EXTENDED REPORT

Bilateral cataract surgery and driving performance

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Background: Cataract surgery is one of the most common medical procedures undertaken worldwide.
Aims: To investigate whether cataract surgery can improve driving performance and whether this can be predicted by changes in visual function.
Methods: 29 older patients with bilateral cataracts and 18 controls with normal vision were tested. All were licensed drivers. Driving and vision performance were measured before cataract surgery and after second eye surgery for the patients with cataract and on two separate occasions for the controls. Driving performance was assessed on a closed-road circuit. Visual acuity, contrast sensitivity, glare sensitivity and kinetic visual fields were measured at each test session.
Results: Patients with cataract had significantly poorer ($p<0.05$) driving performance at the first visit than the controls for a range of measures of driving performance, which significantly improved to the level of the controls after extraction of both cataracts. The change in contrast sensitivity after surgery was the best predictor of the improvements in driving performance in patients with cataract.
Conclusions: Cataract surgery results in marked improvements in driving performance, which are related to concurrent improvements in contrast sensitivity.

Older people comprise the fastest growing sector of the driving population; this has important implications for road safety as they are also reported to have high crash rates per distance travelled.[1] However, not all older drivers are unsafe, and many continue to drive safely well into older age. Recent research has sought to identify tests that can accurately differentiate between safe and unsafe drivers, recognising that it is functional rather than chronological age that best predicts driving ability, as well as seeking interventions, which can extend the time that older drivers can drive safely. Cataract surgery has been suggested as an intervention that can potentially improve the performance of older drivers.

A growing body of evidence suggests that older drivers with cataracts are less safe to drive than their counterparts without cataracts. People with cataracts experience more problems when driving, drive shorter distances and avoid challenging driving situations.[2] Nevertheless, despite limiting their driving exposure, drivers with cataracts have 2.5 times more crashes than controls[2]; and crash involvement is predicted by deficits in contrast sensitivity.[3] Further evidence comes from closed-road and open-road studies, which have shown that drivers with either simulated[4 5] or true cataracts[6–8] have considerably impaired driving performance compared with controls. The presence of cataracts has also been associated with driving cessation.[9]

The positive benefits of cataract surgery on vision and quality of life have been widely reported; however, fewer studies have investigated the impact of cataract surgery on real-world activities such as driving. Crash rates have been shown to halve after cataract surgery compared with controls, suggesting that cataract surgery can result in tangible benefits to road safety.[10] Self-reported improvements in driving have been described within 1 year[11 12] and 5 years after surgery,[13] and the driving subscales of the Activities of Daily Vision Scale improve after cataract surgery, particularly for night driving.[14 15]

This study investigated the effect cataract surgery on real-world measures of driving performance for patients undergoing bilateral cataract surgery within a 3-month period, and determined how well these measures related to changes in visual performance.

METHODS

Participants

Thirty eight patients with cataract scheduled for bilateral cataract surgery were recruited, of whom two withdrew, one had age-related maculopathy and six patients decided to have only one cataract removed; the final sample consisted of 29 patients with cataract, ranging in age from 50 to 89 years (mean (standard deviation (SD)) 73 (8)). The patients with cataract had no ocular disease except cataracts; most patients (75%) had nuclear cataracts or a combination of nuclear and cortical cataracts. Eighteen controls were also tested, who ranged in age from 53 to 78 years (mean (SD) 68 (7)), had normal visual acuity (better than 20/25 or 6/7.5) and were free of ocular pathology. All participants were in good general health and were licensed drivers who drove regularly. In Queensland, Australia, the visual acuity standard is 6/12 binocularly or better, which at the time of the study was tested at 5-yearly intervals on licence renewal.

The study was conducted in accordance with the requirements of the Queensland University of Technology Human Research Ethics Committee. All participants were given a full explanation of experimental procedures and written informed consent was obtained, with the option to withdraw from the study at any time.

Participants attended a series of vision and driving test sessions. Patients with cataract were tested within a month before their first operation and at least 1 month after the second (mean length of time since the last cataract surgery was 80 days). The controls followed a similar testing pattern. The driving and visual performance measures were undertaken with participants wearing the spectacle correction usually worn for driving, and the patients with cataract wearing any new spectacles prescribed after cataract surgery.

Abbreviations: BAT, Brightness Acuity Tester; BGT, Berkeley Glare Test

Table 1 Group mean driving performance scores (SD) for both participant groups at the first and second visits

	Cataracts		Controls	
Driving measures	Preop	Postop	1st visit	2nd visit
Sign recognition	37.41 (12.56)	47.76 (7.79)	48.00 (7.52)	49.61 (7.19)
Road hazard recognition	7.69 (1.54)	8.83 (0.38)	8.83 (0.52)	8.61 (0.78)
Road hazard avoidance	2.04 (1.86)	0.48 (0.91)	0.22 (0.55)	0.39 (0.78)
Gap perception	1.79 (1.57)	1.86 (1.16)	2.11 (1.57)	1.61 (1.65)
Divided attention	5.31 (3.91)	7.04 (3.84)	7.44 (4.26)	9.50 (3.84)
Manoeuvring time	48.44 (16.69)	48.07 (13.85)	49.73 (16.08)	46.17 (11.56)
Time to complete (s)	451.05 (62.35)	437.75 (50.42)	439.00 (43.18)	442.65 (48.07)
Overall driving score	−0.38 (0.75)	0.18 (0.37)	0.14 (0.41)	0.19 (0.51)

Postop, postoperative; preop, preoperative.

Driving performance

Driving performance was assessed under daytime conditions on a closed-road circuit, which is 5.1 km in length, free of other vehicles and representative of rural roads.[4] Driving assessments were undertaken in sunny conditions between 07:00 and 10:00 h, at around the same time of the day for each participant. The assessment was undertaken in a station wagon with automatic transmission and power steering. Each participant completed a practice run performed in the direction opposite to the recorded run. The driving assessment was selected to provide a relatively high degree of complexity, involving tasks of recognition, divided attention, gap perception, speed and manoeuvring, and has been described in detail by Wood *et al*.[16] The outcome measures included sign recognition, road hazard recognition and road hazard avoidance, correct gap judgements, divided attention, manoeuvring time and time to complete the course.

Vision performance

Vision performance was measured at each testing session. Binocular and monocular visual acuities were measured using a high-contrast (90%) Bailey Lovie chart at 3 m. Participants were instructed to guess letters even when unsure; visual acuity was scored on a letter-by-letter basis. Letter contrast sensitivity was measured binocularly and monocularly using the Pelli–Robson chart under the recommended viewing conditions. Participants were instructed to look at a line of letters and guess the letter when they were unsure; each letter reported correctly was scored as 0.05 log units.

Disability glare sensitivity was assessed using both the Berkeley Glare Test (BGT) and the Brightness Acuity Tester (BAT). Both these tests have been used to measure disability glare in previous studies investigating the functional effect of cataract surgery.[3 14] The BGT can assess glare sensitivity monocularly and binocularly, and measures the ability to recognise low-contrast letters (10% contrast) in the presence and absence of a glare source at the medium setting of 750 cd/m^2.[17] The glare score is the difference in visual acuity for glare and no-glare conditions. Disability glare was also estimated with the BAT using the Pelli–Robson chart. Disability glare was defined as the Pelli–Robson score without the BAT minus that with the BAT.

Kinetic fields were measured binocularly using a large low-contrast target (size IV4B) moving at a speed of 4°/s along 12 meridians of the visual field. The area of the kinetic field was calculated using a custom-designed programme.

Statistical methods

The driving and vision measures at the first visit were analysed using a series of independent t tests to highlight any group differences (cataract and control) in performance. To determine whether cataract surgery resulted in any improvements in driving and vision performance over and above practice effects, a series of repeated measures regression models was constructed, with test session as the within-group factor and group allocation (cataracts or controls) as the between-group factor. A series of one-way analyses of variance were conducted on those variables that displayed significant two-way interactions.

To determine whether any of the changes in visual performance after cataract surgery could predict the improvements in driving performance, a bivariate Pearson's correlation matrix was constructed with overall driving score as the outcome measure. A regression model (using a forward stepwise model) was then constructed, including only the significant vision predictors from the bivariate correlations.

RESULTS

The mean age of the cataract group was slightly higher than that of the controls by about 5 years ($t_{(45)} = 2.49$; $p = 0.02$); this difference was of magnitude similar to the age difference

Table 2 Group mean vision performance scores (SD) for both participant groups at the first and second visits

	Cataracts		Controls	
Vision measures	Preop	Postop	1st visit	2nd visit
VA binocular	0.30 (0.15)	0.07 (0.11)	0.02 (0.06)	0.01 (0.10)
VA 1st operated eye	0.53 (0.50)	0.13 (0.12)	0.09 (0.10)	0.11 (0.11)
VA 2nd operated eye	0.31 (0.18)	0.16 (0.15)	0.22 (0.36)	0.18 (0.27)
CS binocular	1.43 (0.16)	1.67 (0.13)	1.77 (0.17)	1.79 (0.16)
CS 1st operated eye	1.26 (0.30)	1.54 (0.13)	1.62 (0.11)	1.69 (0.17)
CS 2nd operated eye	1.36 (0.19)	1.55 (0.13)	1.59 (0.18)	1.58 (0.18)
BGT binocular (n = 20)	10.95 (5.42)	6.28 (5.26)	3.94 (3.56)	6.00 (3.70)
BGT 1st operated eye (n = 13)	10.92 (7.37)	4.31 (4.59)	4.61 (5.31)	8.28 (4.17)
BGT 2nd operated eye (n = 13)	9.31 (6.12)	6.25 (5.38)	5.39 (4.38)	4.78 (3.37)
BAT 1st operated eye	0.32 (0.18)	0.16 (0.15)	0.17 (0.11)	0.23 (0.16)
BAT 2nd operated eye	0.28 (0.21)	0.19 (0.17)	0.22 (0.13)	0.18 (0.17)
Kinetic visual fields	5044.6 (1718.2)	5859.3 (1707.9)	7307.2 (1104.5)	7224.4 (1276.0)

BAT, Brightness Acuity Tester; BGT, Berkeley Glare Test; CS, contrast sensitivity; postop, after operation; preop, before operation; VA, visual acuity.

of a cataract and control group in previous studies.[2] Because of this age differential, we considered the association between the change in overall driving score and age and found it to be non-significant ($r = 0.1$; $p = 0.48$); therefore, no further adjustment for age was made in the data analysis.

Driving performance

Table 1 provides the group mean data for the driving performance measures at the two visits for both groups. At the first visit, the driving performance of the patients with cataract was significantly worse than that of the controls for road sign recognition ($t_{(45)} = -3.23$; $p = 0.002$), road hazard recognition ($t_{(45)} = -3.04$; $p = 0.004$) and avoidance ($t_{(45)} = 4.01$; $p<0.001$), as well as for an index of overall performance ($t_{(45)} = -2.68$; $p = 0.01$) that was determined by calculating the z scores for each of the individual driving measures (with the exception of the manoeuvring task).[7]

Driving performance was shown to improve significantly after cataract surgery for overall driving score ($F_{1,28} = 14.88$; $p = 0.001$), road sign recognition ($F_{1,28} = 20.51$; $p<0.001$), road hazards recognised ($F_{1,28} = 14.72$; $p = 0.001$) and avoided ($F_{1,28} = 17.28$; $p<0.001$). Both the patients with cataract and controls showed a significant improvement in the number of reaction lights seen over the two visits (divided attention task), but there was no significant group×test session interaction, indicating that the improvements may have resulted from the effects of repeated testing rather than improvements in driving function after cataract surgery.

Vision performance

Table 2 provides the mean data for visual performance at the two visits for both groups. At the first visit, the visual performance of the patients with cataract was significantly worse than that of the controls for all vision measures except visual acuity in the second operated eye. Only 20 of the patients with cataract could see the low-contrast letters of the BGT under glare conditions binocularly, and this was reduced to 13 participants monocularly. Participants who could not be assigned a glare score were those with more severe cataracts, and hence inclusion of this variable would have biased the overall analysis of vision and driving after cataract surgery; hence, data for the BGT were excluded from further analysis.

Cataract surgery resulted in four lines of improvement in visual acuity for the first operated eye and 1.5 lines for the second operated eye for the cataract group, with just over two lines binocularly. Mean contrast sensitivity improved by 0.30 log units (two steps) for the first operated eye, 0.20 log units for the second operated eye and 0.25 log units binocularly. Vision performance improved significantly for the patients with cataract after surgery for binocular visual acuity ($F_{1,28} = 56.62$; $p<0.001$), visual acuity in the first operated eye ($F_{1,28} = 20.971$; $p<0.001$) and second operated eye ($F_{1,28} = 20.29$; $p<0.001$), binocular contrast sensitivity ($F_{1,28} = 85.40$; $p<0.001$), contrast sensitivity in the first operated eye ($F_{1,28} = 25.35$; $p<0.001$) and second operated eye ($F_{1,28} = 37.16$; $p<0.001$), and BAT in the first operated eye ($F_{1,27} = 12.89$; $p = 0.001$).

Relationship between the change in vision and driving performance after cataract surgery

Table 3 gives Pearson's r values for the bivariate correlations between changes in visual performance and overall driving score after cataract surgery and shows that change in driving performance was significantly predicted by visual acuity in the first operated eye and contrast sensitivity binocularly and in each eye individually.

The difference in contrast sensitivity scores in the second operated eye was the only visual measure that appeared in the final multiple regression model, showing that it alone was the single best predictor of the change in driving performance after bilateral cataract surgery; the other predictors were highly correlated with this measure and do not appear in the final model.

Table 3 Pearson moment correlation coefficients (r) between the change in overall driving performance and change in vision performance scores after bilateral cataract surgery

Vision measures	Change in driving performance after cataract surgery (p value)
VA binocular	−0.320 (0.094)
VA 1st operated eye	−0.471 (0.01)
VA 2nd operated eye	−0.277 (0.145)
CS binocular	0.399 (0.03)
CS 1st operated eye	0.536 (0.003)
CS 2nd operated eye	0.537 (0.003)
BAT 1st operated eye	−0.260 (0.19)
BAT 2nd operated eye	−0.190 (0.33)
Kinetic visual fields	0.353 (0.065)

BAT, Brightness Acuity Tester; CS, contrast sensitivity; VA, visual acuity.

DISCUSSION

Our findings showed that objective measures of driving performance improved markedly after bilateral cataract surgery compared with a control group, and the improvement in overall driving performance score after cataract surgery was best predicted by the change in contrast sensitivity in the second operated or better eye.

Bilateral cataract surgery resulted in marked improvements in sign recognition, ability to detect and avoid hazards, and overall driving score. In most cases, these improvements brought the performance of the patients with cataract to levels similar to those of the controls. This provides objective evidence of specific improvements in driving performance skills after cataract surgery and has important implications for road safety of older drivers. It is also in accord with the crash data of Owsley *et al*[10] which showed that cataract surgery halved crash rates compared with controls. Similarly, self-reported data suggest that cataract surgery improves many aspects of driving performance and 25% of patients with cataract who had ceased to drive before surgery resumed driving afterwards.[12]

Bilateral cataract surgery also resulted in improvements in both binocular and monocular visual acuity, contrast sensitivity and BAT glare sensitivity, which is in agreement with previous studies.[14 18 19] The changes in visual performance were of a similar order to that reported by Elliott *et al*[14] for visual acuity and contrast sensitivity, but slightly more than that reported by Owsley *et al*.[10]

The improvement in driving performance after cataract surgery was best predicted by the concomitant change in contrast sensitivity scores. This is in accord with the findings of Owsley *et al*,[3] who reported that crash-involved participants were eight times more likely to have reduced contrast sensitivity than controls and that this relationship was strongest for the worst eye, whereas in our study it was strongest for the better eye. Our study does, however, agree with other studies that have shown that vision in the better eye is predictive of real-world visual tasks including face recognition and reading,[20] mobility,[14] as well as Activities of Daily Vision Scale scores.[14 20] Importantly, the study of Elliott *et al*[14] specifically looked at this relationship in patients following cataract surgery. Together, these findings provide a better understanding of the functional benefits of cataract surgery.

The finding that contrast sensitivity is an important predictor of changes in driving performance after cataract surgery both in our study and in that of Owsley *et al*[3] is also supported by previous research. Decina and Staplin[21] reported that contrast sensitivity is a significant factor contributing to the prediction of crash rates in older drivers, and our previous studies found a strong relationship between contrast sensitivity and driving performance for simulated[22] and true cataracts,[7] and also found contrast sensitivity to be a predictor of drivers' recognition performance (signs, hazards and pedestrians) under daytime and night-time conditions.[23] Neither our study nor that of Owsley *et al*[3] found a predictive relationship between glare sensitivity and driving.

Although this study is limited by relatively small subject numbers, resulting from the stringent inclusion criteria and experimental demands at a time when patients are preparing for surgery, it has some important advantages. In particular, our experimental approach meant that any changes in driving were recorded over a relatively short period, so that their additional effects of ageing were minimised; those participants who experienced other events that might affect their driving ability were excluded from the experimental design. Our findings show that cataracts can markedly impair many aspects of driving performance and that cataract extraction has the potential to improve driving performance to normal age-matched controls. Importantly, these benefits in driving performance can be best predicted by changes in contrast sensitivity in the better eye. Cataract surgery can thus be considered to be an important intervention for road safety for older people with cataracts, and potentially has the effect of usefully prolonging the period over which older people can drive, resulting in improved mobility and independence.

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