification including cystoid macula oedema, retinal detachment etc. were not reported in the current study as it is not expected that the addition of BANG would increase the risk of these complications.

The use of implantable glaucoma devices are associated with additional potential complications that are not seen in goniotomy procedures including; stent obstruction (up to 18%), peripheral anterior synechiae (up to 19%), stent migration (up to 2%), and chronic anterior chamber inflammation or iritis (up to 9%).[35–39] In addition, there are a number of bleb-related complications that can occur following XEN Gel stent implantation including hypotony, choroidal effusion, fibrosis, and blebitis.[40]

The limitations of this study include the small sample size, the relatively short follow-up time, and the retrospective design. Given the chronic nature of glaucoma, very long-term outcomes are important in determining the success of the procedure. The control group is the main limitation. It included non-glaucomatous eyes that were not receiving TGMs, so the IOP difference between groups reflects both BANG and baseline glaucoma status, and this study cannot isolate the additional IOP effect of BANG. Glaucomatous eyes may also have a different IOP response to phacoemulsification. Future research should include head-to-head comparisons of phacoemulsification with and without BANG in glaucomatous eyes matched for baseline IOP, direct comparative studies with other MIGS, as well as large-scale, prospective, randomized controlled trials which have not yet been done.

While IOP reduction is a direct measure of efficacy, the consistent and significant reduction in medication burden across multiple studies (including the current one) suggests that for many patients, especially those with mild to moderate glaucoma, improving quality of life by reducing the daily burden and cost of drops is a primary surgical goal, even if absolute IOP reduction is modest. This shifts the paradigm from solely targeting a specific IOP number to also prioritizing patient-centred outcomes. This emphasizes the importance of medication reduction as a key success criterion for MIGS, aligning with patient preferences and potentially improving long-term adherence and reducing healthcare costs associated with chronic medication use.

Conclusions

Adding BANG to phacoemulsification in eyes with glaucoma was associated with a reduction in topical medication use, with IOP remaining stable over 12 months. Because the control group consisted of non-glaucomatous eyes, the additional IOP effect of BANG cannot be confirmed, and prospective comparison with phacoemulsification alone in glaucomatous eyes is needed.

Abbreviations

BANG
bent ab interno needle goniotomy

IOP
intraocular pressure
MD
mean deviation
MIGS
minimally invasive glaucoma surgery
NTG
normal-tension glaucoma
OCT
optical coherence tomography
OHT
ocular hypertension
POAG
primary open-angle glaucoma
RNFL
retinal nerve fibre layer
TGM
topical glaucoma medication
TM
trabecular meshwork.

Declarations

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None

Conflicts of interest:

no conflicting relationship exists for any author

Declarations

Ethics approval and consent to participate:

This study was approved by the Royal Australian and New Zealand College of Ophthalmologists Human Research Ethics Committee

Consent for publication:

None applicable

Competing interests:

The authors declare that they have no competing interests.

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Author Contribution

BC conceived the study, RC acquired the data and performed the analysis, both BC and RC contributed to writing and editing the manuscript.

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Data Availability

The datasets used in the current study are available from the corresponding author on reasonable request.

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Figures

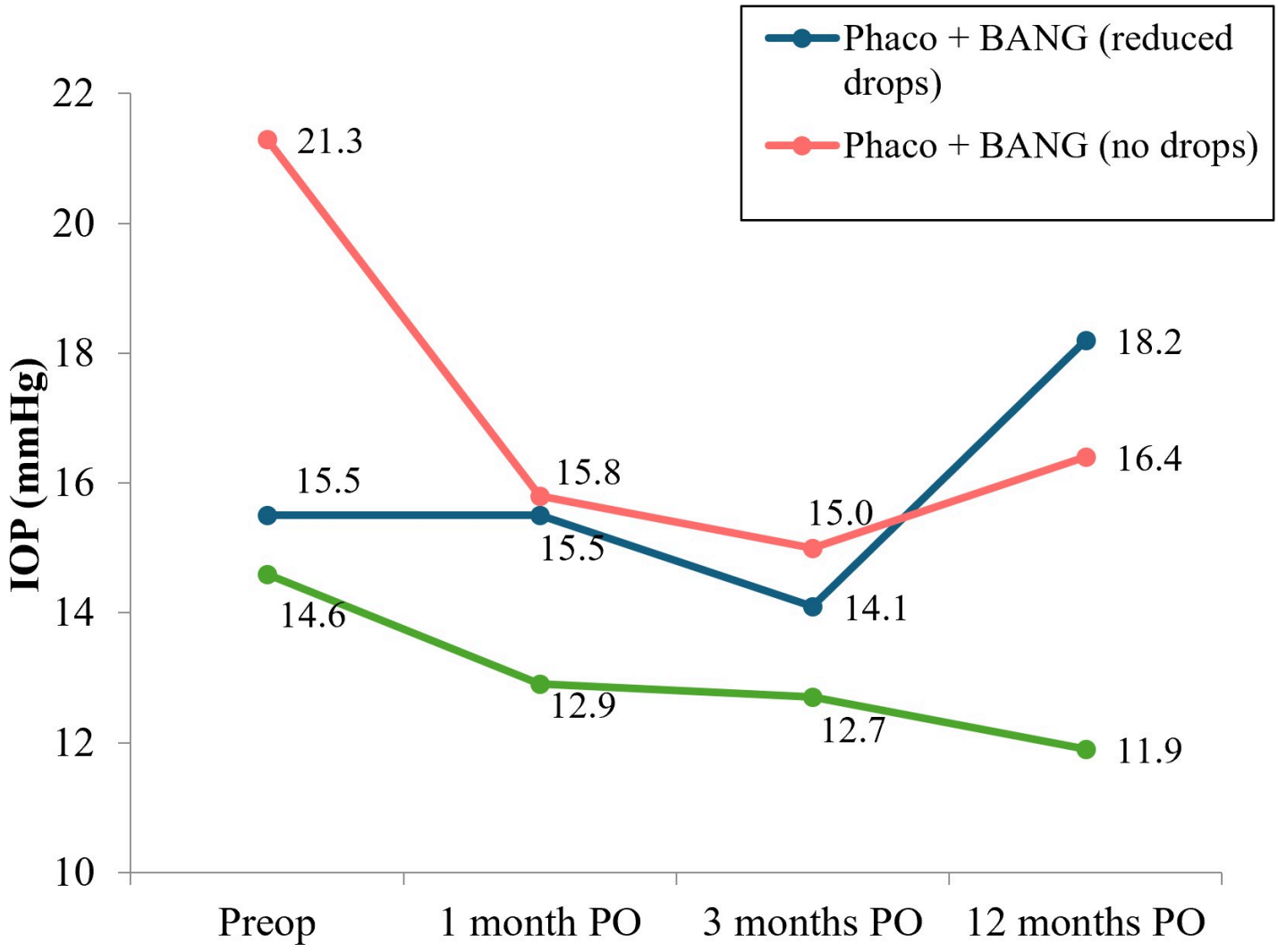


Figure 1

Mean IOP at each measured postoperative time point