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Bilateral cataract surgery improves neurologic brake reaction time and stopping distance in elderly drivers

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ABSTRACT.

Aims: **To determine brake reaction times before and after bilateral cataract surgery in elderly drivers.**

Methods: **Sixty-four patients were evaluated on the day of and 4 weeks after bilateral cataract surgery. Forty-three healthy individuals with a valid driving licence served as the control group. A driving simulator was used to determine brake reaction times after receiving a visual stimulus. Total brake reaction time (BRT) as well as neurologic reaction time (NRT), foot transfer time (FTT) and brake pedal travel time (BPTT) were measured, and the measurements obtained before and after cataract surgery were compared. The correlations between NRT, best-corrected visual acuity (BCVA) and contrast sensitivity (CS) were assessed.**

Results: **Out of the 64 patients with bilateral cataract, 53 were assessed for postsurgical measurements. All time measures improved significantly after cataract surgery (BRT, 815.7(224) versus 647.9(148) ms; NRT, 364.7(91) versus 283.5(44) ms; FTT, 290.8(62) versus 248.6(58) ms; and BPTT, 160.6(96) versus 116.6(72) ms, $p < 0.001$). The calculated stopping distance improved significantly after surgery (22.3(6) versus 19.9(4) m at 50 km/h). Best-corrected visual acuity (BCVA) and contrast sensitivity (CS) improved significantly after surgery (0.25 (0.2) versus 0.05(0.05), $n = 53$, $p < 0.001$; 1.4(0.2) versus 1.6(0.1), $p < 0.001$, respectively). There was a significant negative correlation between CS and NRT before surgery ($r = -0.253$, $n = 64$, $p = 0.04$, Pearson's correlation).**

Conclusion: **Our findings show a significant effect of CS on neurological BRTs and the corresponding stopping distances. This highlights the importance of presurgical CS evaluation as a critical factor in cataract surgery decisions in elderly drivers.**

Key words: neurologic brake reaction time – bilateral cataract surgery – stopping distance – elderly drivers

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Introduction

In an ageing society, elderly people constitute the fastest growing proportion of the driving population (Stamatiadis & Deacon 1995). Driving increases the quality of life of elderly individuals by allowing them to remain self-reliant and should therefore be encouraged, but only in compliance with safety requirements (DECARLO et al. 2003). Cataract is the leading cause of vision impairment in older adults and causes deficits in acuity and contrast sensitivity (CS) along with increased disability glare (Rubin et al. 1993). Evidence shows that older adults who undergo cataract extraction have roughly half the rate of motor vehicle collision involvement per mile driven compared to cataract patients who do not elect to undergo cataract surgery (Mennemeyer et al. 2013). The role of vision in driver safety and in driver performance has been addressed by many researchers over the past few decades (Owsley & McGwin 2010). Among the various important factors identified to be contributing to driving ability, assessed in terms of visual acuity and CS (Wood & Carberry 2006; Owsley & McGwin 2010; Agramunt et al. 2017; Havstam Johansson et al. 2020), brake reaction time (BRT) was reported to be a key parameter (Ganz et al. 2003; Pierson et al. 2003; Al-khayer et al. 2008). However, there is little knowledge outlining how BRTs change after bilateral cataract surgery and if this has an impact on stopping distance. The aim of the study therefore was to analyse different braking times during brake reaction and evaluate their association with visual acuity and CS in elderly drivers before and after bilateral cataract surgery.

Methods

Participants

In this prospective study, subjects scheduled for bilateral cataract surgery at the outpatient unit of the University Hospital for Ophthalmology and Optometry Innsbruck, Austria, were invited to participate. The admission period was between May and August 2019. The study was approved by the Ethics Committee of the Medical University of Innsbruck No. AN 2016-0050 360/4.2 397/5.1 (4410a) and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. This project was conducted in accordance with the STROBE guidelines for observational studies.

Inclusion criteria for participation in this study comprised a minimum age of at least 18 years and possession of a valid driving licence. Subjects were excluded from the study in the presence of neurological diseases, a history of previous eye disease or in case of a suspended driver's licence. Both inclusion and exclusion criteria were determined using a short questionnaire. A total of 107 consecutive participants were recruited. Sixty-four patients with cataract scheduled for bilateral cataract surgery were recruited on the day of surgery and re-evaluated one month after both eyes had been operated. This protocol was chosen to eliminate a possible visual bias of the better seeing eye in brake reaction time. Only patients where both eyes should be operated on were included. Forty-three healthy age-matched volunteers were recruited in the course of local health days and served as the control group when their best-corrected visual acuity (BCVA) was greater than or equal to 0.2 logMAR in the better eye. Written informed consent of all participants was obtained.

Procedure

We devised an adjustable car seat mounted on a frame with pedals hanging from rubber-damped pivots and used it as an experimental driving simulator (Ganz et al. 2003; Al-khayer et al. 2008). This apparatus has been validated in the published literature (Brenner et al. 2018; Laimer et al. 2019). Brake reaction times (BRTs) were determined by an external device containing logic gate electronics. As described in previous investigations, the procedure was initiated when the participants fully depressed the accelerator, which was confirmed electronically to the examiner (Brenner et al. 2018). After an interval of 5–10 s, the examiner activated a red lamp positioned in the binocular standard line of sight, which activated the electronic clock and served as the visual stimulus for the participant. Illumination of the light source was 202.8 lumen. The time interval until the subject operated the brake pedal with 160 N was measured and recorded as the total brake reaction time (BRT). In addition to BRT, neurologic reaction time (NRT, time from stimulus until the patients starts pulling back his/her foot), foot transfer time (FTT, time from the start of foot retraction from the accelerator until initial contact with the brake pedal) and brake pedal travel time (BPTT, time from initial contact with the brake pedal until 160 N was reached) were measured (see Figure 1). Best-corrected visual acuity (BCVA) was obtained by using a high contrast (>90%) Bailey Lovie chart at three metres, whereas contrast sensitivity (CS) was obtained by using a Pelli-Robson Letter Chart (Metropia Ltd, Cambridge, England). Participants were given the opportunity to brake ten times before recording of measurements was started. Cataract group was tested on day of and four weeks after bilateral cataract surgery, whereas healthy volunteers were tested only once. Measurements were carried out in standardized light (747 lux) and dark (10 lux) conditions. Reaction distance was calculated using the following formula: ($s = v*t$, s = reaction distance; v = velocity in m/s, t = brake reaction time = BRT). To gain stopping distance, first braking distance had to be calculated by using the following formula: ($s = [(v)^2/(2*a^2)]$, s = braking distance, v = m/s, a = assumed acceleration for dry road conditions = −8 m/s). Reaction and braking distance were then summed up to give overall stopping distance.

Statistics

All data were analysed for normal distribution and equal variances with the Kolmogorov–Smirnov test by BM Corp. Released 2016. IBM SPSS

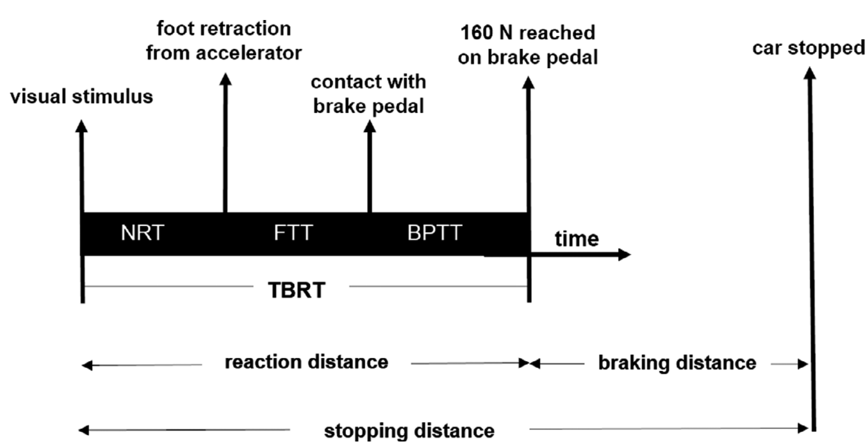

Fig. 1. Total brake reaction time (TBRT) and its components neurologic reaction time (NRT), foot transfer time (FTT) and brake pedal transfer time (BPTT) in the context of stopping distance.

Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. Independent sample *t*-tests were used to analyse differences between the study and control groups. Paired sample *t*-tests were used to compare preoperative and postoperative measurements. Pearson's correlation analysis was used to analyse the correlations of BCVA, CS and driving frequency to NRT before and after surgery. Best-corrected visual acuity (BCVA) is presented in logMAR. Data are presented as mean (SD), and statistical significance was set to <0.05.

Results

Sixty-four patients with cataract scheduled for elective cataract surgery were recruited for the study, of whom 28 were female and 36 were male (mean age, 72 (8) years). Of these, 53 could be recruited for postsurgical evaluation. In addition, 43 healthy volunteers were recruited for the control group, consisting of 27 female and 16 male drivers (mean age, 61 (13) years).

Braking ability

When comparing the braking ability in light versus dark conditions, no difference could be found before and after cataract surgery. Therefore, all the results provided below were obtained under lighted conditions.

Bilateral cataract surgery resulted in significant improvements in braking ability for all measurements (NRT, FTT, BPTT and BRT, paired sample t-test; NRT, 364.7 (91) versus 283.5 (44) ms; FTT, 290.8 (62) versus 248.6 (58) ms; BPTT, 160.6 (96) versus 116.6 (72) ms; BRT, 815.7 (224) versus 647.9 (148) ms, $p < 0.001$, $n = 53$). When comparing mean braking measurements (NRT, FTT, BPTT and BRT) between the control group and cataract group before surgery, the control group showed significantly faster braking times than the cataract group (independent sample t-test; NRT, 296.7 (49) versus 377.5 (117) ms, $p < 0.001$; FTT, 241.5 (58) versus 298.2 (72) ms, $p < 0.001$; BPTT, 95.6 (67) versus 166.05 (101) ms, $p < 0.001$; BRT, 633.7 (147) versus 841.4 (263) ms, $p < 0.001$; $n = 43$ versus $n = 64$, respectively, see Figure 2). After surgery, there was no difference found in brake reaction times between control ($n = 43$) and cataract group ($n = 53$; independent sampled *t*-test, NRT 296.7 (49) versus 283.5 (44) ms, $p = 0.219$; FTT 241.5 (58.2) versus 248.6 (44) ms, $p = 0.983$; BPTT 95.6 (66.8) versus 116.6 (72.1) ms, $p = 0.281$; BRT 633.7 (147) versus 647.9 (147) ms, $p = 0.737$).

BCVA, contrast sensitivity and driving frequency

Bilateral cataract surgery also resulted in significant improvements in BCVA (log MAR), CS and driving frequency (see Table 1).

The control group showed significantly better best-corrected mean visual acuity (BCVA, logMAR) than the cataract group before surgery. Furthermore, the control group showed better CS than patients before surgery but worse CS than patients after surgery (see Table 2).

Stopping distance

Calculated stopping distance improved significantly after bilateral cataract surgery (22.3 (6) versus 19.9 (4) metres at 50 km/h). For detailed stopping distance calculations, see Table 3.

Correlation of BCVA (logMAR), CS and age with NRT

There was no significant correlation between BCVA and NRT before and after surgery. However, there was a negative correlation between CS and NRT before surgery but not after cataract surgery (see Table 4). There was a weak correlation between NRT and age before surgery, but there was no correlation after surgery (see Table 4).

Gender-related aspects

Of 107 participants, 55 were female and 52 were male. Interestingly, no difference was found between female and male study participants in the mean NRT evaluated before and after surgery

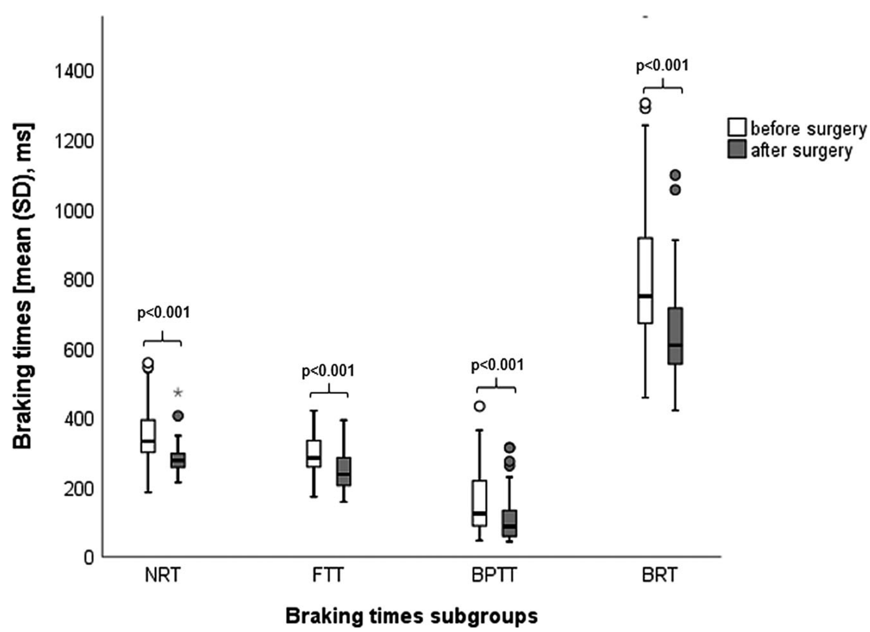

Fig. 2. Changes in brake reaction times before and four weeks after bilateral cataract surgery (NRT = neurological reaction time, FTT = foot transfer time, BPTT = brake pedal transfer time, BRT = overall brake reaction time), SD = standard deviation, ms = milliseconds.

Table 1. Calculated reaction and stopping distances before and after bilateral cataract surgery.

	Reaction distance at 50 km/h (m, SD)	Stopping distance at 50 km/h (m, SD)	p Value	Reaction distance at 100 km/h (m, SD)	Stopping distance at 100 km/h (m, SD)	p Value
Before surgery	11.3 (3.1)	23.4 (3.1)	<0.001	22.7 (6.2)	66.4 (6.2)	<0.001
After surgery	9.0 (2.1)	21.1 (2.1)	<0.001	18.0 (4.1)	61.7 (4.1)	<0.001

BCVA (best-corrected visual acuity) is shown in logMAR (logarithm of minimal angle of resolution), SD = standard deviation, CS = contrast sensitivity, DF = driving frequency, paired sample *t*-test, *n* = number of patients.

Table 2. Comparison of BCVA, CS and DF before and after bilateral cataract surgery.

	Before surgery (*n* = 53)	After surgery (*n* = 53)	p Value
BCVA	0.25 (0.2)	0.05 (0.05)	<0.001
CS	1.4 (0.2)	1.6 (0.1)	<0.001
DF	3.4 (1.5)	3.6 (1.5)	0.006

BCVA (best-corrected visual acuity) in logMAR (logarithm of minimal angle of resolution), SD = standard deviation, CS = contrast sensitivity, independent sample *t*-test, *n* = number of patients.

Table 3. Comparison of BCVA and CS between control and cataract group.

	Control (*n* = 43)	Before surgery with LOF (*n* = 64)	After surgery (*n* = 53)	p Value
BCVA	−0.04 (0.07)	0.27 (0.15)	0.05 (0.06)	<0.001
CS	1.54 (0.1)	1.45 (0.2)	1.6 (0.1)	<0.001

Calculated stopping distances for 50 and 100 km/h before and after bilateral cataract surgery assuming 8 m/s^2 acceleration at dry road conditions, m = metres, SD = standard deviation.

Table 4. Correlation between BCVA, CS, age and NRT.

	NRT before surgery (*r*, *n* = 64)	p Value	NRT after surgery (*r*, *n* = 53)	p Value
BCVA	0.157	0.216	0.257	0.063
CS	−0.253	0.04	−0.268	0.052
Age	0.259	0.039	0.196	0.16

(334.7 (91) ms versus 355.8 (114) ms p = 0.3, before surgery and 289.2 (61) ms versus 279.3 (27) ms, p = 0.43 after surgery). Brake pedal travel time (BPTT) was significantly higher in male participants before and after bilateral cataract surgery (BPTT: 159.4 (101) versus 114.8 (84) ms, p = 0.015, *n* = 55 versus 52; BPTT: 158.9 (79) versus 86.6 (49) ms, p < 0.001, *n* = 22 versus 31). There was no statistical difference in age between women and men (66 (11) years versus 69 (12) years versus, *n* = 55 versus 52, p = 0.14).

Discussion

In this prospective study, we could successfully show that BRTs significantly improved after bilateral cataract surgery. This improvement lead to a significantly reduced stopping distance. Interestingly, CS before cataract surgery correlated negatively with the NRT. Female drivers showed no difference in NRT in comparison with male drivers before and after surgery, but women showed significantly lower FTT and overall BRT after cataract surgery than their male counterparts. Interestingly, the control group showed better CS than patients before surgery but worse CS than patients after surgery.

The study concept of measuring BRTs after surgical procedures is not new in the literature. Brenner et al reported no change in BRT in patients undergoing right-sided puncture of the femoral artery during coronary angiography, concluding that patients might drive at day one after the procedure (Brenner et al. 2018). For more invasive surgical procedures such as inguinal hernia repair (Wright et al. 1999), hip arthroplasty (Macdonald & Owen 1988; Ganz et al. 2003) or total knee arthroscopy (Hau et al. 2000), authors recommended temporary postoperative driving abstinence due to a delay in the BRT. In this regard, detailed brake reaction measurements have not been conducted in studies of driving ability and performance in patients with bilateral cataract.

In our study, we detected an improvement in visual acuity, CS and driving frequency after bilateral cataract surgery, which is in agreement with previous reports (Mangione et al. 1994; Elliott et al. 1997; Elliott et al. 2000; Wood & Carberry 2006). The main improvement in brake measurements could be seen in NRT, representing the first response to the visual stimulus. This measurement had not been reported in literature so far in elderly drivers with cataract. In previous studies, CS was shown to be significantly associated with driving performance (Wood & Carberry 2006; Owsley & McGwin 2010; Agramunt et al. 2017). Therefore, we correlated CS and visual acuity with NRT and found a negative correlation between NRT and CS, implying that the slower the NRT, the weaker was the CS. This is a very important finding underscoring the importance of CS evaluation during screening before cataract surgery. These findings could even help improve driving safety in the future when they are incorporated into the physical examinations and ocular assessments conducted before issuing a driving licence. Interestingly, the control group showed better CS than the patients before surgery but worse CS than the patients after surgery. This might be explained by the fact that volunteers might have already suffered from an incipient cataract that had not yet affected their visual acuity.

When comparing the time measures between female and male drivers, we found no difference in NRT after surgery between these groups, indicating the same quick response to the visual stimulus in both genders. Interestingly, male drivers showed lower values for the peripheral motoric metrics FTT, BPTT and BRT. In the literature, this difference has been attributed to the fact that women have 28% lower maximum isometric strength than men, presumably due to their 32% smaller leg muscle mass, and may therefore need more strength to exert the same amount of force as men (Lipps et al. 2011).

A limitation of this study was that patients and volunteers were driving in an alert ready-to-brake fashion awaiting the visual stimulus. Therefore, the BRTs cannot be directly translated to real-life conditions.

Our findings show a significant effect of CS on neurological BRTs and corresponding stopping distances. This highlights the importance of presurgical CS evaluation as a critical factor in cataract surgery decisions in elderly drivers.

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