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Changing Incidence of Lens Extraction Over Twenty Years: the Beaver Dam Eye Study

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Abstract

Objective—Investigate trends in incidence of lens extraction over the past twenty years.

Design—Longitudinal population-based cohort study.

Participants—Persons who participated in the Beaver Dam Eye Study.

Methods—Eligible persons 43–84 years of age living in the city or township of Beaver Dam, Wisconsin were recruited in 1987–1988. Participants were followed up every five years in 1993–1995, 1998–2000, 2003–2005, and 2008–2010 after the baseline examination in 1988–1990. Examinations consisted of ocular examination with lens photography and grading, medical history, measurements of blood pressure, height, and weight. Adjustments were made for age and sex. Values of risk variables were updated, and incidence of cataract surgery was calculated in each 5-year interval.

Main Outcome Measure—Incidence of lens extraction with regard to presence of clinically significant lens opacity and visual function.

Results—Age- and sex-adjusted incidence of lens extraction increased over the four 5-year intervals from 1.8% (95% confidence interval [CI] 1.3% to 2.5%) in the interval between the first and second study examinations to 11.7% (95% CI 9.9% to 13.8%) in the most recent study interval. The increase in incidence of surgery was significantly higher at successive intervals in persons without clinically significant lens opacity at each preceding examination (interval 1: 0.8% [95% CI 0.6% to 1.1%]; interval 4: 9.4% [7.8% to 11.2%]) compared with persons with at least one detectable type of opacity (interval 1: 9.2% [95% CI 6.4% to 13.2%]; interval 4: 16.5% [13.4% to 20.0%]). Recency of examination was not attenuated by adjusting for additional risk factors. There was no evidence that the increased incidence in surgery was preceded by poorer visual acuity, near vision, or contrast sensitivity at the beginning of each interval.

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Conclusion—The incidence of lens extraction has increased over the past 20 years in persons older than the age of 65. The relative increase of surgery is higher in those without any clinically significant lens opacity, and in persons with visual acuity better than 20/40 at an exam as measured five years prior to observed incidence of lens extraction.

Clinically significant lens opacity is the most important cause of decreased vision worldwide¹ and in the United States (U.S.).² It has been reported that prevalence of ocular-lens opacities and lens extraction have changed in the United States in recent decades; however, there are conflicting reports concerning the direction and magnitude of the change. For example, Zhang and colleagues³ reported lower prevalences of extraction in three ethnic groups in the U.S. in National Health and Nutrition Examination Survey (NHANES) 2005–2008 compared to NHANES III (1988–94). Waudby and colleagues⁴ of the Personalized Medicine Research Project reported higher prevalence of opacities and lens extraction than was reported by the Eye Disease Prevalence Study Research Group.⁵ The former group contained data from as recent as 2008, while the latter contained data from studies performed at least a decade earlier. Lundstrom and colleagues⁶ reported that the rate of ocular lens extraction increased from 4.47 to 7.26 extractions per 1000 inhabitants participating in the Swedish National Cataract Registry between 1992 and 2000. Klein and colleagues⁷ reported a cohort effect such that those born more recently had lower prevalence of nuclear lens opacities and a higher prevalence of lens extractions based on data from 15 years of follow-up. A more recent publication from the Swedish registry indicates that the rate of extractions has continued to rise, with the current rate being 9 per 1000 persons with surgery performed at better levels of overall preoperative vision than before.⁸ Postoperative vision did not improve in that study.

The Beaver Dam Eye Study is a population-based study of age-related eye diseases. There have been 5 examinations spaced 5 years apart, beginning in 1988–1990 and with follow-up in 1993–1995, 1998–2000, 2003–2005, and 2008–2010. Examinations included standardized procedures to assess presence and severity of age-related lens opacities, type of opacity, presence or absence of ocular lens, and many potential risk and protective factors for those outcomes. Building upon past data from this study and others, we hypothesize that there are important time trends in incidence of lens extraction that persist after adjusting for important contemporaneous and predisposing factors that have occurred over the now 20 years of follow-up.

Methods

Participants

A private census of Beaver Dam, Wisconsin, was performed in 1987–1988 to identify all residents eligible for the study.⁹ Of the 5924 eligible, 4926 (83%) persons 43–86 years of age participated in the baseline examination in 1988–1990. Ninety-nine percent of the population was white and 56% was female. The cohort was re-examined at 5-(1993–1995, n=3722), 10-(1998–2000, n=2962), 15-(2003–2005, n=2375) and 20-year (2008–2010, n=1913) follow-up examinations. There was greater than 80% participation among survivors at each examination.^{10–12} Differences between participants and non-participants have been presented elsewhere.^{10–12} In general, participants at each examination were younger, and while controlling for age and sex, had lower blood pressure and had fewer comorbid conditions than non-participants. All data were collected with Institutional Review Board approval from the University of Wisconsin-Madison in conformity with all federal and state laws, the work was Health Insurance Portability and Accountability Act (HIPAA) compliant, and the study was performed in adherence to the tenets of the Declaration of Helsinki.

Participants were examined at the study site in a local hospital, a nursing home, or in their homes. The same protocols for measurements relevant to this investigation were used at each examination.¹³ Height, weight, and blood pressures were measured. Date of birth was recorded. Smoking, drinking, health, education, and self-rated health histories were obtained using a standard questionnaire. All medications and supplements (prescription and over-the-counter) currently being taken by the participant were brought to each examination and recorded. Glycosylated hemoglobin levels were measured at each examination. Diabetes was defined as self-report confirmed by use of insulin or diet to control diabetes, self-report with glycosylated hemoglobin A1c level above 6.5 percent, or no self-report with glycosylated hemoglobin A1c above 7%.¹⁴

Photographs of the lens¹⁵ were taken after pupil dilation according to protocol and graded in masked fashion by experienced graders. Slit lamp photographs were taken to grade the degree of nuclear sclerosis. Retroillumination photographs were taken to grade presence and severity of cortical and posterior subcapsular opacities. The protocols for photography and for the grading procedures have been previously described.¹⁵ Scores for nuclear sclerosis were based on comparisons with standard photographs, which resulted in a 5-step scale of severity based on opacity of the nucleus. Severities greater than standard 3 were considered clinically significant nuclear lens opacity. Scores for cortical and posterior subcapsular lens opacities were based on estimated amount of involvement of the lens. A clinically significant cortical opacity was considered present if 5% of the lens was involved. Clinically significant posterior subcapsular opacity was considered present if 5% of a given lens segment was involved. It is common for more than one type of lens opacity to occur in the same eye; therefore, presence of “any lens opacity” is defined as presence of nuclear, cortical, or posterior subcapsular opacity, or any combination of them in a given eye. Presence of lens extractions was determined by history and was corroborated by red reflex photographs.

Statistical Analysis

We examined the period effect of increasing incidence of lens extractions in the Beaver Dam cohort over a 20-year period from 1988–2010. To do this, we compared the incidence of surgery between each of the four 5-year intervals while adjusting for important risk factors. All analyses are performed by eye. In this way, a participant is included in analyses for a given interval if at least one eye contributed to analyses in that interval. An eye was included in analyses if it was free from extraction surgery at the beginning of the interval (eligible for incidence), had measurable nuclear, cortical, and posterior subcapsular opacity severity at the start of that interval, and had surgery status (incident or non-incident) at the end of that 5-year interval. To contribute to the multivariable model, an eye must also have had complete data regarding visual acuity and other risk factors included in the multivariable model (age, sex, smoking, diabetes, systolic blood pressure and self-rated health) at the beginning of the interval for which it was eligible for surgery. Overall, there were 6865 eyes included in the first 5-year interval from the baseline study visit to the first follow-up (first interval), 4854 eyes included in the second interval, 3642 eyes included in the third interval, and 2699 eyes included in the fourth interval.

SAS version 9.3 (SAS Inc., Cary, NC) was used for all analyses. Generalized estimating equations were used to account for the correlation between the eyes of a given participant at a given examination phase. Age and sex are known risk factors for lens opacities; therefore, the adjusted percentages for incidence are calculated from a multivariable model adjusting for the age and sex distribution within the given interval. P-values presented in Table 1 were obtained by modeling an interaction between the lens opacity presence or visual acuity measure and study visit, which tests for a significant difference in the rate of increase in

surgery over the examination phases between the categories of presence or measures of visual acuity.

The maximally adjusted multivariable model was established by first testing potential risk factors for incidence of lens extraction (education level, smoking history, diabetes, ever heavy drinking, body mass index (BMI), systolic blood pressure, any steroid use, inhaled steroid use, and self-reported health) for statistical significance in an age- and sex-adjusted model. All variables that were significant at a 0.05 level in an age- and sex-adjusted model were added to the multivariable model. Any variable that did not remain significant in the multivariable model was then removed. The maximally adjusted model adjusts for age, age², sex, presence of nuclear, cortical, or posterior subcapsular lens opacity, visual acuity, smoking, diabetes, systolic blood pressure, and self-rated health.

Results

The unadjusted percent incidence of lens extraction surgery, by examination interval and age group, is illustrated in Figure 1. As age is the main risk factor for incidence of lens opacities and extractions, it is important to compare persons of similar age across the examination phases. This figure illustrates the increase in incidence of surgery from the first to last examination interval in all age groups above the age of 65. Incidence of surgery across examination intervals is shown in Table 1, by age group, absence or presence of lens opacity and for each level of visual function at the start of the interval. Incidence of surgery increased gradually over the first 3 intervals and markedly so at the end of the fourth, both in eyes with and without any clinically significant lens opacity. The increased incidence of surgery across examination intervals was significantly higher in those without any clinically significant lens opacity at the start of each interval ($P<0.001$). In addition, for those with visual acuity of 20/20 or better, the age- and sex-adjusted incidence of lens extraction increased from 0.89% (95% confidence interval [CI] 0.59% to 1.34%) during the first interval to 9.72% (95% CI 8.08% to 11.64%) in the last interval. While there were increases in the incidence of lens extraction at all levels of visual acuity, the relative increase was greatest for those with the best visual acuity ($P=0.0002$). There were no statistically significant increases in incidence for near visual acuity ($P=0.72$) or contrast sensitivity ($P=0.19$, Table 1).

Incidence of ocular lens extraction by presence of clinically significant lens opacity at the beginning of each of the intervals indicates that the percentage of eyes that had significant opacity prior to extraction surgery decreased over time (Table 1). Similarly, the increase in the percentage of eyes that underwent surgery at later visits was higher in those with the best visual acuity, indicating that lens extraction was not preceded by poorer visual acuity over time.

There was a significant increase in odds of lens extraction surgery for the entire population, controlling for known risk factors, from the first interval to the second (odds ratio [OR] 1.28; 95% CI 1.02 to 1.59; $P=0.03$) and from the third interval to the fourth (OR 1.71; 95% CI 1.38 to 2.11; $P<0.001$). The increased incidence of lens extraction from the second interval to the third was not significant in the age-sex adjusted model or in the multivariate model (OR 1.24, 95% CI 0.99 to 1.54, $P=0.06$, Table 2). Adjusting for all other factors which remained significant in our maximally adjusted multivariable model (nuclear, cortical and posterior subcapsular lens opacity, visual acuity, smoking, diabetes, systolic blood pressure and self-rated health) did not significantly alter the risk of lens extraction between examination intervals, as compared to those in the age-sex adjusted model. The increasing incidence of surgery is limited to participants aged 65 years and older. At this age, nuclear sclerosis is the most commonly occurring type of lens opacity, and may be more likely to

precede surgery than cortical opacities because it may affect visual function earlier in its development.¹⁶ In persons younger than age 65 years, cortical opacities occur the most commonly.¹⁷

Discussion

The incidence of lens extraction over recent successive 5-year intervals has increased after adjusting for age, sex, and other possible risk factors, and this increase is associated with better visual acuity prior to the surgery. A trend for increasing surgery has been noted in Sweden,^{6,8} Denmark,¹⁸ England,¹⁹ and Rochester, Minnesota.²⁰ Thus our observations are not unique to the Beaver Dam community.

The recent increase in lens extractions has been attributed to changes in surgical technique, especially the use of phacoemulsification and implantation of a hydrophobic intraocular lens,^{8,20} both of which are thought to result in better vision postoperatively and may be associated with a decrease in some surgical complications. Preoperative targets for refraction have been more closely aligned with final post-operative refraction in recent years and surgically induced astigmatism has also decreased.⁶ There is some evidence to suggest decreased frequency of posterior chamber opacities after cataract surgery in recent years.²¹ These improvements may encourage lens extraction in the hope of improving even small decreases in visual acuity. While potentially severe complications of surgery such as endophthalmitis, toxic anterior segment syndrome, high refractive errors, rupture of the posterior capsule with vitreous loss, cystoid macular edema, expulsive hemorrhage, retinal detachments, corneal decompensation, posterior capsule opacification and errors in implantation of the wrong intraocular lens²² are not common, they do still occur. While Haripriya and colleagues report intraoperative complication rates of only 0.79% for staff surgeons,²³ Zaidi and colleagues²⁴ reported complications of lens extraction to be 8.7%, with 2.4% of those being major complications. In addition, evidence suggests there is increased long-term risk of late AMD following lens extraction.²⁵

Medicare reimbursement for lens extraction procedures declined from \$1,092 in 1991 to \$536 by 2000.²⁶ Surgery reimbursement rates have very gradually increased since 2000, with the rate for 2011 being approximately \$700. Sixty-five is the age when most persons in the United States become eligible for and may accept Medicare coverage.²⁷ In our study population, 99.45% of persons aged 65 years and older reported having medical insurance coverage; therefore, we were unable to directly examine the effect of medical insurance coverage on the rate of surgery incidence.

Of note is that the trend for recent increases in lens extraction surgery occurred in many countries, not only in those in which there is reimbursement for each case.

A limitation of our data is that we measured lens opacity status and visual function 5 years before lens extraction was documented. While it is possible that a rapid change occurred in development of lens opacity and/or decreased vision related to cataract prior to the surgery, this seems unlikely. Another limitation of our study is that data on some ocular comorbidities and on all complications of surgery were not available.

In summary, we report an increase in incidence of lens extraction in the past 20 years in persons with and without any clinically significant lens opacity five years prior to observed lens extraction, as well as persons with vision better than 20/20.

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Figure 1.
Unadjusted Percent Incidence of Lens Extraction for Each Age Group and Examination Interval.

Table 1

Incidence of Lens Extraction by Age, Type of Lens Opacity, and Measure of Visual Function at the Beginning of Each 5-Year Interval^a in the Beaver Dam Eye Study.

	Interval 1			Interval 2			Interval 3			Interval 4 ^b			Adjusted P-value ^{b,c}
	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	
Total Eyes at Risk	6865 (4.0)	1.8 (1.3, 2.5)	4854 (6.2)	3.8 (3.0, 4.8)	3642 (8.4)	5.3 (4.2, 6.6)	2699 (15.5)	11.7 (9.9, 13.8)					
Age													0.03
<65 Years	4510 (1.3)	1.7 (1.2, 2.4)	2859 (2.2)	3.7 (2.7, 5.0)	1834 (2.3)	5.3 (3.5, 7.9)	971 (4.2)	9.2 (5.9, 14.0)					
65 Years	2355 (9.1)	2.0 (1.1, 3.5)	1995 (11.9)	4.1 (2.6, 6.4)	1808 (14.5)	5.3 (3.4, 8.2)	1728 (21.8)	13.2 (10.2, 16.9)					
Lens Opacity Type													
Nuclear													0.50
Absent	6177 (2.0)	1.4 (1.0, 1.9)	4071 (3.1)	2.9 (2.3, 3.7)	3164 (4.9)	4.5 (3.6, 5.6)	2241 (10.0)	10.3 (8.7, 12.2)					
Present	688 (21.5)	6.2 (4.1, 9.3)	783 (22.0)	10.2 (7.6, 13.7)	478 (31.6)	12.4 (9.2, 16.5)	458 (42.6)	18.2 (14.5, 22.5)					
Cortical													0.008
Absent	6214 (2.5)	1.5 (1.1, 2.1)	4279 (4.5)	3.4 (2.7, 4.2)	3062 (6.4)	4.8 (3.8, 6.0)	2278 (13.0)	11.4 (9.6, 13.4)					
Present	651 (18.1)	4.8 (3.2, 7.0)	575 (18.8)	8.3 (6.0, 11.5)	580 (19.0)	8.2 (6.0, 11.1)	421 (28.8)	13.6 (10.4, 17.7)					
Posterior Subcapsular													<.001
Absent	6688 (2.8)	1.4 (1.1, 2.0)	4684 (5.3)	3.6 (2.9, 4.6)	3492 (7.1)	4.9 (3.9, 6.1)	2585 (13.9)	11.1 (9.4, 13.0)					
Present	177 (46.9)	18.0 (11.4, 27.3)	170 (30.0)	10.4 (6.2, 16.8)	150 (37.3)	15.9 (10.2, 23.9)	114 (52.6)	22.7 (16.2, 30.7)					
Any													<.001
Absent	5603 (0.7)	0.8 (0.6, 1.1)	3580 (1.7)	2.2 (1.7, 2.9)	2641 (2.6)	3.2 (2.5, 4.1)	1868 (7.2)	9.4 (7.8, 11.2)					
Present	1262 (18.5)	9.2 (6.4, 13.2)	1274 (18.8)	10.1 (7.6, 13.3)	1001 (23.7)	11.0 (8.4, 14.2)	831 (34.2)	16.5 (13.4, 20.0)					
Visual Function Measures													
Visual Acuity													<.001
20/20 and better	4882 (1.2)	0.9 (0.6, 1.3)	3511 (2.6)	2.4 (1.9, 3.2)	2435 (2.8)	3.3 (2.6, 4.3)	1620 (7.2)	9.7 (8.1, 11.6)					
20/25 to 20/40	1711 (8.5)	3.1 (2.1, 4.4)	1206 (15.8)	7.6 (5.9, 9.8)	1101 (19.7)	9.3 (7.2, 12.0)	1007 (27.0)	13.7 (11.3, 16.6)					
Worse than 20/40	245 (29.0)	9.1 (6.0, 13.4)	106 (16.0)	8.7 (5.4, 13.7)	91 (20.9)	8.7 (4.9, 15.2)	72 (40.3)	19.1 (12.0, 29.0)					
Near Vision Visual Acuity ^d													0.72
20/20 and better			4286 (4.4)	3.2 (2.5, 4.0)	3156 (5.7)	4.5 (3.5, 5.6)	2370 (12.2)	10.8 (9.1, 12.7)					

	Interval 1			Interval 2			Interval 3			Interval 4 ^a			Adjusted Incidence, % (95% CI) ^b	Adjusted P-value ^{b, c}
	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b	N at Risk (% Incident)	Adjusted Incidence, % (95% CI) ^b		
20/25 to 20/40														
Worse than 20/40														
Contrast Sensitivity ^e														0.19
1.55	1269 (1.1)	1.2 (0.7, 2.3)	3158 (2.4)	2.5 (1.9, 3.2)	2342 (3.3)	3.9 (3.1, 5.0)	1457 (7.7)	9.5 (7.9, 11.3)						
1.50	246 (6.1)	3.6 (1.7, 7.1)	924 (8.3)	4.7 (3.5, 6.3)	699 (13.5)	7.0 (5.4, 8.9)	604 (16.1)	12.6 (10.4, 15.1)						
1.45	128 (22.7)	7.0 (3.5, 13.3)	718 (19.8)	8.9 (6.7, 11.7)	534 (24.3)	9.4 (7.1, 12.5)	619 (33.3)	15.9 (13.1, 19.2)						

BDES, Beaver Dam Eye Study; CI, confidence interval; OR, odds ratio.

^aIntervals are the 5-year periods between 2 study examination phases. Interval 1 = examinations 1 and 2 (1988–1990 to 1993–1995); Interval 2 = examinations 2 and 3 (1993–1995 to 1998–2000); Interval 3 = examinations 3 and 4 (1998–2000 to 2003–2005); Interval 4 = examinations 4 and 5 (2003–2005 to 2008–2010).

^bAdjusted for age and sex.

^cP-value for difference in rate of increase between age group, cataract or visual acuity level, as described.

^dNot measured at examination 1.

^eAt examination 1, was only measured in a subset of participants; at subsequent examinations, it was measured in the entire population.

Table 2

Period Effect of Study Interval on Incidence of Lens Extraction in the Beaver Dam Eye Study Population.

Study Interval^b	Age- and Sex-Adjusted		Maximally Adjusted^a	
	OR (95% CI)	P-Value	OR (95% CI)	P-Value
Interval 2 vs. Interval 1	1.31 (1.06, 1.62)	0.013	1.28 (1.02, 1.59)	0.03
Interval 3 vs. Interval 2	1.13 (0.92, 1.40)	0.24	1.24 (0.99, 1.54)	0.06
Interval 4 vs. Interval 3	1.62 (1.32, 1.98)	<0.001	1.71 (1.38, 2.11)	<.001

CI, confidence interval; OR, odds ratio.

^a Adjusted for age, age², sex, presence of clinically significant nuclear cortical or posterior subcapsular lens opacity, visual acuity, smoking, diabetes, systolic blood pressure and self-rated health.

^b Interval 1 = examinations 1 and 2 (1988–1990 to 1993–1995); Interval 2 = examinations 2 and 3 (1993–1995 to 1998–2000); Interval 3 = examinations 3 and 4 (1998–2000 to 2003–2005); Interval 4 = examinations 4 and 5 (2003–2005 to 2008–2010).