Original Article

Outcomes of Coaxial Micro-incision Phacoemulsification in Nanophthalmic Eyes: Report of Retrospective Case Series

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Abstract

Purpose: The surgical risk and complication rate after cataract surgery are extremely high in patients with nanophthalmos. This study is designed to compare the visual and refractive outcomes before and after coaxial micro-incision phacoemulsification and evaluate postoperative complications.

Methods: Fifty nine patients (89 eyes) with axial length (AL) < 21 mm diagnosed with nanophthalmos were enrolled in this retrospective study. All patients underwent coaxial micro-incision phacoemulsification and IOL implantation. The main outcome measures included anterior chamber depth (ACD), anterior chamber volume (ACV), anterior chamber angle (ACA), intraocular pressure(IOP) and best corrected visual acuity (BCVA). Wilcoxon signed rank test or Mann-Whitney test, and Chi-square test and logistic regression analysis were performed for statistical tests as appropriate.

Results: The median AL was 19.63 mm. Sixty-six eyes (74.16%) had a history of surgical intervention. Postoperative ACD, ACV and ACA were increased significantly (all $P<0.001$), whereas postoperative IOP was decreased significantly ($P<0.001$) after surgery. Previous surgical intervention was related to a reduction in the postoperative ACD and ACA ($P<0.01$), and both preoperative and postoperative IOP ($P<0.001$). Postoperative BCVA was improved in 94.38% of the cases. Intraoperative complications mainly included iridoschisis (6 eyes, 6.74%). Early postoperative complications included temporary corneal edema (TCE) (23 eyes, 25.84%), anterior inflammatory response (AIR)(19 eyes, 21.35%), cystoid macular edema (CME) (14 eyes, 15.73%), and uveal effusion (4 eyes, 4.49%). Late postoperative complications included CME (8 eyes, 8.99%), uveal effusion (8 eyes, 8.99%), malignant glaucoma (2 eyes, 2.25%) and posterior capsular opacification (PCO) (10 eyes, 11.24%). The majority of complications (80%) were successfully resolved by pharmacotherapy or operation. The risk of surgical complications was greater in patients with lower AL, ACD, ACV or ACA and higher nuclear hardness or mean keratometry (Km).

Conclusion: With reasonable preoperative management, prudent selection of the lens, rigorous surgical technique and unerring cognition of potential complications, coaxial micro-incision phacoemulsification lens surgery can be performed in patients with nanophthalmos and yield favorable outcomes and a low incidence of complications. (***Eye Science 2015; 30: 94-100***)

Keywords: coaxial micro-incision phacoemulsification; nanophthalmos; complication

Introduction

Nanophthalmos is a rare genetic disease characterized by eyes with a short axial length (AL) less than 21 mm[1]. These small eyes have marked anatomic abnormalities, including a small cornea, shallow anterior chamber, narrow angle, and high lens-to-eye volume ratio. Patients with nanophthalmos are at high risk for developing angle closure glaucoma[2] which is hard to treat with traditional therapies. In addition, pupillary block may be exacerbated by miotics, thereby worsening the condition. Removal of the lens was found to relieve anterior chamber crowding, and thus is an optional treatment for nanophthalmos-related glaucoma. Unfortunately, the complication rate of the procedure is high[3]. Phacoemulsification cataract surgery is increasingly being performed for the management of cataract in nanophthalmos[4].

Currently, the outcome of phacoemulsification and intraocular lens (IOL) implantation in nanophthalmic eyes is encouraging[5]. The procedure, which might reduce intraocular pressure (IOP), may indeed be an alternative to glaucoma filtration surgery[6]. Nevertheless, the surgery is associated with a high risk of

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complications compared to surgery for age related cataracts. Previous studies have found the relationship between anterior chamber depth (ACD) and the IOP[6,7], but very little is known about anterior chamber volume (ACV) and anterior chamber angle (ACA). These parameters are as important as anterior chamber depth (ACD). In this study we performed a retrospective analysis of the outcomes of coaxial micro-incision phacoemulsification on anterior chamber profile. We evaluated visual and refractive outcomes and investigated perioperative complications and possible preventative measures among eyes with nanophthalmos.

Materials and methods

Patients and surgical procedures

Our retrospective study involved 89 eyes of 59 patients with nanophthalmos that underwent phacoemulsification surgery by the same surgeon (Zhaohui Li) from January 2010 to May 2014 at the PLA General Hospital. All cases were enrolled from database of medical record management department. This study was approved by the local ethics committee. Our research adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants. The inclusion criteria were that the eyes had an AL <21 mm and were treated with phacoemulsification and IOL implantation. The exclusion criteria included a follow-up period < 3 months; obvious fundus diseases detected by B-scan echography preoperatively, such as retinal detachment and choroidal effusion; other anatomic and structural abnormalities, including chorioretinal colobomas, retinal dysplasia and persistent hyperplastic primary vitreous[2]. In order to investigate the effect of previous antiglaucomatous surgery on anterior chamber and complications, cases were divided into groups of patients who had not undergone previous surgery (Group A) and those who had a previous surgical procedure (Group B).

All cases were performed using superficial anesthesia. Viscoelastic was injected as quickly as possible when paracentesis was created to make a "stab" incision. The clear corneal incision was perforated with a 2.2 mm keratome blade. Coaxial micro-incision phacoemulsification was performed by a stop and chop technique using either the Infinity phacoemulsification system (Alcon Laboratories Inc, Irvine, CA, USA) or the Signature phacoemulsification system (Abbott Medical Optics Inc, Andrew Place Santa Ana, CA, USA). The machine settings were as follows: the bottle height was 95 cm; the vacuum was 400-450 mmHg; the power was 60%; the aspiration rate was 38 ml/min. Three types of foldable acrylic IOLs were implanted as appropriate: Akreos Adapt [Bausch&Lomb Inc, Rochester, NY, USA], SN60WF [Alcon Laboratories Inc, Huntington, WV, USA] or AMO ZCB00 [Abbott Medical Optics Inc, Andrew Place Santa Ana, CA, USA]).

Measurement of parameters

All biometric parameters were measured within 1 week before and 2 weeks after surgery. ACD, ACV and ACA were measured using a Pentacam (HR70900, OCULUS Optikgerate GmbH, Wetzlar, Germany). IOP was recorded as the mean of 3 values using a non-contact tonometer (NCT [TX-F, Canon Inc, Tokyo, Japan]) and Goldmann applanation tonometer (GAT [Keeler Ltd, Berkshire, UK]). An abnormal IOP was defined as 21 mmHg or higher (GAT). Two doctors concurred on and graded the corneal diameter and nuclear hardness by Emery criteria preoperatively. AL and corneal keratometry were measured using an IOLMaster (Carl Zeiss Meditec AG, Jena, Germany). The Hoffer Q formula was used for IOL power calculations. The target refractive diopter, refractive diopter before and 3 months after surgery, and the power of the IOLs were recorded. Best corrected visual acuity (BCVA) was assessed preoperatively and 3 months postoperatively, and then converted into logarithm of the minimum angle of resolution (logMAR) for analysis. BCVA poorer than logMAR 1.6 were estimated as follows: counting finger=2.2 logMAR, and hand movement=2.3 logMAR[8]. All previous surgical histories and preoperative complications were identified from the patients´ medical records. A positive anterior inflammatory response (AIR) was in the form of flare and/or cells ≥ grade 2 by Hogan's criteria[9]. If an abnormal IOP was detected preoperatively, topical brinzolamide (Azopt, s.a.Alcon-Couvreur n.v., Rijksweg, Puurs, Belgium) 1% and timolol maleate (Timoptic, Wujing Inc, WuHan, China) 0.5%, or intravenous mannitol 20% was routinely administrated for better control of IOP.

Statistical analysis

Statistical analyses were executed using SPSS software (19.0 version, SPSS Inc). All data were expressed as the mean and standard deviation. If data were not normally distributed, medians with 25% and 75% interquartile ranges (IQR) were recorded. Differences between groups were analyzed by the Wilcoxon signed rank test or the Mann-Whitney test, as appropriate, and the Chi-square test for enumeration data. Correlations between measurements were analyzed by Spearman's correlation analysis. Univariate and multivariate logistic regressions (backward-selection and forward-selection techniques) were performed to evaluate the odds ratio. Alpha=0.05 for all statistic tests (two sided). A $P < 0.05$ was considered statistically significant.

Results

Patient characteristics

The preoperative characteristics of study patients (mean age was 56.51 years) are summarized in Tables 1 and 2. Female patients accounted for 31 and male patients accounted for 28 in the study.

Table 1 Demographic data

	Min	Max	Mean	SD	Median	IQR*
Age (years)	29	77	56.51	10.96	58	49–64
Follow–up (months)	3	30	11.39	5.96	12	7–13
AL (mm)	15.82	20.97	19.24	1.20	19.63	18.33–20.07
CD (mm)	6.00	12.00	9.41	1.25	10.00	8.50–10.00
Nuclear hardness#	2	5	3.19	0.84	3	3–4

SD = standard deviation; IQR = interquartile ranges; AL = axial length; CD = corneal diameter.
* 25% to 75%
#According to the Emery nuclear hardness classification

Table 2 Surgical history of all eyes

Preceding surgeries	No. of eyes	Percentage(%)
Trabeculectomy + PI	35	39.33
YAG PI	21	23.60
Cyclophotocoagulation	10	11.24
None	23	25.84
Total	89	100

PI = peripheral iridotomy; YAG = neodymium: YAG laser.

Outcomes of anterior chamber parameters and results of IOP

The biometric parameters measured within 1 week before and 2 weeks after phacoemulsification surgery are listed in Table 3. There were significant differences in ACD, ACV, ACA, before and after surgery (Z = -8.193, -8.193, -7.542, all $P < 0.001$) and IOP of NCT and GAT (Z = -6.743, -5.437, all $P < 0.001$). In association with glaucoma, IOP was compared with anterior chamber parameters. The results were analyzed by Spearman's rank correlation. Preoperative IOP was negatively correlated with ACD before and after surgery ($P = 0.032$, $r = -0.228$; $P < 0.001$, $r = -0.475$). Postoperative IOP was also negatively correlated with postoperative ACD ($P < 0.001$, $r = -0.377$) and ACA ($P = 0.007$, $r = -0.285$). Parameters such as AL, nuclear hardness, ACD, ACV and ACA between groups A and B before phacoemulsification surgery were similar (Mann-Whitney test; Z = -0.380, -0.545, -1.020, -0.690 and-0.277; P = 0.704, 0.586, 0.307, 0.490 and 0.782). The GAT IOP of group B was lower compared to group A before surgery(Z= -6.007, $P < 0.001$). After phacoemulsification surgery, group B ACD (Z = -2.676, $P = 0.007$), ACA (Z = -2.685, $P = 0.007$) and GAT IOP (Z = -5.966, $P < 0.001$) were lower compared to group A.

Visual outcome and refractive results

BCVA and refractive diopter 3 months after surgery were compared with those before surgery. The median pre- and post-operative logMAR BCVA were significantly different (Wilcoxon signed rank test, Z = -7.999, $P < 0.001$): 1.4 (range 0.8-2.3) and 0.8 (range 0.1-1.4), respectively. The logMAR BCVA for group B was lower before surgery

Table 3 Preoperative and postoperative biometric parameters of all patients

	Min	Max	Mean	SD	Median	IQR*
Preoperative						
ACD (mm)	1.15	3.50	2.16	0.68	2.03	1.65–2.70
ACV (mm3)	28.00	100.00	45.17	16.27	40.00	34.00–56.00
ACA (°)	14.20	43.20	23.77	7.31	21.20	17.55–28.55
NCT (mmHg)	9.90	40.00	17.97	7.20	15.50	12.40–20.30
GAT (mmHg)	10.00	45.00	19.52	7.05	17.00	14.75–23.00
Postoperative						
ACD (mm)	1.56	4.54	3.16#	0.69	3.14	2.66–3.64
ACV (mm3)	55.00	147.40	92.21#	19.55	95.00	76.00–105.10
ACA (°)	18.70	52.80	37.26#	11.83	40.20	25.00–48.90
NCT (mmHg)	6.00	43.00	14.26#	8.15	11.30	9.50–15.50
GAT (mmHg)	10.00	48.00	16.96#	8.37	14.20	11.30–18.55

SD = standard deviation; IQR = interquartile ranges; ACD = anterior chamber depth; ACV = anterior chamber volume; ACA = anterior chamber angle; NCT = non-contact tonometer; GAT = Goldmann applanation tonometry.

* 25% to 75%

#Wilcoxon signed rank test (all $P < 0.001$)

Table 4 Intraoperative, early and late postoperative complications

	n	%	Interventions; Outcomes
Intraoperative complications			
Iridoschisis	6	6.74	–
Early postoperative complications			
TCE	23	25.84	Tobramycin + Dexamethasone*; All were cured.
AIR#	19	21.35	Tobramycin + Dexamethasone*; Dexamethasone sodium phosphate△; All were cured.
CME	14	15.73	Intravitreal injection of triamcinolone acetonide or bevacizumab; 2 eyes were cured, 12 eyes improved.
Uveal effusion	4	4.49	Dexamethasone sodium phosphate△; Atropine; Mannitol; All were cured.
PCO	0.00	0.00	–
Complications ≥2	11	12.36	–
Late postoperative complications			
CME	8	8.99	Intravitreal injection of triamcinolone acetonide or bevacizumab; 2 eyes were cured, 6 eyes were improved.
Uveal effusion	8	8.99	Dexamethasone sodium phosphate△; Atropine; Mannitol; All were cured.
PCO	10	11.24	YAG-capsulotomy; All were cured.
High IOP	19	21.35	2 eyes underwent YAG PI; 4 eyes were treat successfully with cyclophotocoagulation;9 eyes had antiglaucomatous medication; 2 eyes required trabeculectomy+PI; 2 eyes with malignant glaucoma were resolved
Complications ≥2	4	4.49	after YAG-capsulotomy and anterior vitrectomy.

TCE = temporary corneal edema; AIR = anterior inflammatory response; CME = cystoid macular edema; PCO = posterior capsular opacification; YAG = neodymium: YAG laser; High IOP = 21 mmHg or higher (Goldmann applanation tonometry); PI = peripheral iridotomy.

*Tobramycin + Dexamethasone: topical tobramycin (0.3%) + dexamethasone (0.1%)

#AIR was documented in the form of flare and/or cells ≥ grade 2 by Hogan's criteria

△Dexamethasone sodium phosphate: intravenous dexamethasone sodium phosphate 5–10 mg daily

(Mann-Whitney test, Z =-2.023, P = 0.043). The logMAR BCVA for groups A and B were similar after surgery(Mann-Whitney test, Z = -0.264, P = 0.791).

Visual acuity unchanged in 4 eyes of 4 cases (4.49%) and was poorer due to cystoid macular edema (CME) and uveal effusion in 1 eye of 1 case (1.12%). The degree of hyperopia before surgery varied from +4.50 D to +20.00 D with a median value of +9.00 D. After implantation of the IOLs (median power of 30 D, range 29.00 D to 34.00 D), hyperopia significantly decreased to +3.00 D (range -0.50 D to +14.00D, Wilcoxon signed rank test, Z = -8.205, P < 0.001). The median difference between target refractive diopter and achieved postoperative refractive diopter was +0.50 D (range -1.50 D- +4.00 D), and 37 eyes (41.57%) were within±0.50 D.

Perioperative complications

Early stage was defined as less and late stage as more than 1 month after surgery. Iridoschisis, an intraoperative complication, was observed in 6 eyes with glaucoma. Of these, one eye had received neodymium: YAG laser (YAG) peripheral iridotomy (PI) and 5 eyes had undergone trabeculectomy and PI. Accordingly, the previous surgeries may have caused iris trauma and synechia. The most frequent early postoperative complications were temporary corneal edema (TCE), AIR, CME and uveal effusion, while the most frequent late postoperative complications were CME and uveal effusion. The incidence of complications were not significantly different for group A (73.91%) compared to group B (62.12%), (chi-square test, χ^2 = 1.312, P = 0.252). Excluding transient TCE and AIR, the incidence of complications in group A (73.91%) were significantly higher compared with group B (37.88%, Chi-square test, $\chi2$ = 8.887, P = 0.003).

The edema and inflammatory response after surgery were cleared up, and uveal effusion was resolved in all cases. Treatment of CME was ineffective. YAG-capsulotomy cleared the posterior capsular opacification (PCO) in 10 eyes (11.24%) (Table 4). Phacoemulsification surgery did not correct the elevated IOP in 19 eyes. One eye had normal IOP and no previous surgical history. Antiglaucomatous medication was used to manage 18 eyes with high IOP before surgery, 2 of which developed malignant glaucoma. Surgical intervention, consisting of YAG PI, cyclophotocoagulation, trabeculectomy with PI, and YAG-capsulotomy combined with anterior vitrectomy was performed in 9 eyes (47.37%) which had high IOP after phacoemulsification surgery. No other severe complications were detected in the other 10 eyes (52.63%).

The relationship between risk factors and complications was evaluated. The nuclear hardness of patients presenting with inflammatory response significantly differed from that of their counterparts without inflammatory response (Mann-Whitney test, P= 0.002). PCO was related to AIR (Spearman's rank correlation, P=0.000, r=0.42). Univariate and multivariate logistic regressions were performed to estimate OR for each variable. Factors were included in the final multivariate model only if significant (P < 0.05). The data showed nuclear hardness was related to TCE (P<0.001, odds ratio [OR]= 3.42, 95% confidence interval[CI]=1.75-6.70); AIR was positively associated with AL (P=0.003, OR=0.44, 95% CI= 0.26-0.76) and nuclear hardness (P=0.031, OR= 0.44, 95% CI=1.08-4.45); AL (P=0.001, OR=0.28, 95% CI=0.13-0.59), ACA (P=0.020, OR=0.82, 95% CI =0.70-0.97). Mean keratometry (Km) (P =0.001, OR=1.82, 95% CI=1.26-2.64) was related to CME. Uveal effusion was related to AL (P=0.002, OR= 0.01, 95% CI=0.001-0.22).

Discussion

In our study, there were no complications in the majority (60.67%) of cases (if TCE and AIR were excluded), and improvement of BCVA was achieved in 94.38% of cases. Nonetheless, significant risks are still associated with phacoemulsification surgery on nanophthalmic eyes. Compared with a previous study[10], we achieved a limited gain in BCVA, with greater deviation (from 0.1 logMAR to 1.4 logMAR). This suboptimal visual acuity could be caused by two factors. Firstly, the majority of patients with nanophthalmos came from remote rural regions in China, and had poor visual acuity when they were teenagers or suffered from preexisting ocular diseases such as refractive amblyopia and foveal underdevelopment. Secondly, most of the eyes included in our study had glaucoma which could damage the optic nerve before cataract surgery.

Postoperative BCVA in nanophthalmos was less favorable compared with that in normal eyes. This was also true for the refractive results. The target refraction of ±0.50 D was not reached in 52 eyes (58.43%), most of which remained hyperopic. Several factors may be responsible for this discrepancy, including discrepancies in AL measurement and IOL power calculation. IOL calculations could be inaccurate, with the Holladay Ⅱ formula typically being preferred although it is not readily available[11-12]. The Hoffer Q formula which performed as well as the Holladay Ⅱ formula for small eyes[13] is readily available and therefore was our method of choice. Although Gayton et al[14] demonstrated 2 IOLs, in a piggyback manner, can be successfully implanted, we considered that the zonules in those small eyes may be too weak to support insertion of 2 IOLs. Oshika et al[15] modified the technique by implanting 1 IOL in the capsular bag and another IOL in the sulcus. We determined that insufficient space was available for 2 IOLs, and more importantly, that piggyback IOLs would produce marked hyperopic drift[16]. Based on all of these factors, we used a single high-power IOL instead of piggyback IOLs.

Phacoemulsification lens surgery of nanophthalmic eyes is associated with a high risk of perioperative complications, such as corneal decompensation, severe iritis, explosive choroidal hemorrhage, uveal effusion, retinal detachment, malignant glaucoma and CME[17]. In our cases, TCE, AIR, CME and uveal effusion accounted for the majority of early postoperative complications, while CME, uveal effusion glaucoma and PCO accounted for the majority of late postoperative complications. Nuclear hardness was a major risk factor for TCE and AIR. Once CME occurred, it was difficult to treat. In our study 2 eyes of 2 patients developed malignant glaucoma, presumably because of capsular block and aqueous misdirection and required YAG-capsulotomy combined with anterior vitrectomy to manage the IOP. Both patients had intractable IOP elevation (1 eye had cyclophotocoagulation) before surgery. We deemed that additional surgical interventions were often required as soon as complications were detected, emphasizing the necessity for careful follow-up.

In our study, there were no severe complications. One of the reasons for this may be that the percentage of high-risk eyes (approximately < 18 mm[18]) was low (17.98%). More importantly, we believed the reduction of severe complications was closely related to surgical technique, and the surgery should always be handled by an experienced surgeon. To protect the corneal endothelium, we injected low density vis coelastic (VISCOAT, Alcon Laboratories Inc, Texas, USA) before capsulorrhexis. The coaxial micro-incision technique with a 2.2 mm corneal incision reduced the trauma around the corneal incision site. A stop and chop technique was performed to divide the lens as small as possible (approximately 6-8 pieces). We created paracentesis to make a "stab" incision for the first step, and made the viscoelastic advancing towards the paracentesis to gradually replace the aqueous humor. This may help reduce the aqueous outflow and naturally maintain ACD. We surmised that a 95 cm bottle height may be suitable, as it could maintain normal ACD without causing ocular hypertension or ischemia during surgery. We preferred topical anesthesia to retrobulbar anesthesia, because it reduced the vitreous pressure. Preoperative administration of mannitol may be important in preventing unexpected complications[19]. As expected, we noticed that previous surgical intervention may be helpful for postoperative ACD and IOP, and may protect against the development of complications. The risk for complications in nanophthalmos was greater with reducing AL, ACD, ACV or ACA and with higher nuclear hardness or Km.

Our study represented a fairly comprehensive case series. A previous study indicated that when the AL cut off to define nanophthalmos was < 20.9 mm, 0.1 mm less than the 21 mm AL we used to defined nanophthalmos, the sample size of the present study would reduce the by nearly 25%[20]. By and large, the outcomes that we report were gratifying. Our experience may be useful to surgeons and patients at the time of perioperative preparation and preoperative counseling. The present study was related to the techniques and skills of an individual surgeon, potentially limiting the generalization of our results. IOLs with a power greater than 34 D were not readily available. This could leave nanophthalmos eyes with a higher postoperative refractive diopter receiving less powerful IOLs. Further studies may be more valuable if we included even short eyes. The decision to use ocular hypotensive agents was based on clinical judgment, and patients were not randomized into groups. We only considered the risk factors correlated with the surgery when we studied the incidence of PCO, ignoring the influence of previous holopathy such as diabetes and hypertension. Therefore, our results may be somewhat biased. Future large-scale multicenter randomized controlled clinical trials are recommended to generalize our outcomes.

Conclusion

With reasonable preoperative management, prudent selections of the lens, rigorous surgical technique, and unerring cognition of the potential complications, coaxial micro-incision phacoemulsification surgery can be favorably performed in nanophthalmos with good results. Nonetheless, the surgery in nanophthalmos is still challenging, primarily due to the high incidence of complications.

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