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The Effect of Phacoemulsification on Intraocular Pressure in Glaucoma Patients

A Report by the American Academy of Ophthalmology

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Objective: To examine effects of phacoemulsification on longer-term intraocular pressure (IOP) in patients with medically treated primary open-angle glaucoma (POAG; including normal-tension glaucoma), pseudoexfoliation glaucoma (PXG), or primary angle-closure glaucoma (PACG), without prior or concurrent incisional glaucoma surgery.

Methods: PubMed and Cochrane database searches, last conducted in December 2014, yielded 541 unique citations. Panel members reviewed titles and abstracts and selected 86 for further review. The panel reviewed these articles and identified 32 studies meeting the inclusion criteria, for which the panel methodologist assigned a level of evidence based on standardized grading adopted by the American Academy of Ophthalmology. One, 15, and 16 studies were rated as providing level I, II, and III evidence, respectively.

Results: All follow-up, IOP, and medication data listed are weighted means. In general, the studies reported on patients using few glaucoma medications (1.5–1.9 before surgery among the different diagnoses). For POAG, 9 studies (total, 461 patients; follow-up, 17 months) showed that phacoemulsification reduced IOP by 13% and glaucoma medications by 12%. For PXG, 5 studies (total, 132 patients; follow-up, 34 months) showed phacoemulsification reduced IOP by 20% and glaucoma medications by 35%. For chronic PACG, 12 studies (total, 495 patients; follow-up, 16 months) showed phacoemulsification reduced IOP by 30% and glaucoma medications by 58%. Patients with acute PACG (4 studies; total, 119 patients; follow-up, 24 months) had a 71% reduction from presenting IOP and rarely required long-term glaucoma medications when phacoemulsification was performed soon after medical reduction of IOP. Trabeculectomy after phacoemulsification was uncommon; the median rate reported within 6 to 24 months of follow-up in patients with controlled POAG, PXG, or PACG was 0% and was 7% in patients with uncontrolled chronic PACG.

Conclusions: Phacoemulsification typically results in small, moderate, and marked reductions of IOP and medications for patients with POAG, PXG, and PACG, respectively, and using 1 to 2 medications before surgery. Trabeculectomy within 6 to 24 months after phacoemulsification is rare in such patients. However, reports on its effects in eyes with advanced disease or poor IOP control before surgery are few, particularly for POAG and PXG. *Ophthalmology 2015;■:1–14 © 2015 by the American Academy of Ophthalmology.*

The American Academy of Ophthalmology prepares Ophthalmic Technology Assessments to evaluate new and existing procedures, drugs, and diagnostic and screening tests. The goal of an Ophthalmic Technology Assessment is to review systematically the available research for clinical efficacy, effectiveness, and safety. After review by members of the Ophthalmic Technology Assessment Committee, other Academy committees, relevant subspecialty societies, and legal counsel, assessments are submitted to the Academy's Board of Trustees for consideration as official Academy statements. The purpose of this assessment by the Ophthalmic Technology Assessment Committee Glaucoma Panel is to investigate the longer-term (≥6 months) effect of phacoemulsification on intraocular pressure (IOP) in patients with medically treated primary open-angle glaucoma (POAG), pseudoexfoliation glaucoma (PXG), or primary angle-closure glaucoma (PACG) who have not undergone prior or concomitant incisional glaucoma surgery.

Background

Because IOP is the primary treatable risk factor for glaucoma progression, and because cataracts usually occur in the same patient demographic as the most common forms of chronic glaucoma, treatment of coexisting cataract and glaucoma is an important clinical problem. Although others

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have reviewed the effect on IOP of cataract extraction combined with trabeculectomy and have shown it to be superior to cataract extraction alone,[1] more recent reports using modern cataract surgery performed with phacoemulsification have shown significant short-term and midterm reduction in IOP in patients with ocular hypertension and glaucoma in some,[2,3] but not all,[4] studies. Cataract extraction as a stand-alone procedure typically results in improvement in visual functioning in patients with glaucoma,[5] and the addition of a glaucoma procedure to phacoemulsification can result in more complications during and after surgery and prolonged visual recovery.

Resource Requirements

Because cataract surgery using phacoemulsification is ubiquitous in developed countries at this time, little incremental cost is accrued to use this technology.

Questions for Assessment

This assessment addressed the following questions:

1. What is the effect of phacoemulsification on IOP and glaucoma medication use in patients with medically treated POAG, PXG, or PACG, who have not undergone prior or concomitant incisional glaucoma surgery?
2. What are the primary glaucoma-related complications of phacoemulsification in such patients?

Description of Evidence

Literature searches conducted on June 13, 2013, January 6, 2014, and December 23, 2014, in PubMed and the Cochrane Library resulted in 541 potentially relevant citations; 60 of these were in non-English languages and were excluded. The search terms used are described below:

("Glaucoma, Open-Angle"[Mesh] OR "Glaucoma, Angle-Closure"[Mesh] OR glaucoma[tiab]) AND ("Phacoemulsification"[Mesh] OR "phacoemulsification") AND ("Intraocular Pressure"[Mesh] OR "intraocular pressure") AND ("Randomized Controlled Trial"[Publication Type] OR randomised[tiab] OR randomized[tiab] or randomization[tiab] or randomisation[tiab] or randomly[tiab] OR "Cohort Studies"[Mesh] OR "cohort studies" OR "cohort study" OR "Outcome Assessment (Health Care)"[Mesh] OR "outcome assessment" OR "outcome research" OR "outcomes research" OR "outcomes assessment" OR "Case-Control Studies"[Mesh] OR "case control study" OR "case control studies" OR "case series" or "clinical trial") AND ("Adult"[Mesh] OR "Middle Aged"[Mesh] OR "Aged"[Mesh] OR "Aged, 80 and over"[Mesh] OR "adult" OR "adults"), limited to studies conducted in humans and published in English.

Inclusion criteria were as follows: the study reported on original research, the population consisted of at least 25 adults (ages 18 and older) treated for open-angle or angle-closure glaucoma, phacoemulsification was used for cataract extraction without adjunctive glaucoma surgery, IOP was reported before and after phacoemulsification, and the minimum follow-up was 6 months. The titles and abstracts were reviewed by the authors and 86 were selected for full-text review. Of these, 32 met the inclusion criteria. The methodologist (K.S.) assessed these 32 studies according to the strength of evidence. A level I rating was assigned to well-designed and well-conducted randomized clinical trials, a level II rating was assigned to well-designed case-control and cohort studies and lower-quality randomized studies, and a level III rating was assigned to case series, case reports, and lower-quality cohort and case-control studies. One, 15, and 16 studies were rated as providing level I, II, and III evidence, respectively.

Studies of patients with prior or concomitant incisional glaucoma surgery, including minimally invasive glaucoma procedures and goniosynechialysis by any method, were excluded from this review. Also excluded were studies of patients who had undergone large-incision extracapsular cataract extraction, who had untreated glaucoma, or who had untreated ocular hypertension, because the results of phacoemulsification for such patients are less pertinent to the clinician faced with a management decision for the patient with medically treated glaucoma. In addition, 9 studies were excluded because the data were not presented in a manner that allowed accurate determination of the outcome measures; the population studied was not clearly defined; the population was not predominantly medically treated POAG, PXG, or PACG; or a combination thereof. In articles where the population studied included multiple glaucoma diagnoses, the data on POAG, PXG, and PACG were considered separately to the extent possible. For articles in which results at multiple time points were presented, the longest follow-up time point with the population that fit the inclusion criteria was used. The minimum number of patients for inclusion was 25, although this was waived for prospective studies in some cases.

Published Results

For grouped data synthesizing the results from more than 1 study, the patient number used for analysis from each study was that with the longest follow-up time, and mean and standard deviation measurements were weighted for total number of patients in each respective study. All references to medications are to glaucoma medications. For individual studies, unless otherwise noted, controlled glaucoma refers to IOP control, a single baseline IOP measurement before surgery was used, phacoemulsification was performed with a clear corneal incision and foldable intraocular lens (IOL), and eyes with complications during surgery were included.

The mean ages of the patients in most of the 32 studies were similar; the overall mean age was 73.1±4.3 years (range, 55.0–81.6 years). The mean age of patients in studies of PACG was younger than in studies of POAG and PXG (mean, 69.9±3.8 years vs. 75.1±3.4 years, respectively; $P < 0.001$, independent samples 2-tailed t test).

Primary Open-Angle Glaucoma

Summary. Among the 9 studies[6–12] that included only POAG patients (2 with level II evidence and 7 with level III evidence; total, 461 patients), 2 studies[10,13] were prospective (n = 67) and 6 studies[7,8,10–12,14] (67%) also included patients with normal-tension glaucoma (NTG; Table 1). After mean follow-up of 16.7 months, the mean IOP before surgery of 17.7 mmHg using a mean of 1.7 medications decreased to 15.4 mmHg with 1.5 medications, a 13% decrease in IOP and a 12% reduction of medications. Among the 13 studies[3,6–17] that included mostly (>50%) POAG patients (including the 9 studies discussed above; 1 with level I evidence, 4 with level II evidence, and 8 with level III evidence; n = 741 patients), the mean follow-up was 19.2 months; 4 studies[3,10,13,15] were prospective (n = 249). Among the 4 studies that included patients with a glaucoma diagnosis other than POAG, in 3 studies,[3,15,16] the non-POAG patients comprised solely or mostly PXG patients. For the 13 studies, the mean IOP before surgery of 18.1 mmHg with 1.5 medications decreased to 15.8 mmHg with 1.2 medications, a 13% reduction of IOP and a 20% reduction of medications.

Studies Including Only Primary Open-Angle Glaucoma Patients. Among studies including only POAG patients,[6–14] Kim et al[6] (level III) retrospectively studied 31 American patients with controlled POAG who underwent uncomplicated phacoemulsification. All patients had an increased cup-to-disc (C/D) ratio, with or without stable early visual field (VF) changes. After mean follow-up of 16.4 months (range, 10–32 months), the mean IOP decreased from 18.1 to 15.2 mmHg (reduction of 2.9 mmHg [−16%]; $P < 0.001$). The number of medications used decreased from a mean of 1.7 to 0.7 (−59%). Most eyes (28/31 [90%]) had either a reduction of more than 3.0 mmHg with the same medications or the same IOP as before surgery (±3.0 mmHg) with fewer medications.

Leelachaikul and Euswas[8] (level III) retrospectively studied 58 Thai patients with controlled POAG, including an undefined number of NTG patients, who had undergone uncomplicated phacoemulsification. All patients had glaucomatous optic nerve changes with or without VF defects. After follow-up of 18 months, the mean IOP decreased from 16.8 to 15.2 mmHg (reduction of 1.6 mmHg [−10%]; $P = 0.070$). The number of medications used decreased from a mean of 1.4 to 1.0 (−29%), and 35% required no medications at 18 months.

Mathalone et al[7] (level III) retrospectively studied 58 Israeli patients with controlled POAG, including an undefined number of NTG patients, who had undergone uncomplicated phacoemulsification. The extent of glaucoma damage was not reported, but all had VF defects. After follow-up of 12 months (n = 34), the mean IOP decreased from 16.3 to 14.8 mmHg (reduction of 1.5 mmHg [−9%]; P value not significant). In a separate group with follow-up of 24 months (n = 24), the mean IOP decreased from 17.0 to 15.1 mmHg (reduction of 1.9 mmHg [−11%]; P value not significant). The number of medications used decreased from a mean of 1.1 to 0.65 (−41%) among the 1-year group and from a mean of 1.5 to 1.1

Table 1. Studies Examining the Effect of Phacoemulsification on Intraocular Pressure in Patients with Primary Open-Angle Glaucoma and without Prior Incisional Glaucoma Surgery

Author(s) and Year	Level of Evidence	No. of Patients	Primary Open-Angle Glaucoma (%)	Follow-up (mos)	Preoperative Intraocular Pressure (mmHg)	Postoperative Intraocular Pressure (mmHg)	Intraocular Pressure Change (mmHg/%)	Preoperative Medications	Postoperative Medications	Medication Change (%)	Notes
Kim et al[6] 1999	III	31	100	16.4	18.1	15.2	−2.9/−16	1.7	0.7	−59	
Leelachaikul and Euswas,[8] 2005	III	58	100	18.0	16.8	15.2	−1.6/−10	1.4	1.0	−29	Includes NTG
Mathalone et al,[7] 2005	III	24	100	24.0	17.0	15.1	−1.9/−11	1.5	1.1	−27	Includes NTG
Damji et al,[10] 2006*	III	29	100	24.0	18.5	17.0	−1.5/−8	NR	NR	0	Includes NTG
Shoji et al,[11] 2007	III	35	100	36.0	16.7	15.6	−1.1/−7	0.8	0.8	0	NTG only
Mierzejewski et al,[9] 2008	III	52	100	15.9	18.4	14.4	−4/−22	1.53	1.36	−11	
Slabaugh et al,[12] 2014	II	157	100	12.0	16.3	14.5	−1.8/−11	1.9	1.9	+4	Includes NTG
Iancu and Corbu,[13] 2014*	II	38	100	12.0	23.8	21.6	−2.2/−9	2.7	2.9	+7	Uncontrolled
Arthur et al,[14] 2014	III	37	100	12.0	16.2	13.7	−2.5/−15	1.4	1.4	0	Includes NTG
All 100% POAG		461	100	16.7 ± 6.8	17.7 ± 2.0	15.4 ± 2.0	−2.3/−13	1.7 ± 0.4	1.5 ± 0.6	−12	
Hayashi et al,[15] 2001*	II	68	71	24.1	20.7	15.2	−5.3/−26	1.4	0.8	−43	29% PXG; some NTG
Shingleton et al,[16] 2006	II	55	84	59.4	18.4	16.6	−1.8/−10	1.1	1.1	0	16% PXG
Samuelson et al,[3] 2011*	I	114	91	12.0	18.4	17.4	−1/−5	1.5	0.4	−73	6% PXG, 3% PDG
Zhang et al,[17] 2013	III	43	75	6.0	16.3	14.3	−2/−12	0.8	0.2	−71	25% PACG
All >50% POAG		741	93 ± 10	19.2 ± 13.1	18.1 ± 1.9	15.8 ± 1.8	−2.3/−13	1.5 ± 0.4	1.2 ± 0.7	−20	

NR = not reported; NTG = normal-tension glaucoma; PACG = primary angle-closure glaucoma; PDG = pigmentary glaucoma; POAG = primary open-angle glaucoma; PXG = pseudoexfoliation glaucoma.
*Prospective.

(−27%) among the 2-year group. At 1 and 2 years after surgery, 47% and 38% of patients were not using medications, respectively.

Damji et al[10] (level III) prospectively studied IOP control in 29 Greek, Canadian, and American patients with mild POAG (mean vertical C/D ratio, 0.48); some NTG patients were included because the definition of POAG did not require elevated IOP. The surgical technique was reported as being standard, but neither incision location nor IOL type was noted. Inclusion of eyes with complications during surgery was not reported. After 24 months of follow-up, the mean IOP decreased from 18.52 to 16.98 mmHg (reduction of 1.54 mmHg [−8%]; *P* value not reported). The number of medications before and after surgery was not reported, but patients continued the same medication regimen before and after phacoemulsification.

Mierzejewski et al[9] (level III) retrospectively studied 52 Polish patients with POAG. The extent of glaucoma damage was not reported, nor was IOP control before phacoemulsification. After mean follow-up of 15.9 months, the mean IOP decreased from 18.44 to 14.43 mmHg (reduction of 4.01 mmHg [−22%]; $P < 0.0001$); however, 10% had an increase in IOP at last follow-up. The number of medications used decreased from a mean of 1.53 to 1.36 (−11%); 4% required an increase in medication.

Shoji et al[11] (level III) retrospectively studied 35 Japanese patients with medically controlled POAG; all had NTG. This was 1 arm of a comparison of outcomes with phacoemulsification alone versus phacoemulsification with viscocanalostomy. The extent of VF loss was mild (mean Aulhorn stage, 1.7 on a 0−5 scale[18]). The mean of 3 measurements was used to determine the IOP before surgery. After follow-up of 36 months, the IOP decreased from 16.7 to 15.6 mmHg (reduction of 1.1 mmHg [−7%]; $P = 0.145$). Medication use was unchanged from the mean before surgery of 0.8. At 12 and 36 months, the likelihood of a 20% reduction in IOP was approximately 20% and 10%, respectively.

Slabaugh et al[12] (level II) retrospectively studied 157 American patients with medically controlled POAG, including NTG patients, who had uncomplicated phacoemulsification. The average VF mean deviation was −5.72 dB. The mean of 3 readings was used to determine the IOP before surgery. A scleral tunnel or clear corneal incision was used. After 12 months, the IOP decreased from 16.27 to 14.47 mmHg (reduction of 1.8 mmHg [−11%]; $P < 0.001$), but 6% had an increase in IOP of at least 3 mmHg. Medication use was increased from a mean of 1.85 to 1.92 (+4%); 38% required an increase in medications or had a higher IOP on the same medications.

Iancu and Corbu[13] (level II) prospectively studied 38 Romanian patients with uncontrolled POAG (IOP >21 mmHg but <28 mmHg with maximum medical therapy) before uncomplicated phacoemulsification. The severity of glaucoma was not reported, but all had optic nerve damage and VF defects. At least 2 IOP readings were obtained before surgery. After 12 months, the IOP decreased from 23.8 to 21.6 mmHg (reduction of 2.2 mmHg [−9%]; $P < 0.0001$). Medication use increased from 2.7 to 2.9 (+7%), and in addition, 32 (84%) of 38 patients were still considered to have uncontrolled glaucoma and required glaucoma surgery (mean time to surgery, 11.6 months).

Arthur et al[14] (level III) retrospectively studied 37 eyes of 37 American patients with medically controlled POAG, including 3 NTG patients. This group was compared with a second group who underwent phacoemulsification combined with canaloplasty. The average VF mean deviation was −7.4 dB. After 12 months (n = 34), the IOP decreased from 16.2 to 13.7 mmHg (reduction of 2.5 mmHg [−15%]; $P < 0.001$). Medication use was unchanged from the mean before surgery of 1.4 medications.

Studies Including Primary Open-Angle Glaucoma and Non-Primary Open-Angle Glaucoma Patients. Among studies including POAG and non-POAG patients,[3,15–17] Hayashi et al[15] (level II) prospectively studied 68 Japanese patients with open-angle glaucoma, including 48 with POAG and 20 with PXG, although results were not reported separately for POAG and PXG. An undefined number of NTG patients were included. The severity of glaucoma was not reported, but all patients had optic nerve damage and an abnormal VF before surgery. The level of IOP control before phacoemulsification was not reported, nor was inclusion of eyes with complications during surgery. After mean follow-up of 24.1±9.8 months, the IOP decreased from 20.7 to 15.2 mmHg, although the mean reduction in IOP was reported to be 5.3 mmHg (−26%; $P < 0.0001$). The number of medications used decreased from a mean of approximately 1.4 to 0.8 (−43%).

Shingleton et al[16] (level II) retrospectively studied 55 eyes of 48 American patients with medically controlled glaucoma, including 84% POAG and 16% PXG patients who underwent uncomplicated phacoemulsification. Patients had optic nerve damage and VF defects. At follow-up of 36 months, the IOP decreased from 18.4 to 17.0 mmHg (reduction of 1.4 mmHg [−8%]; $P = 0.0025$); at the last follow-up of 59 months, the IOP decreased to 16.6 mmHg (reduction of 1.8 mmHg [−10%]; $P = 0.005$). Medication use did not change significantly, with a mean of 1.1 medications used before surgery and a mean of 1.0 and 1.1 at 36 and 59 months, respectively, used after surgery. At 1, 3, and 5 years, the proportion of eyes with IOP less than or equal to the IOP before surgery using the same number of glaucoma medications or fewer was 91%, 85%, and 76%, respectively.

Samuelson et al[3] (level I) prospectively studied 114 American patients with mild open-angle glaucoma (average VF mean deviation, −3.7 dB) who had uncomplicated phacoemulsification, including 91% POAG, 6% PXG, and 3% pigmentary glaucoma patients. This was 1 arm of a randomized trial comparing outcomes with phacoemulsification alone, versus phacoemulsification with a trabecular microbypass stent (iStent; Glaukos Corporation, Laguna Hills, CA) placement. Glaucoma medications were discontinued, the IOP was rechecked after a medication washout period, and the patients were then followed up after phacoemulsification, with medications restarted as required to keep the IOP at 21 mmHg or less. At 12 months, IOP decreased from 18.4 mmHg before medication washout to 17.4 mmHg (reduction of 1.0 mmHg [−5%]; *P* value not

reported), and the number of medications used decreased from 1.5 to 0.4 (−73%). An IOP reduction of 20% or more without use of medications was seen in 48% of patients, and only 35% of patients were using medications.

Zhang et al[17] (level III) retrospectively studied 43 eyes of 36 American patients with POAG (75%) and PACG (16%) who underwent uncomplicated phacoemulsification. The extent of glaucoma damage was not reported, nor was the level of IOP control before phacoemulsification. Results for different glaucoma types were not recorded separately. After follow-up of at least 6 months, the IOP decreased from 16.3 to 14.3 mmHg (reduction of 2.0 mmHg [−12%]; $P = 0.003$). The number of medications used decreased from a mean of 0.8 to 0.23 (−71%).

Pseudoexfoliation Glaucoma

Summary. Among 5 studies[9,10,19–21] that included only PXG patients (3 with level II evidence and 2 with level III evidence; total, 132 patients), 3 studies[10,19,20] were prospective (total, 58 patients). See Table 2 for additional information. After mean follow-up of 34.2 months, the mean IOP before surgery of 20.7 mmHg with a mean of 1.7 medications decreased to 16.6 mmHg with 1.0 medication, a 20% decrease in IOP, and a 35% reduction in number of medications used. Seven studies[9,10,19–23] (including the 5 listed above; 3 with level II evidence and 4 with level III evidence; total, 294 patients; 3 prospective studies; total, 58 patients) included mostly (>50%) PXG patients, including 2 studies[22,23] with 45% and 36% POAG patients (total, 162 patients). After mean follow-up of 21.3 months, the mean IOP before surgery of 19.0 mmHg with 1.4 medications decreased to 16.0 mmHg with 0.9 medications, a 16% decrease in IOP and a 38% reduction in number of medications used. An IOP spike after surgery, which is a particular concern in PXG patients, is considered in the section on Glaucoma-Related Complications after Phacoemulsification below.

Studies Including Only Pseudoexfoliation Glaucoma Patients. Among studies including only PXG patients,[9,10,19–21] Jacobi et al[19] (level II) prospectively studied 22 German patients with mixed-severity, uncontrolled PXG (C/D ratio, ≥0.9 in 36%). This was 1 arm of a randomized trial comparing outcomes with phacoemulsification alone versus phacoemulsification with trabecular aspiration; the study also included a case-control arm of phacoemulsification with trabeculectomy. Up to 5 measurements (minimum 3) were used to determine IOP at each visit. At 12 months, 16 patients (72%) were still being followed up, and the IOP decreased from 32.0 to 18.4 mmHg, a reduction of 13.6 mmHg (−43%; $P < 0.001$). The number of medications used decreased from a mean of 2.1 to 0.8 (−62%).

Georgopoulos et al[20] (level II) prospectively studied 12 Greek patients with PXG controlled with up to 2 medications and without prior surgery or laser trabeculoplasty. This was 1 arm of a randomized trial comparing outcomes with uncomplicated phacoemulsification alone versus phacoemulsification with trabecular aspiration. At least 3 measurements were used to determine IOP at each visit. After follow-up of 15.7 months, the IOP decreased from 18.7 to 16.7 mmHg, a reduction of 2.0 mmHg (−11%; $P = 0.06$). The number of medications used decreased from a mean of 1.5 to 1.0 (−26%).

Damji et al[10] (level III) prospectively studied IOP control in 29 Greek, Canadian, and American patients with mild PXG (mean vertical C/D ratio, 0.6). The incision location and IOL type were not specified, nor was inclusion of eyes with complications during surgery. After 24 months of follow-up, the IOP decreased from 19.8 to 16.7 mmHg, a reduction of 3.2 mmHg (−16%; P value not reported). The number of glaucoma medications before and after surgery was not reported, but patients continued the same glaucoma medication regimen before and after phacoemulsification.

Mierzejewski et al[9] (level III) retrospectively reported on 19 Polish patients with PXG as part of a larger group of open-angle glaucoma patients being studied. The severity of glaucoma damage was not reported, nor was IOP control before phacoemulsification. After a mean follow-up of 15.9 months, the IOP decreased from 20.6 to 15.1 mmHg (reduction of 5.6 mmHg [−27%]; $P < 0.00001$); 5% had an increase in IOP. The number of medications used decreased from a mean of 1.7 to 1.2 (−33%); 5% required an increase in medication. Results also were given for an additional 4 patients with angle-closure glaucoma associated with PXG. In these 4 patients, after a mean follow-up of 15.9 months, the IOP decreased from 22.9 to 11.3 mmHg (reduction of 11.7 mmHg [−51%]; P value not significant); none had an increase in IOP. The number of medications used decreased from a mean of 1.5 to 1.0 (−33%).

Shingleton et al[21] (level II) retrospectively studied 240 eyes of Americans (patient number not reported) with medically controlled PXG who underwent uncomplicated scleral tunnel or clear corneal incision phacoemulsification. The extent of glaucoma damage was not reported. Among 51 eyes without prior laser trabeculoplasty or trabeculectomy, at a follow-up of 60 months, the IOP decreased from 18.0 to 16.9 mmHg (reduction of 1.1 mmHg [−6%]; $P < 0.03$), and the number of medications used decreased from a mean of 1.6 to 1.0 (−38%).

Studies Including Pseudoexfoliation Glaucoma and Non-Pseudoexfoliation Glaucoma Patients. Among studies including PXG and non-PXG patients,[22,23] Perasalo[22] (level III) retrospectively studied 182 Finnish patients (226 eyes) with medically controlled PXG (124 eyes [55%]) and POAG (102 eyes [45%]) who underwent scleral tunnel incision phacoemulsification with polymethyl methacrylate IOL placement. Among eyes with complications (6%), 75% of complications were in PXG eyes. The results for POAG and PXG were not reported separately. The extent of glaucoma damage was not reported, but the VF was stable before phacoemulsification. Results for 126 eyes (56%) at 12 months of follow-up were reported; the IOP decreased from 17.1 to 15.3 mmHg (reduction of 1.8 mmHg [−11%]; $P < 0.001$); no difference was found between PXG and POAG groups. The number of medications used decreased from a mean of 1.5 to 0.9 (−40%); however, 37% required an increase in medication.

Yalvac et al[23] (level III) retrospectively studied 35 Finnish patients with PXG (54%), POAG (36%), and PACG (12%). This was 1 arm of a trial comparing

Table 2. Studies Examining the Effect of Phacoemulsification on Intraocular Pressure in Patients with Pseudoexfoliation Glaucoma and without Prior Incisional Glaucoma Surgery

Author(s) and Year	Level of Evidence	No. of Patients	Pseudoexfoliation Glaucoma (%)	Follow-up (mos)	Preoperative Intraocular Pressure (mmHg)	Postoperative Intraocular Pressure (mmHg)	Intraocular Pressure Change (mmHg/%)	Preoperative Medications	Postoperative Medications	Medication Change (%)	Notes
Jacobi et al,[19] 1999*	II	16	100	12.0	32.0	18.4	−13.6/−43	2.1	0.8	−62	Uncontrolled
Georgopoulos et al,[20] 2000*	II	13	100	15.7	18.7	16.7	−2/−11	1.5	1.1	−26	
Damji et al,[10] 2006*	III	29	100	24.0	19.8	16.7	−3.1/−16	NR	NR	0	
Mierzejewski et al,[9] 2008	III	19	100	15.9	20.6	15.0	−5.6/−27	1.7	1.2	−33	
Mierzejewski et al,[9] 2008	III	4	100	15.9	22.9	11.3	−11.6/−51	1.5	1.0	−33	PACG resulting from PXG
Shingleton et al,[21] 2008	II	51	100	60.0	18.0	16.9	−1.1/−6	1.6	1.0	−38	Initial n = 169
All 100% PXG		132	100	34.2 ± 20.8	20.7 ± 4.4	16.6 ± 1.3	−4.1/−20	1.7 ± 0.2	1.0 ± 0.1	−35	
Perasalo,[22] 1997	III	127	55	12.0	17.1	15.3	−1.8/−11	1.5	0.9	−40	45% POAG
Yalvac et al,[23] 1997	III	35	54	6.0	19.7	16.3	−3.4/−17	1.7	1.0	−35	36% POAG, 12% PACG
All >50% PXG		294	75 ± 23	21.3 ± 18.3	19.0 ± 3.4	16.0 ± 1.0	−3/−16	1.6 ± 0.2	1.0 ± 0.1	−38	

NR = not reported; PACG = primary angle-closure glaucoma; POAG = primary open-angle glaucoma; PXG = pseudoexfoliation glaucoma.
*Prospective.

Table 3. Studies Examining the Effect of Phacoemulsification on Intraocular Pressure in Patients with Chronic Primary Angle-Closure Glaucoma

Author(s) and Year	Level of Evidence	No. of Patients	Follow-up (mos)	Preoperative Intraocular Pressure (mmHg)	Postoperative Intraocular Pressure (mmHg)	Intraocular Pressure Change (mmHg/%)	Preoperative Medications	Postoperative Medications	Medication Change (%)	Notes
Hayashi et al,[15] 2001*	II	74	25.7	21.4	14.5	−7.2/−34	1.3	0.6	−54	8% PXG
Lai et al,[24] 2006*	II	21	20.7	19.7	15.5	−4.2/−21	1.9	0.5	−73	Some uncontrolled
Tham et al,[25] 2008*	II	35	24.0	16.3	14.5	−2.1/−13	2.2	1.1	−50	
Pachimkul and Intajak,[26] 2008*	III	58	17.2	23.3	14.8	−8.5/−36	2.1	NR	NA	Some uncontrolled
Tham et al,[27] 2009*	II	27	24.0	24.4	16.1	−8.3/−34	3.3	1.7	−48	Uncontrolled
Tham et al,[28] 2013*	II	26	24.0	24.1	15.9	−8.4/−34	3.7	1.5	−43	Uncontrolled
Moghimi et al,[33] 2014*	II	46	12.0	22.3	14.0	−8.3/−37	1.2	0.1	−92	Some uncontrolled
All prospective		287	20.5±4.6	21.7±2.4	14.7±0.6	−7.0/−32	2.0 ± 0.8	0.8 ± 0.5	−60	
Euswas and Warrasak,[29] 2005	III	14	6.0	22.0	17.1	−4.9/−22	1.8	1.4	−22	See text
Mierzejewski et al,[9] 2008	III	29	15.9	20.0	14.0	−6.0/−30	1.5	1.2	−18	14% PXG
Liu et al,[30] 2011	III	50	12.0	16.4	13.5	−2.9/−18	1.8	1.0	−44	IOP <30.0 mmHg before surgery
Yudhasompop and Wangsupadilok,[31] 2012	III	60	6.0	17.4	12.9	−4.5/−26	1.9	0.4	−77	
Shams and Foster,[32] 2012	III	55	7.2	18.7	14.1	−4.6/−25	1.4	1.0	−29	35% PAC, no medications
All retrospective		208	9.1±3.6	18.2±1.6	13.6±1.3	−4.2/−25	1.7±0.2	0.9±0.3	−47	
All chronic PACG		495	15.7±7.0	20.2±2.7	14.2±1.1	−6.0/−30	1.9±0.7	0.8±0.4	−58	

IOP = intraocular pressure; NA = not applicable; NR = not reported; PAC = primary angle closure; PACG = primary angle-closure glaucoma; PXG = pseudoexfoliation glaucoma.
*Prospective.

outcomes with phacoemulsification alone versus phacoemulsification with trabeculectomy. Results for different glaucoma types were not recorded separately. The extent of glaucoma damage was not reported, but all patients had VF defects. The level of IOP control before phacoemulsification was not reported. A scleral tunnel incision and a polymethyl methacrylate IOL were used. After follow-up of 6 months, IOP decreased from 19.7 to 16.3 mmHg (reduction of 3.4 mmHg [−17%]; $P < 0.001$). The number of medications used decreased from a mean of 1.7 to 1.0 (−35%); 9% required an increase in medication.

Chronic Primary Angle-Closure Glaucoma

Summary. Twelve studies[9,15,24–33] (6 with level II evidence and 6 with level III evidence; total, 495 patients; Table 3) included chronic PACG patients, of which 2 studies[9,15] included patients (8%–14%) with an underlying diagnosis of pseudoexfoliation syndrome, which is known to be associated with angle-closure glaucoma. All studies used a definition of PACG that included an occludable angle with appositional closure, along with some combination of presence of peripheral anterior synechiae (PAS), IOP of more than 21 mmHg, and glaucomatous optic nerve changes. After mean follow-up of 15.7 months, the mean IOP before surgery of 20.2 mmHg with 1.9 medications decreased to 14.2 mmHg with 0.8 medications, a 30% reduction of IOP and a 58% reduction in the number of medications used. Among 7 prospective studies[15,24–28,33] (6 with level II evidence and 1 with level III evidence; total, 287 patients), after mean follow-up of 20.5 months, the mean IOP before surgery of 21.7 mmHg with 2.0 medications decreased to 14.7 mmHg with 0.8 medications, a 32% reduction in IOP and a 60% reduction in the number of medications used. Among 5 retrospective studies[9,29–32] (5 with level III evidence; total, 208 patients), after mean follow-up of 9.1 months, the mean IOP before surgery of 18.2 mmHg with a mean of 1.7 medications decreased to 13.6 mmHg with 0.9 medications, a 25% reduction in IOP and a 47% reduction in the number of medications used. Unless otherwise noted, all patients underwent peripheral iridotomy before phacoemulsification.

Prospective Studies. Among prospective studies,[15,24–28] Hayashi et al[15] (level II) studied 74 Japanese patients with chronic angle-closure glaucoma, including 68 with PACG and 6 with PXG, although results were not reported separately for PACG and PXG. All patients had optic disc excavation or retinal nerve fiber layer findings compatible with VF defects, and all VF tests had abnormal glaucoma hemifield test results before surgery. An iridotomy was present before surgery in 33 (45%) of 74 patients. The level of IOP control before phacoemulsification was not reported, nor was inclusion of eyes with complications during surgery. After mean follow-up of 25.7±8.5 months, the IOP decreased from 21.4 to 14.5 mmHg, but the mean reduction in IOP was listed as 7.2 mmHg (−34%; $P < 0.0001$). The number of medications used decreased from a mean of approximately 1.3 to 0.6 (−54%). No difference was seen in outcomes between patients with and without an iridotomy.

Lai et al[24] (level II) studied 21 Chinese patients with PACG (mean vertical C/D ratio, 0.6). The mean of 2 IOP readings obtained on 2 separate days was used for each study visit. Some patients had poorly controlled IOP (as high as 40.0 mmHg). After mean follow-up of 20.7 months, the IOP decreased from 19.7 to 15.5 mmHg (−4.2 mmHg [−21%]; $P < 0.001$). The number of medications used decreased from a mean of 1.9 to 0.5 (−73%). Most patients had lower IOP (71%), and all were using the same number of (19%) or fewer (81%) medications.

Tham et al[25] (level II) studied 35 Chinese patients with medically controlled PACG of mixed severity, including some with severe glaucoma (average VF mean deviation, −17.4 dB). This was 1 arm of a randomized trial comparing outcomes with phacoemulsification alone versus phacoemulsification with trabeculectomy. The mean of 3 readings was used to determine the IOP before surgery. After 24 months of follow-up, the mean IOP decreased from 16.3 to 14.5 mmHg (2.1 mmHg reduction [−13%]; $P < 0.05$). The number of medications used decreased from a mean of 2.2 to 1.1 (50%). The IOP was less than 21.0 mmHg in 93% of patients at 24 months. These effects were not statistically significant, although the study may have lacked adequate power.

Pachimkul and Intajak[26] (level III) studied 58 eyes of 46 Thai patients with PACG of mixed severity but without advanced damage, including some with poor IOP control (not defined). Inclusion of eyes with complications during surgery was not reported. After 17.2 months of follow-up, the mean IOP decreased from 23.3 to 14.8 mmHg (8.5-mmHg reduction [−36%]; $P = 0.003$). Before surgery, a mean of 2.1 medications was used, but medication use after surgery was not reported.

Tham et al[27] (level II) studied 27 Chinese patients with medically uncontrolled (IOP >21 mmHg or >3 medications) PACG of mixed severity, including some with severe glaucoma (average VF mean deviation, −17.5 dB). This was 1 arm of a randomized trial comparing outcomes with phacoemulsification alone versus phacoemulsification with trabeculectomy. The mean of 3 readings was used to determine the IOP before surgery. After 24 months of follow-up, the mean IOP decreased from 24.4 to 16.1 mmHg (8.3-mmHg reduction [−34%]; $P < 0.0001$). The number of medications used decreased from a mean of 3.3 to 1.7 (48%). The IOP was less than 21.0 mmHg in 93% of patients at 24 months.

Tham et al[28] (level II) studied lens extraction without visually significant cataract in 26 Chinese patients for treatment of medically uncontrolled (IOP >21 mmHg or >3 medications) PACG. This was 1 arm of a randomized trial comparing outcomes with phacoemulsification versus trabeculectomy. The mean age of the included patients (66.4 years; range, 47.0–74.0 years) and the inclusion criteria of visual acuity of 20/40 or better, without cataract that affected activities of daily living, implied the presence of nonvisually significant cataract in most patients. Some patients had severe glaucoma (average VF mean deviation, −19.4 dB). The mean of 3 readings was used to determine the IOP before surgery. After 24 months of follow-up, the mean IOP decreased from 24.4 to

16.1 mmHg (8.3-mmHg reduction [−34%]; $P < 0.0001$). The number of medications used decreased from a mean of 3.3 to 1.7 (−48%). No medications were required in 26% of patients at 24 months.

Moghimi et al[33] (level II) reported on 46 eyes of 46 Iranian patients with PACG who had uncomplicated phacoemulsification. Although the severity of disease was not recorded, all had optic nerve and VF damage. Some had poor IOP control (but <35 mmHg). Eyes that had a history of acute PACG were excluded. At a follow-up of 12 months, the mean IOP decreased from 22.3 to 14.0 mmHg (8.3-mmHg reduction [−37%]; $P < 0.001$). The number of medications used decreased from a mean of 1.2 to 0.1 (−92%).

Retrospective Studies. Among retrospective studies,[9,29–32] Euswas and Warrasak[29] (level III) reported on 48 eyes of 28 Thai patients with PACG; however, 34 eyes with PAS of 180° or less were using essentially no medications (mean, 0.03) and were not included in this review. The extent of glaucoma damage was not reported, nor was inclusion of eyes with complications during surgery. At follow-up of 6 months, the mean IOP decreased from 22.0 to 17.1 mmHg (reduction of 4.9 mmHg [−22%]; *P* value not reported). The number of medications used decreased from a mean of 1.8 to 1.4 (−22%).

Mierzejewski et al[9] (level III) reported on 29 Polish patients with chronic angle-closure glaucoma, including 25 patients with PACG and 4 with angle closure associated with PXG (the latter 4 patients also were included in the PXG section of this assessment). The extent of glaucoma damage was not reported, nor was the level of IOP control before phacoemulsification. After mean follow-up of 15.9 months, the mean IOP decreased from 20.0 to 14.0 mmHg (reduction of 6.0 mmHg [−30%]; $P < 0.001$); no patient had an increase in IOP. The number of medications used decreased from a mean of 1.5 to 1.2 (−18%); 4% required an increase in medication.

Liu et al[30] (level III) studied 56 Taiwanese patients with controlled PACG who underwent uncomplicated phacoemulsification. The average VF mean deviation was −14.7 dB, but patients with severe glaucoma were excluded. At 12 months of follow-up (n = 50), the mean IOP decreased from 16.4 to 13.5 mmHg (2.9-mmHg reduction [−18%]; $P < 0.05$). The number of medications used decreased from 1.8 to approximately 1.0 (−44%).

Yudhasompop and Wangsupadilok[31] (level III) reported on 60 Thai patients with PACG who underwent uncomplicated phacoemulsification. The extent of glaucoma damage and level of IOP control were not reported, nor was presence of an iridotomy before phacoemulsification. After a minimum follow-up of 6 months, the mean IOP decreased from 17.4 to 12.9 mmHg (reduction of 4.5 mmHg [−26%]; $P < 0.001$); none had an increase in IOP. The number of medications used decreased from a mean of 1.9 to 0.4 (−77%).

Shams and Foster[32] (level III) studied 55 patients with angle closure, including 36 (65%) with medically controlled PACG and 35% with primary angle closure without medications required for IOP control. The VF mean deviation among those with PACG was −9.0 dB. A mean of 2 measurements was used to determine the IOP before surgery. An iridotomy was present in 62% of patients. After follow-up of 7 months, the mean IOP decreased from 18.7 to 14.1 mmHg (reduction of 4.6 mmHg [−25%]; $P < 0.0001$); 87% had reduction of IOP and 9% had elevation of IOP. The number of medications used before surgery decreased from a mean of 1.4 to 1.0 (−29%), but among those requiring medications before phacoemulsification, the number of medications used decreased from a mean before surgery of 2.2 to 1.5 (−32%), and no eyes required more medications.

Acute Primary Angle-Closure Glaucoma

Summary. Four studies[34–37] (3 with level II evidence and 1 with level III evidence) included 119 patients with acute PACG, of which 3[34,35,37] were prospective (n = 93; Table 4). After mean follow-up of 24.2 months, the mean presenting IOP of 50.1 mmHg decreased to 14.7 mmHg with 0.1 medication.

Studies Included. Jacobi et al[34] (level II) prospectively studied 43 German patients with acute PACG. This was 1 arm of a nonrandomized trial comparing outcomes with phacoemulsification versus surgical iridectomy. The mean presenting IOP was 40.5 mmHg, which was decreased using topical and systemic ocular hypotensive medications before phacoemulsification. The mean time between acute PACG and phacoemulsification was 2.1 days. After mean follow-up of 10.2 months after phacoemulsification, the mean IOP decreased to 17.8 mmHg (a reduction of 22.7 mmHg [−56%]). Most patients (72%) had an IOP of less than 21.0 mmHg without medications or further surgery, but 16% required medications for IOP control.

Lam et al[35] (level II) prospectively studied 31 Chinese patients with acute PACG (mean vertical C/D ratio, 0.4). This was 1 arm of a randomized trial comparing outcomes with phacoemulsification versus laser peripheral iridotomy. The median of 3 IOP readings was used for each study visit. The mean presenting IOP was 59.7 mmHg, which decreased to 15.8 mmHg using topical and systemic ocular hypotensive medications before phacoemulsification. The mean time between acute PACG and phacoemulsification was 5.7 days. After 18 months of follow-up after phacoemulsification, the mean IOP decreased to 12.6 mmHg, a reduction of 47.1 mmHg from the IOP at presentation (−79%). One patient (3%) had an IOP of more than 21.0 mmHg and required medications.

Lee et al[36] (level III) retrospectively studied 26 Korean patients with acute phacomorphic PACG. Patients received intravenous mannitol, oral acetazolamide, and topical glaucoma medications before undergoing scleral tunnel phacoemulsification. The time between acute PACG and phacoemulsification was not reported, nor was presence of an iridotomy before phacoemulsification. After mean follow-up of 54.8 months (minimum, 48 months) after phacoemulsification, the mean IOP decreased from 49.0 to 13.2 mmHg (35.8 mmHg reduction [−73%]). All patients had reduced IOP after phacoemulsification, although 1 patient (4%) required 2 medications.

Table 4. Studies Examining the Effect of Phacoemulsification on Intraocular Pressure in Patients with Acute Primary Angle-Closure Glaucoma

Author(s) and Year	Level of Evidence	No. of Patients	Follow-up (mos)	Preoperative Intraocular Pressure (mmHg)*	Postoperative Intraocular Pressure (mmHg)	Intraocular Pressure Change (mmHg/%)	Postoperative Medications	% Using Medications	Notes
Jacobi et al,[34] 2002†	II	43	10.2	40.5	17.8	−23/−56	0.2	16	
Lam et al,[35] 2008†	II	31	18.0	59.7	12.6	−47/−79	0.0	3	
Lee et al,[36] 2010	III	26	54.8	49.0	13.2	−36/−73	0.1	4	Phacomorphic
Husain et al,[37] 2012†	II	19	24.0	57.4	12.9	−45/−78	NR	32	
All acute PACG		119	24.2 ± 16.9	50.1 ± 8.1	14.7 ± 2.4	−35.4/−71	0.1 ± 0.1	13 ± 10	

IOP = intraocular pressure; NR = not reported; PACG = primary angle-closure glaucoma.
*Presenting IOP (acute PACG).
†Prospective.

Husain et al[37] (level II) prospectively studied 19 Singaporean patients with acute PACG. This was 1 arm of a randomized trial comparing outcomes with phacoemulsification versus laser peripheral iridotomy. The mean presenting IOP was 57.4 mmHg, which decreased to 14.5 mmHg using topical and systemic ocular hypotensive medications before phacoemulsification. The time between acute PACG and phacoemulsification was 5 to 7 days. At 24 months after phacoemulsification, the mean IOP was 12.9 mmHg (reduction of 44.5 mmHg from presentation [−78%]; $P < 0.001$). With failure defined as either IOP between 22.0 and 24.0 mmHg on 2 occasions or IOP of 25.0 mmHg or more once during follow-up, the Kaplan-Meier survival estimate for success was 90% at 2 years. Six patients (32%) required medications for IOP control, of which 2 (11%) were considered failures because of high IOP.

Factors Associated with Lower Intraocular Pressure after Phacoemulsification

Among the studies included for this assessment, higher IOP before phacoemulsification is the single most-common significant factor associated with a greater drop in IOP after phacoemulsification. This includes patients with POAG,[3,8,12] PXG,[21] and PACG.[13,30–34] However, in 2 prospective studies, a higher IOP before surgery was associated with a higher likelihood of IOP failure after phacoemulsification by Kaplan-Meier analysis among POAG, PXG, and PACG patients[15] and with a need for trabeculectomy after phacoemulsification in patients with uncontrolled POAG.[13]

Few other factors have been identified consistently with IOP changes after phacoemulsification in these patients. In POAG patients, Slabaugh et al[12] found older age (perhaps indicative of a denser cataract that required greater ultrasound energy to emulsify) and a deeper anterior chamber depth before surgery (as measured by biometry before surgery) to be associated with greater IOP reduction after phacoemulsification, although IOP before surgery was the most important factor. In PXG, Damji et al[10] reported that a greater volume of irrigation during phacoemulsification was associated significantly with a greater decrease in IOP. For PACG, several studies have shown that IOP reduction is associated with various measures related to anterior chamber depth, and a narrower anterior chamber and a greater change in anterior chamber depth are associated with more IOP reduction after phacoemulsification.[30,32,34] Jacobi et al[34] found that the change in anterior chamber depth and the lens thickness-to-axial length ratio was associated with IOP reduction after phacoemulsification. Liu et al[30] noted that shallower anterior chamber depth before surgery was associated with more IOP reduction after phacoemulsification; the product of IOP before surgery multiplied by anterior chamber depth accounted for 49% of IOP change at 1 year, with a smaller product predicting a larger IOP change; patients with a product of 35 or less had a greater chance of having an IOP of 12 mmHg or less after surgery. Shams and Foster[32] noted that IOP reduction was associated with more than 180° of PAS and a narrower angle width before surgery by gonioscopy, yet eyes with an axial length of more than 22.0 mm had greater reduction of IOP compared with shorter eyes. Moghimi et al[33] noted that female gender was associated with IOP reduction after phacoemulsification.

However, some studies have not found associations between some of these risk factors and IOP reduction after phacoemulsification. In POAG, Slabaugh et al[12] did not find gonioscopy grade, axial length, or prior laser trabeculoplasty to be associated with IOP change after phacoemulsification. Similarly, for PXG, Shingleton et al[21] did not find axial length or age to be associated with IOP change. For PACG, factors found to be unrelated in some studies included anterior chamber depth or lens thickness,[31] the extent of PAS after surgery,[26] the presence of laser peripheral iridotomy before surgery,[15,32] and gonioscopy findings before surgery.[33,30]

Glaucoma-Related Complications after Phacoemulsification

Intraocular Pressure Spike after Surgery. An early IOP spike after surgery has traditionally been considered undesirable in glaucoma patients, given the possibility of further glaucoma damage that may occur. Among the 6 studies that included mostly POAG patients and that reported on IOP spikes,[3,6,9–11] the percentage of spikes ranged from 3% to 27% (median, 17.5%), using various definitions and with no prophylactic treatment in 4 of 6 studies (Table 5). The

Table 5. Definitions and Prevalence of Intraocular Pressure Spike after Phacoemulsification Reported in the Included Studies

Author(s) and Year	No. of Patients	Diagnosis	Intraocular Pressure Spike Definition (mmHg)	Intraocular Pressure Spike (%)	Intraocular Pressure Spike Prophylaxis
Arthur et al,[14] 2014	37	POAG	≥ 30	22	None
Kim et al,[6] 1999	31	POAG	>28.0	13	Carbachol
Shoji et al,[11] 2007	35	POAG (NTG)	>25.0	3	None
Mierzejewski et al,[9] 2008	71	POAG/PXG	≥25.0	10	None
Samuelson et al,[3] 2011	114	POAG/PXG	≥10.0 higher	27	Apraclonidine
Damji et al,[10] 2006	29	POAG, normals	≥6.0 higher	25	None
Yalvac et al,[23] 1997	35	PXG/POAG/PACG	>30.0	11	None
Shingleton et al,[21] 2008	240	PXG	>30.0	17	Timolol/pilocarpine/brimonidine/ acetazolamide 1 g
Perasalo,[22] 1997	127	PXG/POAG	>25.0	24	Acetazolamide 1 g
Damji et al,[10] 2006	29	PXG, PXF	≥6.0 higher	35	None
Jacobi et al,[19] 1999	16	PXG uncontrolled	>5.0 higher	0	Acetylcholine
Lai et al,[24] 2006	21	PACG uncontrolled	>30.0	12	None
Husain et al,[37] 2012	19	Acute PACG	>30.0	5	Acetazolamide 250 mg
Mierzejewski et al,[9] 2008	29	PACG including PXG	≥28.0	21	None
Jacobi et al,[34] 2002	43	Acute PACG	>25.0	9	None
Shams and Foster,[32] 2012	55	PACG	>22.0	6	None
Pachimkul and Intajak,[26] 2008	58	PACG uncontrolled	Undefined	7	None

NTG = normal tension glaucoma; PACG = primary angle-closure glaucoma; POAG = primary open-angle glaucoma; PXF = pseudoexfoliation without glaucoma; PXG = pseudoexfoliation glaucoma.

occurrence of IOP spikes is likely higher among PXG patients, with a frequency of 11% to 35% (median, 21%) if the 4 studies with mostly controlled PXG patients are included.[10,21–23] Notably, Perasalo[22] reported 24% of patients had IOP of more than 25.0 mmHg despite 1 g acetazolamide administered after surgery, and Shingleton et al[21] reported that 17% of 240 PXG patients demonstrated an IOP of more than 30.0 mmHg despite receiving timolol, pilocarpine, brimonidine, and 1 g acetazolamide after phacoemulsification. In PACG, including phacoemulsification after acute PACG, among the 6 studies[9,24,26,32,34,37] reporting on IOP spike, the percentage ranged from 6% to 21% (median, 8%), but no IOP prophylaxis was given in 5 of 6 studies. Husain et al[37] administered 250 mg acetazolamide following phacoemulsification after acute PACG and found that 5% had an IOP of more than 30.0 mmHg.

Long-Term Intraocular Pressure Increase. Long-term IOP increase has been reported in up to 14% to 26% of POAG patient populations at 1 to 5 years after phacoemulsification,[12,15,16] and an increase in medication was required in up to 4% to 26%,[9,12] although many studies do not report on these measures. Slabaugh et al[12] reported 6% of patients with an IOP increase of 3.0 mmHg or more on the same glaucoma medication regimen at 1 year after phacoemulsification. Although no study on PXG reported a long-term IOP increase, several[19,22,23] found a need for additional medication ranging from 9% to 64% at 6 to 12 months after phacoemulsification. In contrast, few studies with PACG patients have found worse IOP control after phacoemulsification, with some exceptions. Hayashi et al[15] found poor IOP control among 3% of angle-closure glaucoma patients (including PACG and PXG) prospectively followed up for 2 years, Shams and Foster[32] noted worse IOP in 9% at 14 months, and Tham et al[28] reported worse IOP in 19% among patients with poor IOP control before phacoemulsification and followed up prospectively for 2 years. Lai et al[24] reported that more medications were necessary in up to 24% of 21 patients after 18 months, although some patients had poor IOP control before phacoemulsification. Pachimkul and Intajak[26] and Mierzejewski et al[9] also reported that 3% to 7% of PACG patients required more medications.

Glaucoma Progression. Glaucoma progression after phacoemulsification has been reported in some of the included studies, more commonly among studies in which enrolled patients had poorly controlled IOP or had NTG. Shoji et al[11] found 17% of NTG patients had VF progression at 36 months after phacoemulsification using Aulhorn staging criteria.[18] Tham et al[25,27] noted confirmed VF progression using event-based criteria in 14% of controlled PACG[25] and 41% of uncontrolled PACG patients at 24 months,[27] and they also reported optic disc progression in 11% of controlled PACG patients.[25] Tham et al[28] also found confirmed VF progression in 4% among patients with uncontrolled PACG at 24 months. Some studies found worsened central visual acuity as well: Liu et al[30] noted 2% lost best-corrected visual acuity because of PACG at 1 year, and Hayashi et al[15] reported that 6% with open-angle glaucoma showed vision decrease because of glaucoma progression at 2 years in a prospective study. It remains unclear what role phacoemulsification played in the development of glaucoma progression in these patients.

Need for Further Glaucoma Surgery. Trabeculectomy is usually the initial incisional glaucoma surgery undertaken when IOP control is inadequate with medicines, laser treatment, or both. Among the studies included in this review, some authors found filtering surgery unlikely to be necessary after phacoemulsification in patients with controlled glaucoma, with rates of 0.6% to 0.8% among controlled POAG patients at 1 year.[3,12] Moreover, most authors did not report any eyes requiring trabeculectomy, and the median rate was 0% among studies that included patients with POAG, PXG, or PACG controlled with 1 to 2 medications, who were followed up for 6 to 24 months after phacoemulsification. For PXG, Shingleton et al[21] noted 4% of patients required trabeculectomy, but the mean time to surgery was 5.1 years after phacoemulsification. For PACG, several studies,[15,25,26] including 2 prospective 2-year studies, found that 0% to 3% of patients (including some PXG with angle closure in 1 study) required trabeculectomy.

However, others have reported higher rates, particularly among patients with poorly controlled glaucoma. In a prospective study of 38 POAG patients with poor IOP control, Iancu and Corbu[13] found that 84% required glaucoma surgery after uncomplicated phacoemulsification, with a mean time between phacoemulsification and trabeculectomy of 11.6 months. In another prospective study, Hayashi et al[15] found that 7% of patients with POAG or open-angle PXG had required trabeculectomy at 2 years after phacoemulsification. Liu et al[30] found that 16% of PACG patients who had an IOP of less than 30 mmHg before phacoemulsification required trabeculectomy after mean follow-up of 1 year. Tham et al[27,28] reported that patients with uncontrolled PACG had higher rates, up to 15% to 20% by 2 years after phacoemulsification. Among 4 studies investigating treatment of acute PACG with phacoemulsification, only 1 study[34] noted a requirement for trabeculectomy (5%), although 7% received cyclophotocoagulation after phacoemulsification in that study.

Phacoemulsification-Related Complications. Complications related to phacoemulsification reported in the included studies generally were not qualitatively or quantitatively different from complications seen in any population undergoing phacoemulsification. However, some authors reported phacoemulsification-related complications that seem to be more common in patients with a history of acute PACG, probably related to the relatively short axial length, shallow anterior chamber depth, and frequently dense cataracts that are seen commonly in patients with acute PACG. Lai et al[24] noted 2 eyes (10%), both with a prior history of acute PACG, that showed corneal decompensation after phacoemulsification. Patients undergoing phacoemulsification after acute PACG were noted to have corneal edema (21%–32%) during and after surgery, fibrin formation in the anterior chamber (14%–23%), and wound leak (2%), the latter presumably because of corneal wound burn.[34,35] However, these complications were not reported to be persistent.

Conclusions

The studies included in this assessment represent the best knowledge available at the time of the literature searches on the effect of phacoemulsification on IOP in patients with treated POAG, PXG, and PACG, but the level of evidence is relatively low (3% with level I evidence, 47% with level II evidence, and 50% with level III evidence). As an example of a problem common to many studies included in this review, 18 (56%) of 32 studies used only 1 tonometry reading for the IOP measurement before surgery, which could result in type I error because of regression to the mean with IOP measurements after surgery. Most of the cited studies included relatively small numbers of patients who were followed up for relatively short periods. Many studies, with some exceptions, excluded patients with advanced disease and poor IOP control, likely because combined phacoemulsification with glaucoma surgery, or a staged approach with trabeculectomy first, was considered the best management approach for such patients. Relatively few studies reported essential data on glaucoma severity before phacoemulsification (i.e., optic disc characteristics, VF indices, or both), which made it difficult to determine the generalizability of those studies. The number of glaucoma medications before surgery may be used as a proxy for glaucoma severity, with the understanding that this may not always be a fair assumption.

No standardized treatment algorithm for the management of IOP elevation after surgery exists, and this may greatly affect the reported glaucoma medications used after phacoemulsification. For example, one study[3] found larger reductions in medications than other studies when such an algorithm was followed prospectively after phacoemulsification. Likewise, standards for determining the need for trabeculectomy likely varied among the authors. Many studies excluded patients who had complications during phacoemulsification, which could bias the results because of nonreporting of associated glaucoma-related complications, although notably no association between complications during surgery and glaucoma-related complications after surgery was reported among studies that included such patients. Few prospective studies have been performed, particularly for POAG patients, and only 1 level I study has been published on this topic. Even among prospective clinical trials, the number that explicitly followed an intent-to-treat analysis was few.[3,25,27,28] The vast majority of patients included in these studies were white or Asian; this may limit the applicability of the findings to patients of African or Hispanic ancestry, although no studies with relatively large proportions of nonwhite and non-Asian patients reported a difference in outcomes based on race.[6,12,14] Finally, despite the ubiquity of cataract in glaucoma patients, few studies met the criteria for inclusion in this assessment, probably because emphasis in the past has been on outcomes of combined glaucoma and cataract surgery. Clearly, more well-designed prospective clinical trials are necessary to provide the best data possible for management of patients with glaucoma and cataract.

However, based on the available data, it seems reasonable to state that for patients with POAG (including NTG) that is controlled with 1 or 2 medications, phacoemulsification alone results in a modest decrease in IOP (−13%) and medication requirement (−12%) and seems to be relatively safe, although some patients (up to 26%)

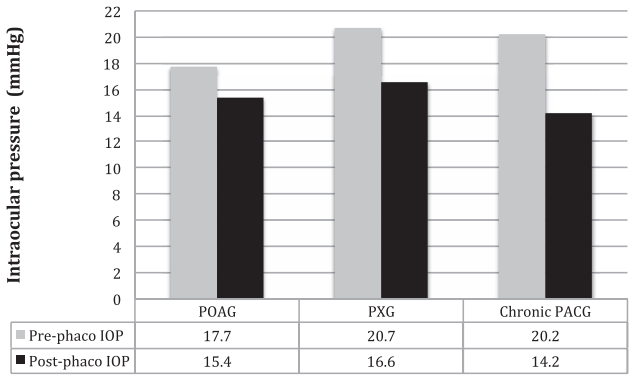

Figure 1. Bar graph showing intraocular pressure (IOP; in millimeters of mercury) before and after phacoemulsification (phaco) in eyes with primary open-angle glaucoma (POAG), pseudoexfoliation glaucoma (PXG), and chronic primary-angle closure glaucoma (PACG).

experience worse IOP control after phacoemulsification and may require additional medications, laser treatment, or both (Figs 1 and 2). Rarely, incisional glaucoma surgery will be necessary for IOP control within 1 year. The median risk of an IOP spike among the studies reporting on this complication was 17.5%, although definitions of IOP spike and prophylactic treatment to prevent it varied widely. The IOP before surgery is probably the most important factor before surgery associated with IOP after surgery. Interestingly, many of these findings are in agreement with the findings reported among patients with untreated ocular hypertension who underwent phacoemulsification while enrolled in the Ocular Hypertension Treatment Study.[2] In that study, among 63 eyes of 42 patients, the mean reduction in IOP was 17% up to 3 years after phacoemulsification; 11% had an increase in IOP.

For patients with mild to moderate PXG controlled with 1 or 2 medications, phacoemulsification results in a moderate decrease in IOP (−20%) and in the number of medications required after surgery (−35%; Figs 1 and 2). Although the risk of requiring more medications for IOP control after phacoemulsification was up to 37%,

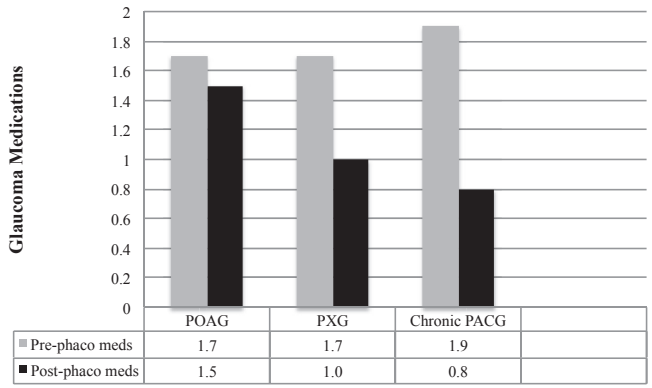

Figure 2. Bar graph showing the number of glaucoma medications (meds) before and after phacoemulsification (phaco) in patients with primary open-angle glaucoma (POAG), pseudoexfoliation glaucoma (PXG), and chronic primary-angle closure glaucoma (PACG).

phacoemulsification may be considered for treatment of PXG in patients with a visually significant cataract for whom an IOP spike after surgery would not be considered dangerous, because the risk of the latter is probably higher in PXG (median 21%) than in POAG, although IOP spike definitions and prophylactic treatment varied widely. Limitations of this assessment for patients with PXG are similar to those listed for POAG above, and more studies are necessary for a stronger recommendation.

For patients with chronic PACG controlled with 1 or more medications, phacoemulsification alone results in a substantial decrease (−30%) in IOP and medication use after surgery (−58%; Figs 1 and 2). The risk of having worse IOP control is lower (4%−9%) than for POAG or PXG. Prospective data show that even in patients with poorly controlled IOP before surgery, phacoemulsification usually results in a marked improvement in IOP and medication requirement, and a relatively small proportion (up to 15%−20%) of patients will require incisional glaucoma surgery within 2 years. Notably, the IOP reduction does not seem to be related to the extent of PAS before surgery, but it may be related to angle width. The risk of an IOP spike seems to be less than for POAG or PXG (median, 8%), although IOP spike definitions varied widely. A limitation of the current literature for this patient group is that almost all of these studies originate from 1 region of the world (Southeast Asia). Although the few studies that included patients without prior laser iridotomy did not find a difference in IOP outcomes after phacoemulsification,[15,32] more studies are needed to confirm this finding.

For patients with acute PACG, phacoemulsification performed soon after initial medical reduction of IOP seems to be highly effective in maintaining reduction of IOP, and most patients did not require medication for IOP control afterward. However, the number of studies and patients on this topic is small, and this is the principal limitation of this assessment. Given the uniformly positive results reported and the relative strength of the evidence (3 of 4 studies were prospective), patients who have had an acute PACG attack and whose IOP has been decreased with medications to a normal level, and who have had improvement in acute inflammation, could be offered phacoemulsification with the possible benefit of reducing the likelihood that chronic PACG would develop in the affected eye. Consideration should be given to complications after surgery commonly seen in eyes with short axial length, shallow anterior chamber depth, and often, relatively dense cataracts. Although these complications, including corneal edema and decompensation, can be vision threatening, for most patients they are not persistent.

Future Research

Research is needed to describe more accurately the effects of phacoemulsification in patients who have uncontrolled POAG, who have advanced POAG, or who are using at least 3 medications or maximum medications (i.e., patients who have allergic reactions or intolerances to 1 or more classes of ocular hypotensive agents). Are such patients at

higher risk for loss of IOP control and subsequent need for incisional glaucoma surgery? More prospective, level I-quality studies are needed not only to determine risk factors for poor IOP control in POAG and PXG patients after phacoemulsification, but also to test different protocols for reducing IOP spikes after surgery. Both of these types of studies may identify better patient selection criteria for phacoemulsification and minimize the risks of phacoemulsification after surgery, such as IOP spikes. The effect of an IOP spike after surgery on the VF, optic nerve status, or both needs further study. Although 1 report[38] on IOP spikes after trabeculectomy showed that such spikes may not be dangerous for patients with mild to moderate glaucoma, IOP may be altered more easily after trabeculectomy (via laser suture lysis or other maneuvers) than after phacoemulsification. If future high-quality studies with long-term follow-up show results similar to those examined in this assessment, phacoemulsification alone, with its attendant lower risk and cost compared with phacoemulsification combined with a glaucoma procedure, could be recommended with greater confidence in appropriate patients who have both functionally significant cataract and medically controlled POAG and PXG, and in patients who have PACG regardless of level of control.

References

1. Friedman DS, Jampel HD, Lubomski LH, et al. Surgical strategies for coexisting glaucoma and cataract: an evidence-based update. Ophthalmology 2002;109:1902–13.
2. Mansberger SL, Gordon MO, Jampel H, et al; Ocular Hypertension Treatment Study Group. Reduction in intraocular pressure after cataract extraction: the Ocular Hypertension Treatment Study. Ophthalmology 2012;119:1826–31.
3. Samuelson TW, Katz LJ, Wells JM, et al. Randomized evaluation of the trabecular micro-bypass stent with phacoemulsification in patients with glaucoma and cataract. Ophthalmology 2011;118:459–67.
4. Chang TC, Budenz DL, Liu A, et al. Long-term effect of phacoemulsification on intraocular pressure using phakic fellow eye as control. J Cataract Refract Surg 2012;38:866–70.
5. Musch DC, Gillespie BW, Niziol LM, et al. Cataract extraction in the collaborative initial glaucoma treatment study: incidence, risk factors, and the effect of cataract progression and extraction on clinical and quality-of-life outcomes. Arch Ophthalmol 2006;124:1694–700.
6. Kim DD, Doyle JW, Smith MF. Intraocular pressure reduction following phacoemulsification cataract extraction with posterior chamber lens implantation in glaucoma patients. Ophthalmic Surg Lasers 1999;30:37–40.
7. Mathalone N, Hyams M, Neiman S, et al. Long-term intraocular pressure control after clear corneal phacoemulsification in glaucoma patients. J Cataract Refract Surg 2005;31:479–83.
8. Leelachaikul Y, Euswas A. Long-term intraocular pressure change after clear corneal phacoemulsification in Thai glaucoma patients. J Med Assoc Thai 2005;88(Suppl 9):S21–5.
9. Mierzejewski A, Eliks I, Kaluzny B, et al. Cataract phacoemulsification and intraocular pressure in glaucoma patients. Klin Oczna 2008;110:11–7.
10. Damji KF, Konstas AG, Liebmann JM, et al. Intraocular pressure following phacoemulsification in patients with and without exfoliation syndrome: a 2 year prospective study. Br J Ophthalmol 2006;90:1014–8.
11. Shoji T, Tanito M, Takahashi H, et al. Phacoviscocanalostomy versus cataract surgery only in patients with coexisting normal-tension glaucoma: midterm outcomes. J Cataract Refract Surg 2007;33:1209–16.
12. Slabaugh MA, Bojikian KD, Moore DB, Chen PP. The effect of phacoemulsification on intraocular pressure in medically controlled open-angle glaucoma patients. Am J Ophthalmol 2014;157:26–31.
13. Iancu R, Corbu C. Intraocular pressure after phacoemulsification in patients with uncontrolled primary open angle glaucoma. J Med Life 2014;7:11–6.
14. Arthur SN, Cantor LB, WuDunn D, et al. Efficacy, safety, and survival rates of IOP-lowering effect of phacoemulsification alone or combined with canaloplasty in glaucoma patients. J Glaucoma 2014;23:316–20.
15. Hayashi K, Hayashi H, Nakao F, Hayashi F. Effect of cataract surgery on intraocular pressure control in glaucoma patients. J Cataract Refract Surg 2001;27:1779–86.
16. Shingleton BJ, Pasternack JJ, Hung JW, O'Donoghue MW. Three and five year changes in intraocular pressures after clear corneal phacoemulsification in open angle glaucoma patients, glaucoma suspects, and normal patients. J Glaucoma 2006;15:494–8.
17. Zhang N, Tsai PL, Catoira-Boyle YP, et al. The effect of prior trabeculectomy on refractive outcomes of cataract surgery. Am J Ophthalmol 2013;155:858–63.
18. Aulhorn E, Karmeyer H. Frequency distribution in early glaucomatous visual field defects. Docum Ophthal Proc Series 1977;14:17–83.
19. Jacobi PC, Dietlein TS, Krieglstein GK. Comparative study of trabecular aspiration vs trabeculectomy in glaucoma triple procedure to treat pseudoexfoliation glaucoma. Arch Ophthalmol 1999;117:1311–8.
20. Georgopoulos GT, Chalkiadakis J, Livir-Rallatos G, et al. Combined clear cornea phacoemulsification and trabecular aspiration in the treatment of pseudoexfoliative glaucoma associated with cataract. Graefes Arch Clin Exp Ophthalmol 2000;238:816–21.
21. Shingleton BJ, Laul A, Nagao K, et al. Effect of phacoemulsification on intraocular pressure in eyes with pseudoexfoliation: single-surgeon series. J Cataract Refract Surg 2008;34:1834–41.
22. Perasalo R. Phacoemulsification of cataract in eyes with glaucoma. Acta Ophthalmol Scand 1997;75:299–300.
23. Yalvac I, Airaksinen PJ, Tuulonen A. Phacoemulsification with and without trabeculectomy in patients with glaucoma. Ophthalmic Surg Lasers 1997;28:469–75.
24. Lai JS, Tham CC, Chan JC. The clinical outcomes of cataract extraction by phacoemulsification in eyes with primary angle-closure glaucoma (PACG) and co-existing cataract: a prospective case series. J Glaucoma 2006;15:47–52.
25. Tham CC, Kwong YY, Leung DY, et al. Phacoemulsification versus combined phacotrabeculectomy in medically controlled chronic angle closure glaucoma with cataract. Ophthalmology 2008;115:2167–73.
26. Pachimkul P, Intajak Y. Effect of lens extraction on primary angle closure in a Thai population. J Med Assoc Thai 2008;91:303–8.
27. Tham CC, Kwong YY, Leung DY, et al. Phacoemulsification versus combined phacotrabeculectomy in medically uncontrolled chronic angle closure glaucoma with cataracts. Ophthalmology 2009;116:725–31.
28. Tham CC, Kwong YY, Baig N, et al. Phacoemulsification versus trabeculectomy in medically uncontrolled chronic

angle-closure glaucoma without cataract. Ophthalmology 2013;120:62–7.
29. Euswas A, Warrasak S. Intraocular pressure control following phacoemulsification in patients with chronic angle closure glaucoma. J Med Assoc Thai 2005;88(Suppl): S121–5.
30. Liu CJ, Cheng CY, Ko YC, Lau LI. Determinants of long-term intraocular pressure after phacoemulsification in primary angle-closure glaucoma. J Glaucoma 2011;20:566–70.
31. Yudhasompop N, Wangsupadilok B. Effects of phacoemulsification and intraocular lens implantation on intraocular pressure in primary angle closure glaucoma (PACG) patients. J Med Assoc Thai 2012;95:557–60.
32. Shams PN, Foster PJ. Clinical outcomes after lens extraction for visually significant cataract in eyes with primary angle closure. J Glaucoma 2012;21:545–50.
33. Moghimi S, Latifi G, ZandVakil N, et al. Phacoemulsification versus combined phacoemulsification and viscogonioplasty in primary angle-closure glaucoma: a randomized clinical trial. J Glaucoma. In press.
34. Jacobi PC, Dietlein TS, Luke C, et al. Primary phacoemulsification and intraocular lens implantation for acute angle-closure glaucoma. Ophthalmology 2002;109: 1597–603.
35. Lam DS, Leung DY, Tham CC, et al. Randomized trial of early phacoemulsification versus peripheral iridotomy to prevent intraocular pressure rise after acute primary angle closure. Ophthalmology 2008;115:1134–40.
36. Lee SJ, Lee CK, Kim WS. Long-term therapeutic efficacy of phacoemulsification with intraocular lens implantation in patients with phacomorphic glaucoma. J Cataract Refract Surg 2010;36:783–9.
37. Husain R, Gazzard G, Aung T, et al. Initial management of acute primary angle closure: a randomized trial comparing phacoemulsification with laser peripheral iridotomy. Ophthalmology 2012;119:2274–81.
38. Chen PP, Musch DC, Niziol LM. The effect of early postrabeculectomy intraocular pressure spike in the collaborative initial glaucoma treatment study. J Glaucoma 2011;20: 211–4.

Footnotes and Financial Disclosures

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Abbreviations and Acronyms:
C/D = cup-to-disc; **IOL** = intraocular lens; **IOP** = intraocular pressure; **NR** = not reported; **NTG** = normal-tension glaucoma; **PACG** = primary angle-closure glaucoma; **PAS** = peripheral anterior synechiae; **POAG** = primary open-angle glaucoma; **PXG** = pseudoexfoliation glaucoma; **VF** = visual field.

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