The Effect of Cataract Surgery on Postural Control

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Purpose. Falls are a significant cause of morbidity in the elderly. Because decreased vision is known to be a significant risk factor for falling in this age group, we sought to examine the effect of the removal of cataract, a major cause of visual handicap, on postural stability.

Methods. Postural stability was measured in 23 patients who underwent cataract surgery, before and 1 to 4 months after surgery. Stability indices included *Stability Effect*, *Fourier Spectrum of Postural Sway*, and *Synchronizations*, and, based on these measurements, *Falling Index*, which had been shown in earlier studies to predict the risk of falling.

Results. Visual acuity in the surgical eye significantly improved in all patients after surgery ($P < 0.01$) and did not change in the fellow eye. *Stability* improved in most patients (19/23) and *Fourier Spectrum of Postural Sway* improved in the high-frequency bands (above 0.5 Hz), when viewing with the surgical eye, but not when viewing with the nonsurgical eye ($P < 0.05$). By *Falling Index*, before surgery, 12 of 23 patients were at high risk of falling, and only six were at low risk. After surgery, 16 of 23 were at low risk and only three remained at high risk (χ^2 test, $P < 0.008$).

Conclusions. Cataract surgery significantly improves postural stability. Considering the high cost of treating fall-related injuries in the elderly, the findings may imply that cataract surgery is cost effective in this regard. (*Invest Ophthalmol Vis Sci.* 2005;46:920–924) DOI:10.1167/iovs.04-0543

Falls and fall-related injuries are one of the major health problems among the elderly, causing substantial morbidity and mortality and excessive costs of treatment and hospitalization.[1] In such a context, adequate postural function, being the necessary (albeit not sufficient) factor in preventing the loss of equilibrium and falling, has become a focus of interest. Vision is one of the three basic input channels controlling balance, together with the vestibular and somatosensory subsystems.[2,3] It is not surprising therefore that visual dysfunction has been reported to be associated with an increased risk of falling,[4–13] and that decreased vision has been shown to be correlated with decreased postural stability.[2,12,14,15] It has also been reported that elderly patients admitted to hospitals, especially those who have fallen, have a high prevalence of visual impairment.[10]

Cataract is a major cause of diminished visual function in the elderly population. There is considerable evidence that cataract is a risk factor for falling in the elderly.[3,4,11,16] However, the direct effect of cataract surgery on postural control has not yet reported. The examination of such an effect was the objective of this study.

Methods

We conducted a prospective study among a series of consecutive patients. The study was approved by the Assaf Harofeh Medical Centre's Review Board for Human Trials and adhered to the tenets of the Declaration of Helsinki. All patients gave their informed consent for participation. The study population included 23 consecutive patients, 7 men and 16 women, who were scheduled for cataract surgery during October 2002 in the Department of Ophthalmology, Assaf Harofeh Medical Centre, Zrifin, Israel. The mean age was 71.6 ± 9.6 years (range, 51–85). On the day of admission for surgery, each patient underwent a detailed medical history intake and an ophthalmic examination. Afterward, a postural examination was conducted. Patients with any neurologic, vestibular or orthopedic illness were excluded. We also excluded patients with any ocular disease other than cataract, such as age-related macular degeneration, diabetic retinopathy, or glaucoma. All underwent uneventful cataract extraction surgery by the phacoemulsification technique with implantation of an intraocular lens. Twenty-nine to 128 days (mean, 60.4 ± 23) after the operation, a second examination was performed with a complete ocular examination, including manifest refraction and determination of best-corrected visual acuity, and a postural stability examination. Visual acuity was measured with the standard Early Treatment Diabetic Retinopathy Study (ETDRS) chart. The line in which the patient could identify all letters was recorded as the best visual acuity line.

Postural stability was examined using the Interactive Balance System (IBS; Tetrax Inc., Ramat Gan, Israel). In this method of posturography, the vertical pressure fluctuations on four independent force plates, each supporting one heel or toe of each leg, are recorded. A detailed description of the system is available elsewhere.[17] The system provides three mutually noncorrelated parameters:

Stability, calculated as the square root of the sum of the squared differences between adjacent pressure fluctuation signals, sampled at a rate of 32 Hz. The higher the score, the greater the sway and instability.[18] We defined the *Stability Effect* as the difference between the preoperative and postoperative stability of the subjects.

Fourier Spectrum of Postural Sway, which is subdivided into eight ranges of frequencies. Intensified sway within individual frequency ranges has been shown to be indicative of abnormal function of postural subsystems. Deviations of ~0.3 Hz reflect vestibular disturbances; 0.5 to 1.00 Hz is sensitive to somatosensory problems, and spectral aberrations above 1.00 Hz characterize central nervous system, usually cerebellar, disease.[19–21]

Synchronizations are correlations between simultaneous signals of pressure fluctuations obtained when comparing the output of two of the four plates. This parameter actually reflects the coordination of the agonist–antagonist activity of the lower extremities.

In addition to the traditional interpretation of the IBS data, a recently developed *Falling Index* (Sunlight Ltd., Tel-Aviv, Israel) was

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TABLE 1. The Effect of Cataract Surgery on Visual Acuity and Stability for Each Patient

Patient	Preoperative Visual Acuity (LogMAR)	Postoperative Visual Acuity (LogMAR)	Visual Acuity Improvement (LogMAR)	Preoperative Stability	Postoperative Stability	Stability Effect
1	2.22	0.82	1.4	11	10	1
2	0.3	0.1	0.2	32	17	15
3	0.18	0.03	0.15	22	14	8
4	0.18	0.03	0.15	11	8	3
5	0.7	0.18	0.52	15	13	2
6	0.78	0.03	0.75	25	15	10
7	0.6	0.54	0.06	16	12	4
8	0.78	0.48	0.3	27	23	4
9	0.78	0.52	0.26	32	33	−1
10	0.3	0.1	0.2	30	15	15
11	0.52	0.3	0.22	32	24	8
12	0.3	0.0	0.3	14	14	0
13	0.3	0.15	0.15	30	25	5
14	0.6	0.03	0.57	18	16	2
15	0.6	0.15	0.45	14	9	5
16	0.82	0.18	0.64	19	19	0
17	0.48	0.3	0.18	52	41	11
18	0.18	0.1	0.08	13	12	1
19	0.3	0.1	0.2	11	13	−2
20	0.52	0.1	0.42	15	12	3
21	2.52	0.03	2.49	20	16	4
22	0.78	0.52	0.26	15	10	5
23	0.48	0.15	0.33	20	17	3

used to reevaluate the data. Its algorithm is based on the addition of standard deviation scores, which are obtained when calculating by how many standard deviations the performance of an examinee deviates from the mean of the normative database provided by the IBS software. Adding the Standard Scores for Stability, Fourier Intensities of ~0.3 and ~1.00 Hz and Synchronizations, a Fall Index is obtained, with three numerical ranges 0 to 20, 21 to 30, and >30, indicating, low, moderate, or high risk of falling, respectively. The index has been validated by clinical observations in geriatric clinics and hospitals in Israel and Austria as well as in a German study of independent elderly women with osteoporosis.[22,23] It should be noted that Postural Stability Scores do not show learning effects, as documented in studies involving test–retest over short- and long-term periods.[17,22–24]

Postural stability was recorded as follows: While wearing his or her best optical correction, as determined on the day of examination, each subject was asked to stand on the platforms, which were placed in an illuminated room. Subjects were asked to look at a fixation target in the size of a 6/60 Snellen letter, placed at 3 m distance. Stability was recorded for 30 seconds while the patient was viewing with the surgical eye and again while the patient was viewing with the nonsurgical eye.

A paired *t*-test was used to evaluate the pre- and postsurgical differences. Correlations were examined with the Spearman correlation test.

RESULTS

The effect of cataract surgery on visual acuity and stability for each patient are presented in Table 1. Mean logarithm of the minimum angle of resolution (logMar) of best-corrected visual acuity, which was 0.6 ± 0.1 before the operation (median, 0.52), significantly improved to 0.22 after the operation (median 0.15, $P < 0.01$). Best-corrected vision in the fellow eye was 0.3 ± 0.1 before and after the operation.

Pre- and postoperative postural stability effect results were correlated in each patient ($r^2 = 0.88$, $P < 0.01$), indicative of reproducible measurements. While viewing with the surgical eye, 19 (82.61%) patients showed an improvement in stability effect, 2 patients did not show any improvement, and another 2 had a slight deterioration (patients 09 and 19). As seen in Table 2, mean stability while viewing with the surgical eye was 21.2 ± 2.1 and 20.1 ± 1.9 before surgery and 16.1 ± 2.3 and 17.3 ± 2.2 after surgery (left and right eyes, respectively, $P < 0.05$ and <0.01 for the left and right eyes, respectively). Stability did not change when viewing with the nonsurgical eye (20.1–22.1 for both eyes before and after surgery). The improvement in stability did not correlate with age ($r^2 = 0.09$, $P < 0.15$). No correlation was found between the improvements in visual acuity and stability.

Analyses of the Fourier Spectrum of Postural Sway showed significant decrease in sway intensity after the operation when the patient viewed with the surgical eye (Table 2). In this context two additional observations should be noted: (1) the effect of surgery on the right eye spreads over a wider frequency range of the spectrum and (2) the removal of the cataract damps predominantly sway intensity at the higher part of spectrum (above 0.5 Hz), reported to be linked with the somatosensory postural subsystem.[19–21]

The quality and efficiency of coordination movements between the heels and toes of each foot also improved after the operation, as seen in the measurements of toe synchronization (Table 2). Synchronization improved globally when each eye was examined and reached statistical significance while the right eye was viewing ($P < 0.05$), whereas, when the left eye was viewing, this difference reached only marginal statistical significance ($P < 0.12$).

Figure 1 displays the distribution of the relative risk of falling according to the Falling Index in our study group, before and after surgery. The values of the Falling Index are based on the combined posturographic data obtained on both positions (surgical or nonsurgical eye open). The mean score decreased from 34.2 ± 25.4 before surgery to 16.6 ± 14.2 after surgery ($P < 0.005$). Before surgery, 12 (52%) of 23 of the patients were at high risk of falling and only 6 were at low risk. After surgery 16 (70%) of 23 were at low risk, and only 3 remained

TABLE 2. Mean Stability Parameters before and after Cataract Surgery

	Surgery Left Eye (n = 9)				Surgery Right Eye (n = 14)			
	Left Eye Viewing		Right Eye Viewing		Left Eye Viewing		Right Eye Viewing	
	Before Surgery	After Surgery	Before Surgery	After Surgery	Before Surgery	After Surgery	Before Surgery	After Surgery
Stability	21.2 ± 2.1*	16.1 ± 2.3*	20.1 ± 1.5	19 ± 1.8	22.1 ± 0.9	20.2 ± 1.8	20.1 ± 1.9**	17.3 ± 2.2**
Sway intensity range (Hz)								
0.35–0.50	4.0 ± 1.51	3.4 ± 1.01	3.9 ± 1.09	3.3 ± 2.47	4.3 ± 1.41	4.3 ± 1.54	5.3 ± 2.07*	4.0 ± 1.40*
0.50–0.75	3.1 ± 1.38**	2.2 ± 0.91**	2.4 ± 0.81	2.4 ± 1.05	3.0 ± 1.91	2.9 ± 1.28	3.4 ± 1.40**	2.7 ± 1.31**
0.75–1.00	2.3 ± 1.10*	1.8 ± 1.07*	2.0 ± 1.15	1.7 ± 1.14	2.1 ± 1.39	1.9 ± 0.91	2.3 ± 1.56*	1.9 ± 1.13*
1.00–3.00	0.9 ± 0.47	0.7 ± 0.48	0.6 ± 0.37	0.7 ± 0.91	0.8 ± 0.91	0.6 ± 0.24	0.8 ± 0.53**	0.6 ± 0.42**
Synchronization	467 ± 344	519 ± 307	412 ± 420*	696 ± 200*	359 ± 432	503 ± 424	266 ± 486*	595 ± 314*

Data are presented as the mean ± SD. All differences of sway intensity below the frequency range of 0.35 Hz were not significant and therefore are not tabulated. Lower Spectral Intensities and Stability Scores indicate better performance, and higher Synchronization Scores indicate better performance.

* $P < 0.05$.

** $P < 0.01$.

at high risk (χ^2 test $P < 0.008$). In total, the Falling Index improved in 18 (78%) of 23 patients.

We did not find any effect of age or the time interval between pre- and postoperative measurements and any of the postural control indices. There were also no significant differences in all the investigated parameters between patients who underwent surgery in the right versus the left eye. We did find, however, that female patients had a significantly higher postural Fall Index both before and after the operation ($P < 0.05$).

DISCUSSION

Our study demonstrated improvement in postural stability in most patients after cataract extraction, with a considerable reduction of fall risk in most patients (78%). These results are well in line with those in several studies. Hong et al.,[25] compared postural stability in 55 diabetic patients and 55 healthy control subjects. He had found cataract to be a significant risk factor for decreased stability in the diabetic group. Anand et al.,[15] reported that simulation of cataract by a refractive blur in elderly subjects degrades postural stability. Moreover, our results are in excellent concordance with the results of Brannan et al.,[26] who prospectively followed 97 patients scheduled for cataract extraction, examining them 6 months before and 6 months after the surgery. They reported an 80% decrease in the rate of falls between before surgery (31 falls) and after surgery (6 falls, $P < 0.001$), very similar to our results.

The results of our study show that cataract surgery not only improved postural sway but also reduced sway intensity at higher frequency bands (linked with somatosensory disease), and normalized synchronizations, which are expressions of the agonist–antagonist coordination of the muscles of the lower extremities, ensuring postural steadiness. It thus appears that the improvement of vision by cataract removal affects, probably indirectly through the visual–vestibular and vestibular spinal pathways, the postural somatosensory subsystem. The exact structure and dynamics of this linkage, although anatomically and neurophysiologically plausible, is currently poorly understood and needs further systematic research. It seems, however, that this theoretically postulated mechanism is *not* controlled by visual resolution, as there was no correlation between the improvement in visual acuity and stability.

Although poor visual acuity has been shown to approximately double the rate of falls,[13,16] a linear relation between

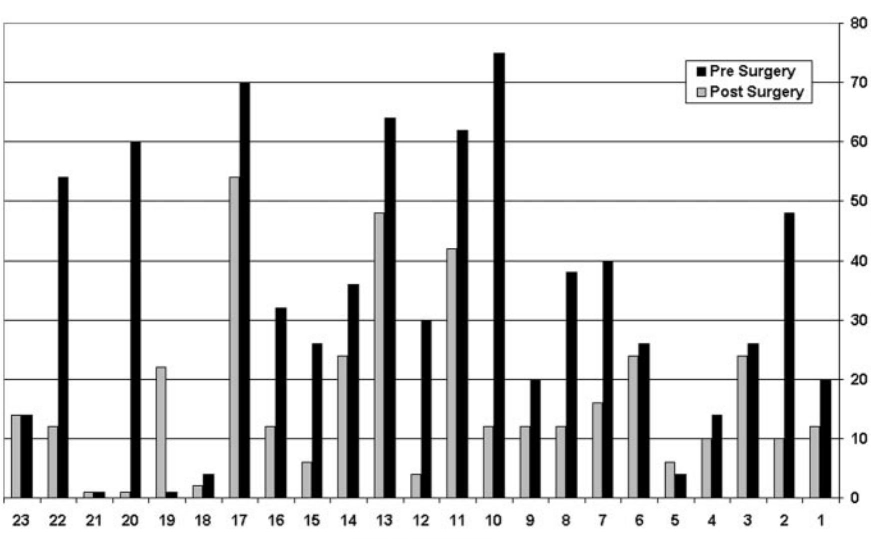

FIGURE 1. Falling Index values before (■) and after (▦) cataract surgery in each patient. Patients with Falling Index levels above 30 are considered to be at high risk of falling.

falls and visual acuity was not reported in large-scale studies. The Blue Mountains Eye study showed increased risk of falls with decreased visual acuity; however, the risk was not linear.[4] Another large-scale study, the Framingham study, showed a progressive decrease in hip fracture risk for better acuity in the *worse* eye. Because binocular acuity is usually better than that of the *better* eye, the researchers suggested that it was not acuity itself, but something related to it, such as contrast sensitivity or depth perception, that is important.[7] Similarly, in a study examining risk factors for hip fracture in 9516 white women 65 years of age or older, contrast sensitivity and depth perception and not visual acuity were found to be independent risk factor.[6] Other studies have also demonstrated that postural stability is driven by contrast sensitivity rather than by visual resolution.[9,12,27,28] It may therefore be assumed that visual–somatosensory linkage is controlled by an interplay between foveal and peripheral vision, which in turn is dependent on vestibular involvement, as postulated by Lovegrove et al.[29] in the context of investigating visual deficits in dyslexia. We are in the process of assessing how the change in factors such as contrast sensitivity, depth perception, and visual field after cataract extraction is related to postural stability.

Another factor that was not related to the improvement in stability was age. Stability is impaired in the elderly for reasons other than degraded vision. Diabetic peripheral neuropathy is only one example of many common disorders among the elderly that influence stability.[19] Age-related factors other than disease processes also alter the function of the balance system.[30] It is therefore conceivable that individuals at different ages will react differently to improvement in visual acuity after cataract extraction. The absence of age effects in our study may be explained by our strict exclusion criteria, which excluded patients with neurologic, vestibular, or orthopedic illness from the study. Another possible explanation is that our study group was homogenous with regard to age, with only two subjects younger than 59 years. These two subjects did not improve their stability much (0–2 stability effect) after surgery. It may be that in a study with a larger, more heterogeneous group of patients would yield different results.

By using the IBS system (Tetrax), Schwesig et al.[22,23] designed a Falling Index that can predict the risk of falling. In a sample of 26 women 55 to 80 years of age with osteoporosis, this index differentiated between falling and nonfalling subjects at significance level of $P < 0.002$ (Falling Index, 31.4 as opposed to 11.0, respectively). The test–retest reliability of the Falling Index after 2 weeks and after 2 months was high ($r^2 = 0.89$). The application of this index to our study group further validated the substantial postoperative improvement in stability.

Toe synchronization measures the coordination and reciprocal innervation of the agonist and antagonist motor system of the lower extremities. It reflects the quality and efficiency of coordination movements between the heels and toes of each foot. This parameter is an important indicator of fall risk.[22] We found toe synchronization to be improved after cataract surgery; however, the improvement was statistically significant only when the right eye was examined, regardless of the side of the operation. Although the improvement in synchronization was not statistically significant while the left eye was viewing, the relatively low probability (0.12) may imply that there would be a statistically significant difference if a group larger than the current one ($n = 9$) were examined.

In conclusion, in light of the well-documented burden of falls among the elderly on the health system,[31] the results of the present study add further evidence that the removal of cataract is important for prevention of falls. Further study is needed to elucidate the exact mechanism by which cataract surgery actually improves postural stability.

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