



Visual outcomes after cataract surgery in monocular compared to binocular patients: a case–control study

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Abstract

Purpose We aimed to identify ocular comorbidities and reasons of blindness in monocular patients and to compare visual outcomes of cataract surgery between monocular and binocular patients.

Methods A single-center case–control study was conducted between November 2011 and May 2019 to compare consecutive series of patients needing cataract surgery in Strasbourg University Hospitals, France. Cases were patients with permanent monocular vision loss. Controls were binocularly sighted patients. All patients underwent cataract surgery using phacoemulsification technique. Chart analysis included demographic data, medical history, and surgical determinants data. Student's *t* tests and Fisher's

exact tests were the main methods used for statistical analysis.

Results Each group included 80 patients. The mean age at the time of surgery was significantly higher in monocular than binocular patients (77 vs. 71 years, $p < 0.001$). Thirty-two monocular patients (40%) had ocular comorbidities, compared to only 19 (23%) in the control group ($p < 0.05$). The leading cause of monocular status was amblyopia caused by strabismus (22 patients, 27.5%). Age-related macular degeneration, open-angle glaucoma, and diabetic retinopathy were the three main ocular comorbidities that were observed in the monocular group. Monocular patients had significantly lower visual acuity than the control group ($p < 0.01$) before and after cataract surgery. Conversely, improvement in visual acuity after surgery was not statistically different between groups ($p = 0.054$). There was no statistically significant difference in the rate of surgical complications between groups ($p = 0.622$).

Conclusions This study illustrates that cataract surgery in monocular patients is not more complicated than in binocular patients, but that it is significantly delayed.

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Cataract in adults is an acquired, primarily age-related condition causing partial or total clouding of

the lens. In 2015, cataract was the second-leading cause (35.1%) of moderate-to-severe vision impairment globally, following uncorrected refractive errors [1]. Surgical extraction is the only effective treatment to recover vision. Cataract surgery is by far the most common surgical procedure worldwide [2]. It has also been proven to be one of the most cost-effective health-care interventions, with remarkably fast visual rehabilitation [3]. Although various surgical techniques are currently used, phacoemulsification remains the standard method [4].

There is no clear definition of the term “monocular patients,” although the World Health Organization (WHO) defines monocular patients as those with poor vision in one eye, while the other eye has normal or noticeably normal vision [5]. This term combines both undeniably one-sighted patients (i.e., patients whose eye has been enucleated or is totally deficient) and functionally severe monocular patients (i.e., those whose worst eye has a best-corrected visual acuity [BCVA] inferior to 20/200) [2, 5]. Nevertheless, at the same level of visual acuity, monocular patients clearly suffer from a greater deficiency than binocular patients, as well as poorer quality of life [6, 7].

Encountering cataract in functionally monocular patients is far from exceptional in the daily practice of ophthalmologists. As an example, in the UK, approximately 9,000 cataract extractions on amblyopic patients are performed every year, which represent around 3% of all cataract operations [8]. However, many ophthalmologists are still reluctant to recommend or perform cataract surgery for monocular patients. This is due to the possibility of a potential intraoperative complication causing subsequent poor visual outcome, which is perceived as more serious for a monocular patient than a binocular patient [6]. Very few studies have explored this topic, most of which were conducted by the same team.

This study sought (1) to identify the ocular comorbidities in the operated eye and the reasons for poor vision in the blind, non-operated, fellow eye in a population of monocular patients and (2) to compare visual outcomes of phacoemulsification surgery in monocular patients using a group of binocularly sighted control subjects.

Methods

An observational single-center case-control study was conducted between November 2011 and May 2019. The study adhered to the tenets of the Declaration of Helsinki and was approved by the ethical committee of the French Ophthalmological Society (SFO).

We reviewed the medical reports of all cataract operations performed in our center by a single surgeon (approximately 3000 cases). Monocular cases accounted for 80 of these 3000 patients. The case group therefore consisted of a cohort of 80 monocular patients, all of whom underwent cataract surgery. Cases were considered “monocular” if the patient had one eye removed or if the Snellen BCVA in their “functionally blind” eye (i.e., the non-operated fellow eye) was inferior to 20/200, with no possibility of vision improvement through medical or surgical treatment. Before surgery, BCVA in the patient’s fellow eye had to be inferior to 20/32.

The control group consisted of a cohort of 80 binocular subjects, who were chosen by consecutive case-series selection. Patients’ BCVA before surgery was greater than 20/200 and inferior to 20/32, while the fellow, non-studied eye had a BCVA greater than 20/32.

All study subjects underwent cataract surgery alone. No combined procedures were included. Patients presenting with other than senile cataract (traumatic, iatrogenic, diabetic) were excluded from the study. This condition was verified by reviewing medical charts and limiting inclusion to patients aged over 60.

The primary outcome was the evolution of the BCVA, which was measured using Snellen charts. Preoperative visual acuity was obtained 4–8 weeks prior to surgery, whereas postoperative BCVA was measured 30 days after surgery. BCVA was measured at a distance of 5 m, using subjective refraction and an automatic refractometer. We recorded the patient’s demographic characteristics, ocular medical history, methods of anesthesia, ocular comorbidities associated with cataract in the operated eyes, causes of poor vision in the blind eye, as well as the eyes’ axial lengths, which were assessed by non-contact biometry (Carl Zeiss Meditec AG, Jena, Germany).

All surgeries were performed in the same hospital center and by the same surgeon (TB). The method

of cataract extraction was phacoemulsification in all procedures. The method of anesthesia (topical or general anesthesia) was decided on a case-by-case basis, depending on the patient's condition and choice, and the needs of both the surgeon and anesthesiologist to perform the safest procedure. Preoperative dilatation of the eyes was performed using Mydriaser® (Thea, Clermont-Ferrand, France). Infinity® and Centurion® vision phacoemulsification systems were used (Alcon, Fort Worth, TX). The standard procedure started with a superior 2.2-mm main corneal incision, which was followed by viscoelastic injection into the anterior chamber. The secondary corneal incision was created approximately 60 degrees to the left of the primary incision. After the flap was created, a 5–6-mm continuous curvilinear capsulorhexis was performed. Then, we proceeded to hydro-dissection, which was followed by phacoemulsification using the “divide and conquer” fracturing technique. Once the quadrants and cortex had been removed, the anterior chamber and the capsular bag were refilled with dispersive viscoelastic. Dispersive viscoelastic was injected into the capsular bag, and a preloaded, one-piece, monofocal, acrylic, hydrophobic intraocular lens was injected into the capsular bag through the main incision. Patients with corneal astigmatism of more than 1.25 dioptres were implanted with a toric IOL. Viscoelastic was removed using the irrigation and aspiration (I/A) hand piece, and the corneal incision was sutured with stitches of 10/0 nylon. At the end of the procedure, 0.1 ml of cefuroxime was injected into the anterior chamber.

Successful completion of surgery, with or without complications or unexpected events, was assessed for each procedure. For those performed with the Centurion® vision system, we recorded the cumulative dissipated energy (CDE), i.e., the amount of ultrasound energy delivered to the eye during the phacoemulsification surgery.

Postoperative follow-up visits were scheduled on Day 1, Day 7, and Day 30, during which visual acuity and intraocular pressure were measured, and a slit-lamp examination was performed. Final visual acuity was recorded and confirmed during the last follow-up examination on Day 30. Postoperative macular coherence tomography was performed in patients with less than expected visual gain and/or secondary decline in visual acuity. Some patients continued follow-up after

the initial 30 days, particularly in the case of patients with ocular comorbidities and/or complications.

GraphPad Prism 8.0 software (GraphPad Motulsky Company, San Diego, CA) was used to calculate the means and standard deviations for all variables. Significant differences in and between the groups were determined using one-way analysis of variance with unpaired *t* tests. Qualitative data were determined using the Chi-square and Fisher's tests. Differences were considered statistically significant if the *p* value was less than 0.05.

Results

Eighty monocular patients were compared to 80 consecutive cases of binocular subjects. Patients' demographic characteristics and methods of anesthesia are presented in Table 1, while the main ophthalmological comorbidities associated with cataract in the operated eyes are illustrated in Table 2. None of the subjects had a history of ocular surgery in the study eye. Patients with age-related macular degeneration received regular intravitreal injections when deemed necessary.

Furthermore, Table 3 illustrates the different reasons for poor vision in the blind non-operated fellow eye. We encountered 77 “functionally” monocular patients and three “true” monocular subjects with eye prostheses. Of these, one patient had a congenital cataract with a history of end-stage glaucoma complications, while two others had a history of severe ocular trauma.

Figure 1 compares the mean preoperative and postoperative BCVA in the two groups. Monocular patients had a lower BCVA compared to binocular patients, both before and after surgery ($p < 0.01$). The visual acuity of both groups significantly improved after surgery ($p < 0.05$), with no significant difference in visual-acuity improvement between the two groups ($p = 0.054$).

The mean axial length of the operated eye in the monocular group was 23.41 ± 1.68 mm vs. 22.94 ± 2.35 mm in the control group. The difference between the two groups was not statistically significant ($p = 0.219$).

The CDE value was available in 54/160 surgical reports. The mean CDE was 11.39 ± 3.67 for monocular patients ($n = 21$) and 9.63 ± 4.08 in the

Table 1 Patient demographic characteristics and methods of anesthesia

	Case group (monocular patients)	Control group (binocular patients)	Statistical differences
Number of patients	80	80	–
Age (years \pm SD)	77.1 \pm 9.06	71.24 \pm 8.46	$p=0.0006$
<i>Sex (number, %)</i>			
Male	30 (37.5%)	37 (46.25%)	$p=0.162$
Female	50 (62.5%)	43 (53.75%)	$p=0.063$
<i>Operated eye (number)</i>			
Right	32	45	$p=0.022$
Left	48	35	$p=0.025$
<i>Anesthesia (number, %)</i>			
Topical	62 (77.5%)	69 (86.25%)	$p=0.217$
General	18 (22.5%)	11 (13.75%)	$p=0.180$

The mean age at the time of surgery was significantly higher in the monocular group than in the binocular group ($p<0.001$). A female predominance was noted in the two groups. Left eyes were more frequently operated than right eyes in the monocular group, while we noted the opposite in the binocular group ($p<0.05$). There was no significant difference in the anesthesia methods between the two groups

Table 2 Ocular comorbidities associated with cataract in the operated eyes

Ocular comorbidities	Case group (monocular patients)	Control group (binocular patients)
Age-related macular degeneration	15	6
Fuchs corneal dystrophy	2	3
Diabetic retinopathy	4	2
Open-angle glaucoma	8	7
High myopia	3	1
Total	32	19

There was a statistically significant difference in the total number of comorbidities between the two groups ($p<0.05$). Two comorbidities were present in the same patient in seven cases in the monocular group and in two cases in the binocular group. Three or more comorbidities were present in the same patient in two cases in the monocular group, while none of the patients in the binocular group exhibited three or more comorbidities. Age-related macular degeneration and open-angle glaucoma were the two main comorbidities observed in the case group and in the control group. High myopia was defined as myopia associated with chorioretinal degenerations

binocular group ($n=33$). The difference between the two groups was not statistically significant ($p=0.206$).

No intraoperative complications were noted in the procedures that were performed in the binocular group. Conversely, we identified one case of posterior capsule rupture, without vitreous loss, in the monocular group. In this instance, the intraocular lens was inserted into the sulcus.

In addition, we encountered two postoperative complications in the monocular group. The first was a retained lens fragment in the anterior chamber, while the second was a dendritic keratitis that occurred on

postoperative Day 26 in a patient without a herpetic history.

In the binocular group, one patient developed Irvine–Gass syndrome, which was noted on Day 30 after an uneventful procedure.

In terms of rates of intraoperative and postoperative complications, there was no significant difference between the two groups ($p=0.622$).

Table 3 Monocular status: reasons of poor vision or blindness in non-operated eyes

Reasons for poor vision in the fellow eye	Number of eyes (%)
Amblyopia and/or strabismus	22 (27.5%)
Age-related macular degeneration	19 (23.75%)
Retinal detachment	13 (16.25%)
Retinal vein occlusion	5 (6.25%)
Retinal artery occlusion	2 (2.50%)
Ischemic optic neuropathy	2 (2.50%)
Ocular trauma	6 (7.50%)
Infectious keratitis	3 (3.75%)
Toxoplasmic chorioretinitis	1 (1.25%)
Acute angle-closure glaucoma	4 (5%)
Congenital cataract	3 (3.75%)

Amblyopia caused by strabismus was the main reason for poor vision in the non-operated eye (22 patients). Infectious keratitis cases included one case of bacterial keratitis and two cases of herpetic keratitis with corneal opacities

Discussion

The last 50 years have seen continuous and remarkable progress in surgical techniques for cataract

extraction, which have improved patients' visual outcomes and quality of life, as well as the procedure's efficiency and safety [4]. Our study aimed to identify monocular patients' visual comorbidities and reasons for blindness and evaluate the visual impact of cataract surgery on this group. Few similar studies have been conducted in the past, using either intracapsular or extracapsular cataract extraction [9] or, more recently, phacoemulsification as the surgical procedure [10–12]. These studies used a method that matches patients by age and sex. Our study used a consecutive case-series selection in which all procedures were performed in the same hospital center and by the same surgeon (TB).

With regard to the etiology of the monocular loss of vision, amblyopia and strabismus were the main reasons for monocular status in this study, followed by age-related macular degeneration (ARMD) and retinal detachment. In the early 2000s, Miller et al. reported that the main reason for poor vision in non-operated eyes was ARMD, followed by end-stage glaucoma and proliferative diabetic retinopathy [11, 13]. Conversely, in the 1950s, Callahan et al. concluded that the major causes of visual impairment

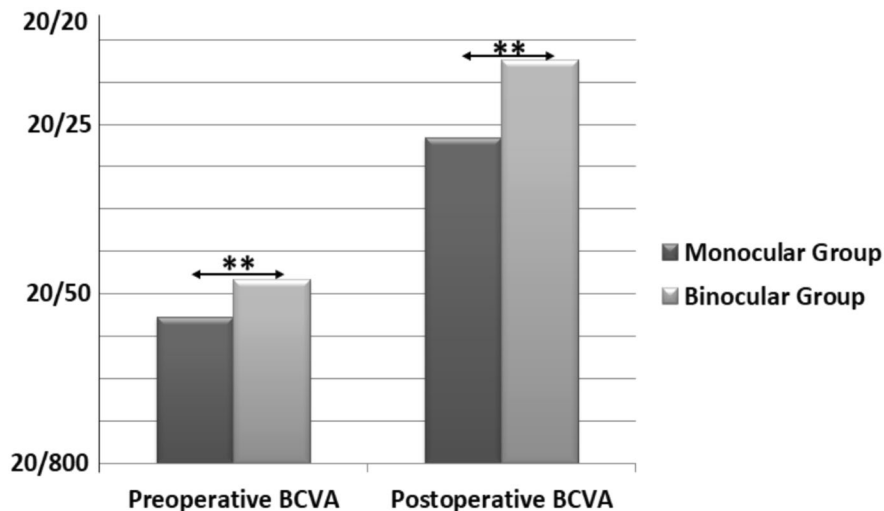


Fig.1 The mean preoperative best-corrected visual acuity (BCVA) was significantly different between the two groups: 20/58 (± 0.363 , range 20/200–20/30) in the monocular group and 20/46 (± 0.365 , range 20/200–20/30) in the binocular group ($p < 0.01$). On Day 30 after surgery, the BCVA was 20/26 (± 0.26 , range 20/50–20/20) in the monocular group and 20/21 (± 0.890 , range 20/30–20/20) in the binocular group ($p < 0.01$). In the monocular group, 69 eyes (86%) were cor-

rected to at least 20/32 and 21 eyes (26%) to 20/20, while in the binocular group, 80 eyes (100%) were corrected to at least 20/32 and 53 eyes (66%) to 20/20. Only one functionally monocular patient was operated from his advanced cataract in his fellow blind eye; this patient had an atrophic age-related macular degeneration, with a BCVA of 20/200 preoperatively that improved to 20/63 postoperatively. $** p < 0.01$

in functionally monocular patients were complications following cataract surgery, end-stage glaucoma, and severe ocular trauma [9]. Ranking differences between reasons for blindness among monocular patients reflects first of all a general evolution in ophthalmologic practices over time and secondly, a disparity between geographical regions with unequal access to care, particularly in terms of the prevention, early diagnosis, and treatment of these medical conditions. Although ARMD, open-angle glaucoma, and diabetic retinopathy are age-related diseases with well-codified treatment options (e.g., intravitreal injection of anti-vascular endothelium growth factor [VEGF] drugs, intraocular pressure-reducing medications, and retinal laser therapy), amblyopia is still a public-health concern. The high proportion of amblyopic patients in our study may be explained by the recruitment of many patients from a mountainous region (the Vosges), with very poor access to visual care.

The prevalence of ocular comorbidities was significantly higher in the monocular group (32 vs. 19 $p < 0.05$), which could be the result of the age gap between the two groups. However, Miller et al. also reported such a difference in the prevalence of ocular comorbidities, while their control subjects were matched to study patients by age, sex, and date of surgery [11]. In our series, ARMD, open-angle glaucoma, and diabetic retinopathy were the three main ocular comorbidities observed in the monocular group, as previously published. Interestingly, in our study, axial myopia and hyperopia did not appear to be correlated with monocular conditions, since axial lengths were similar in both groups and could be considered normal.

The timing of the surgical procedure in monocular patients remains a major dilemma for cataract surgery. Both ophthalmologists and patients tend to delay cataract surgery in monocular patients, which is likely to worsen the patient's quality of life [6, 7]. Our results confirm that monocular patients were significantly older when compared to binocular patients (77 vs. 71 years old, $p < 0.001$). Preoperative BCVA was also lower in monocular patients (20/58 vs. 20/46), since cataract is an age-related condition and other age-related comorbidities were present. However, the age difference between the two groups may have several causes. Firstly, monocular patients had more associated ophthalmological comorbidities, which

could have delayed detection of cataract-related vision loss. On the other hand, patients who rely on an only eye would be more likely to consult a specialist in the event of reduced acuity in that eye. Another explanation could be that, as some of the patients in our monocular group came from a mountainous region, they had more difficult access to healthcare, which could have led to a delay in surgical care.

The distribution of anesthesia methods was not statistically different between the two groups. Surprisingly, we used more general anesthesia than the Miller et al. study (22.5% vs. 13%), which was published in 2002 [11]. This disparity can be explained by patient, anesthesiologist, and surgeon preferences. We believe that all anesthetic options should be proposed to monocular patients, due to the level of psychological stress before surgery. This increased level of stress can be caused by fear of an intraoperative complication or poor visual outcome, likely to lead to complete blindness. Some patients and surgeons also believe the surgery is safer and more comfortable when performed under general anesthesia.

Interestingly, Kataguirri et al. reported in 2021 on a small case-control study investigating the intraoperative emotional reactions of monocular patients versus binocular patients by recording objective stress indicators (vital signs: blood pressure, heart rate) and subjective signs (head and eye movements, signs of vitreous cavity pressure). All their study subjects were under topical anesthesia, with sedation adjusted intraoperatively if deemed necessary. No statistical difference was found in terms of sedation drugs use and objective or subjective stress indicators between the monocular and the binocular group. [12]. Aside from the patient, the surgeon's stress is also a factor to be considered, especially among less-experienced ones. In a 2019 publication, Chen et al. investigated the outcomes of resident-performed cataract surgery on one-sighted patients in the US and found that, if the outcomes and complication rates were not significantly different, the surgery was the source of greater anxiety among residents than among attendings [14]. Those parameters were not investigated in our study.

The complication rate in the present study was quite low in comparison with data reported in the literature for series of binocular and monocular patients [7, 11, 13]. We confirm that cataract surgery is as safe for monocular patients as binocular patients. Therefore, delaying surgery seems to be unnecessary and

might even increase the risk of complications that are associated with dense cataracts or loss of visual acuity, as a result of the accumulation of medical comorbidities over the years.

As described in the literature, the CDE reflects the amount of energy released during phacoemulsification. A higher CDE value is related to longer surgical and recovery times [15]. When comparing the case and control groups, the CDE was not statistically different (11.39 vs. 9.63). However, this analysis should be viewed critically due to the small number of included values, which is a result of the retrospective design of the study.

Visual improvement of three lines in postoperative BCVA was statistically significant in both monocular and binocular patients, and the improvement in visual acuity measured in both groups was statistically similar ($p=0.054$). We thus confirm the results of previous studies, in which both groups experienced the same three-line improvement in median Snellen BCVA [10, 11]. Using the same method of cataract extraction, namely phacoemulsification, as well as the relative similarity in the population of patients (in terms of both age and socioeconomic status) could explain the similar outcomes.

Our study is not free of limitations. We selected patients using a consecutive case-series selection, instead of matching patients by age and sex, the method used by other case-control studies. As there are few monocular patients per year, this consecutive selection method increased the possibility for us to focus on differences between the two groups, particularly concerning age and comorbidities. We sought to decrease dispersion by limiting the procedures to those performed in the same hospital center and by the same surgeon. A significant deficit in our study lies in the absence of subjective quality-of-life instruments, such as the SF-36, and particularly vision-specific survey instruments, such as the VF-14. As noted by Pomberg and Miller, the Snellen BCVA is a poor measure of visual impairment when it is caused by cataract [10]. Thus, it is both an inadequate criterion for determining the need for surgery and a poor measure of the change in visual function following cataract surgery. Notably, monocular patients do not have another seeing eye to alleviate the disability caused by cataract, the development of which, in this group, leads directly

to serious bilateral visual dysfunction. Since the surgical procedure is performed on the eye that allows the patient to see better, this provides them with the greatest gain in functional vision. Therefore, we recommend conducting a prospective case-control study that includes a self-reported visual function questionnaire, both before and after surgery. On this subject, Li et al. reported that, while monocular patients have a lower vision-related quality of life before and after cataract surgery, they achieve an increase in vision-related quality of life approximately twice that of binocular controls, as assessed by the VFQ-25 [16].

In conclusion, functionally monocular patients present increased rates of ocular comorbidities, some of which may limit visual outcomes of cataract surgery either immediately after the procedure or in the long term. As certain observed comorbidities are related to age, delaying surgery is not recommended. As procedures in monocular patients are currently significantly delayed despite indications that cataract surgery is safe for monocular patients, future studies, particularly prospective case-controls that employ a quality-of-life questionnaire and observational studies that analyze the stress of patients and surgeons before and during cataract extraction, should yield interesting results and significantly impact practice recommendations.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by OD. FA helped in data collection. AEH and TA performed the statistical analysis. EK helped with the literature review and the draft manuscript preparation. The first draft of the manuscript was written by OD, and all authors commented on previous versions of the manuscript. TB and AS supervised the project. All authors read and approved the final manuscript.

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Declarations

Conflict of interests The authors have no relevant financial or non-financial interests to disclose.

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