Upper Eyelid Motility in Blepharoptosis and in the Aging Eyelid

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PURPOSE. To study the metrics of lid saccades in blepharoptosis and to distinguish any differences in the dynamics of eyelid movements that are related to the cause of blepharoptosis and to aging.

METHODS. The lid and vertical eye saccades of 7 patients with congenital blepharoptosis and those of 18 patients with aponeurogenic blepharoptosis, either involutional or rigid-contact-lens–induced, were recorded with electromagnetic search coils. For each saccade, two parameters were assessed: amplitude and peak velocity. Two age-matched control groups were assessed in the same manner. Repeated measures analysis of variance was used to investigate any observed differences between the included groups.

RESULTS. Congenital and rigid-contact-lens–induced blepharoptosis were readily distinguishable from one another, as well as from the age-matched control group, in both lid saccadic amplitude and peak velocity. For example, 40° downward lid saccades in the congenital blepharoptosis group averaged 22.9° ± 4.0° (SD), whereas 30.0° ± 4.7° lid saccades were made by the age-matched control group. The subjects in the two groups with aponeurogenic blepharoptosis also made lid saccades that were distinctive for their group (P < 0.02), in both amplitude and peak velocity. For 40° downward saccades in involutional and rigid-contact-lens–induced blepharoptosis, lid saccadic amplitude averaged 32.7° ± 4.3° and 40.3° ± 3.5°, respectively. Lid saccadic peak velocity declined significantly with age. Lid saccadic peak velocity for 40° upward saccades in the younger control group averaged 40.1° ± 11.4 deg/sec, whereas the older control group achieved an average peak velocity of 560.7 ± 60.4 deg/sec. The lid saccadic dynamics in the involutional blepharoptosis group proved to be similar (P > 0.05) in saccadic amplitude and peak velocity to those of age-matched controls.

CONCLUSIONS. In different forms of blepharoptosis, distinctive metrics of lid saccades occur. The current data suggest that involutional blepharoptosis is not a consequence of normal age-related changes in eyelid function. (Invest Ophthalmol Vis Sci. 2001;42:620–625)

There are several known causes of blepharoptosis, such as a diseased levator palpebrae muscle or its aponeurosis and neurologic and mechanical disorders.1 Various types of blepharoptosis may be identified by proper assessment of established clinical parameters such as levator function, a commonly used parameter of the functional integrity of the levator palpebrae muscle. Levator function has been defined as the maximum eyelid amplitude (in millimeters), measured from downgaze to upgaze.2,3 Another measure of levator function is the so-called levator force, which is infrequently used, because no clinically useful device is currently available.4 Other parameters, such as the position of the upper eyelid crease, the interpalpebral fissure height, upper eyelid margin–corneal reflex distance, fatigue with sustained upgaze, and ocular motility may provide additional information toward establishing the correct diagnosis. Nevertheless, the cause of the blepharoptosis may remain obscure,5–4 whereas a correct diagnosis facilitates its adequate management.

Aponeurogenic blepharoptosis is caused by disinsertion, or thinning, of the levator muscle aponeurosis.5–7 Typically, the levator function is good,8 and a high eyelid crease is usually found. In the elderly it is most often an involutional disorder.4,9 In the younger population, a period of rigid contact lens wear is frequently the only identifiable cause.5,10 In aponeurogenic blepharoptosis it is clinically difficult to discriminate between the possible causes—that is, involutional or contact lens wear. Only history and the age of occurrence can currently be used to differentiate between the two. Intraocular surgery, postoperative edema, ocular inflammation, and topically applied steroids are other factors related to aponeurogenic blepharoptosis.1,7

In congenital myogenic blepharoptosis, the levator function is typically diminished, and the eyelid shows a lag during downgaze. Upper eyelid crease position is unaffected. Although most congenital blepharoptoses are myogenic,6 some are caused by a neurologic abnormality,11 an aponeurotic defect,4 or a mechanical distortion of the upper eyelid, as with neurofibroma.12 During clinical examination, such other causes of congenital blepharoptosis are readily distinguished from the myogenic ones. Genetic linkage has recently been established for at least some cases of congenital blepharoptosis.13

Few studies have described the metrics of lid saccades in normal subjects.14–17 Concurrent lid and eye saccades have repeatedly been shown to have similar amplitudes and peak velocities.16 Several investigators14,15,17 have found higher peak velocities in downward lid saccades than in upward ones. In one study,16 however, the opposite was found, possibly because of the small number of subjects included in that study.

In the present experiments, we compared the metrics of lid saccades among several forms of blepharoptosis and in age-matched control groups.

MATERIALS AND METHODS

The investigations adhered to the tenets of the Declaration of Helsinki and were approved by the institutional human experimentation committee. Informed consent was obtained from each subject after the experiments were fully explained.

Patients and Control Subjects

We included seven patients with congenital blepharoptosis (CB; age range, 22–70 years). Each patient had a history of unilateral or bilateral blepharoptosis since birth. For inclusion, the maximum eyelid ampli-
tude had to be less than 8 mm at clinical examination, with lid lag
during downgaze. In addition, 18 patients with the clinical signs of
aponeurogenic blepharoptosis, either attributed to involutional
changes (IB; n = 13; age range, 68–87 years), or secondary to rigid
contact lens wear (CLB; n = 5; age range, 21–46 years) were included.
For inclusion, the maximum eyelid amplitude had to be 10 mm or
more, and a high upper eyelid crease had to be present. They had a
history of gradually progressive unilateral or bilateral blepharoptosis.

If each upper eyelid showed blepharoptosis, the most affected
upper eyelid was included for analysis, although both eyelids were
simultaneously recorded. Blepharoptosis was defined as an interpap-
pherical fissure height of 7 mm or less, measured between the lower
and the upper eyelid margin, or an asymmetry between the two upper
eyelids of more than 2 mm. Maximum eyelid amplitude was measured
downgaze to upgaze while the additional action of the frontalis
muscle was blocked by digital pressure on the eyebrow on the orbital
rim. Patients were excluded if they had previously undergone eye or
eyelid surgery or if they had a systemic disease that might affect upper
eyelid position or motility, such as Graves’ disease or a generalized
neuromuscular disease. In addition, patients were excluded if they
showed any progression of blepharoptosis after sustained upgaze,
jaw-winking, or a visible lid twitch.

Two groups of young normal control subjects (YC; age range,
25–51 years; n = 10, or older control subjects (OC; age range, 64–84
years; n = 16) took part in our experiments as age-matched control
groups. All normal subjects had a vertical eyelid fissure of 8 mm or
more, and each had a levator function of 10 mm or more. None of the
subjects in the control groups had any history of ocular or oculomotor
disease. We randomly included the measurements of one upper eyelid
and the associated eye of each normal subject.

Recording Technique and Calibration
Lid and eye saccades were recorded simultaneously by means of the
electromagnetic search coil technique. Lid saccades were recorded with handmade search coils. Every such coil consisted of 50
turns of insulated copper wire (diameter, 0.05 mm). A typical coil had
an outer diameter of approximately 4 mm, weighed 15 mg, and was
less than 0.5 mm thick. To reduce spurious induction, the leads of the
coil were tightly twisted together. The coils were fixed on the lower
part of the eyelid, just above the eyelid margin and right above the
center of the pupil with a piece of adhesive tape (diameter, 6.5 mm).
Once the coils were attached, the subjects hardly noticed them. Eye
saccades were recorded with commercially available search coils
(Skalar, Delft, The Netherlands).

The field frequency used was 20 kHz. The recordings were ampli-
fied to ±5 V range, low-pass filtered at 120 Hz (~3 dB), digitized with
12-bit precision, and sampled at a frequency of 250 Hz. The recordings

FIGURE 1. Lid saccadic amplitude
(in degrees) and peak velocity (in
degrees per second) with those of
the eye in all five groups, pooled for
saccadic direction.

FIGURE 2. Regression lines for the
estimated linear relationship of the
saccadic amplitude (lid–eye; in de-
grees), as a function of the target
amplitude for each group.
were stored on disc for off-line analysis. Signal noise level was less than 1.8 minutes of arc. Both the recording equipment and the search coils were calibrated objectively before each recording session, with the coils mounted on a calibration device. Any misalignment of the coils on the eyes, determined when the subjects monocularly fixated a lit LED in the primary position of gaze, was later adjusted by software. The accuracy of the calibration procedure was better than 0.5%.

One search coil was attached to the upper eyelid, and a scleral search coil was placed on the ipsilateral eye under topical anesthesia (0.4% oxybuprocaine; Novesine; Chauvin, Düsseldorf, Germany). Subjects were then seated, with their heads centered in a cubic coil frame in which an alternating horizontal and vertical electromagnetic field was generated. Head movements were restricted by a chin rest and forehead support. The subjects faced a stimulus screen, containing red LEDs at a viewing distance of 1 m. The LEDs were positioned symmetrically around the straight-ahead position along the midvertical meridian, 10°, 20°, 30°, and 40° apart. The subjects were asked to shift their gaze from one lit LED to the other after hearing an electronically generated tone, at a pace of 1 per second. The four target ranges were tested in a randomized sequence. Each trial lasted 16 seconds, in which, typically, eight saccades in each saccadic direction were made.

### Data Analysis

The recorded data were analyzed with a previously devised computer program. The criteria adopted for observer-independent detection of saccadic onset were acceleration exceeding 25 deg/sec and velocity exceeding 25 deg/sec. Saccadic offset was detected by a deceleration of less than 1000 deg/sec and a velocity of less than 50 deg/sec. The amplitude and peak velocity of each detected saccade were determined. Only primary eye saccades and the associated lid saccades were selected for analysis, by an eye amplitude criterion (set at 50% of the target amplitude). Repeated measures analysis of variance (mixed-model ANOVA) was used to investigate any observed differences among the included groups. Two outcome (dependent) variables were defined: the difference in saccadic amplitude between lid and eye (in degrees) and the difference in saccadic peak velocity between lid and eye (in degrees per second). Each outcome variable was analyzed separately in a linear model with random coefficients and with the following independent variables: patient group (five groups), saccadic direction (up and down), and target amplitude (10°, 20°, 30°, and 40°). Also interactions between group and target amplitude and between group and direction were tested. Amplitude squared was included to test for curvilinearity. The fitted linear model provided estimates for the mean coefficients. Pairwise comparisons were used to test whether these mean coefficients differed between groups.

### RESULTS

Assessing the dynamics of eyelid saccades was valuable as a means of differentiating between two clinically similar forms—involutional and contact lens-induced—of aponeurogenic blepharoptosis. Moreover, large differences were found in the amplitudes and peak velocities of the eyelid saccades made by patients with congenital blepharoptosis on the one hand and by those with the aponeurogenic condition on the other. For example, in the group with congenital blepharoptosis the lid saccadic amplitude for 40° saccades averaged 23.6° (average peak velocity, 278 deg/sec), whereas the contact lens group achieved an average of 38.8° (average peak velocity 450.8 deg/sec). Lid saccadic peak velocity was affected by age, averaging 410.0 deg/sec for the younger control group and 352.2 deg/sec for the older control group and 40° saccades. Lid saccadic dynamics in the involutional blepharoptosis group were closely similar to those of the age-matched control group. Both the amplitude and the peak velocity of the eyelid saccades increased with those of the eye in all five groups (Fig. 1). The eye saccadic amplitudes of the group of patients with congenital blepharoptosis were significantly smaller ($P < 0.05$; independent samples $t$-test) from those of the age-matched control group. No differences in eye saccadic amplitude ($P > 0.05$; independent samples $t$-test) were found between the other groups. However, eye saccadic peak velocities differed significantly between all groups ($P < 0.05$; independent sam-

### Table 1. P for Testing the Null Hypothesis that the Regression Lines of Two Groups Coincide

<table>
<thead>
<tr>
<th></th>
<th>Comparison between Groups</th>
<th>Lid–Eye Saccadic Amplitude (deg)</th>
<th>Lid–Eye Saccadic Peak Velocity (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YC vs. OC</td>
<td>0.0663</td>
<td>0.0368*</td>
<td></td>
</tr>
<tr>
<td>IB vs. OC</td>
<td>0.8674</td>
<td>0.5757*</td>
<td></td>
</tr>
<tr>
<td>CLB vs. YC</td>
<td>0.0001*</td>
<td>0.0012*</td>
<td></td>
</tr>
<tr>
<td>CB vs. YC</td>
<td>0.0001*</td>
<td>0.0115*</td>
<td></td>
</tr>
<tr>
<td>CB vs. CLB</td>
<td>0.0001*</td>
<td>0.0001*</td>
<td></td>
</tr>
<tr>
<td>IB vs. CLB</td>
<td>0.0177*</td>
<td>0.0107*</td>
<td></td>
</tr>
</tbody>
</table>

* Statistically significant difference at $P < 0.05$. 

**TABLE 2. Estimated Linear Relationships of the Difference in Saccadic Amplitudes**

<table>
<thead>
<tr>
<th>Group</th>
<th>Downward Saccades</th>
<th>Upward Saccades</th>
<th>Mean Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>0.892 ± 0.712</td>
<td>0.013 ± 0.757</td>
<td>−0.366 ± 0.040</td>
</tr>
<tr>
<td>IB</td>
<td>0.755 ± 0.492</td>
<td>−0.124 ± 0.560</td>
<td>−0.060 ± 0.028</td>
</tr>
<tr>
<td>CLB</td>
<td>2.445 ± 0.772</td>
<td>1.566 ± 0.817</td>
<td>0.013 ± 0.044</td>
</tr>
<tr>
<td>YC</td>
<td>−0.746 ± 0.550</td>
<td>−1.625 ± 0.611</td>
<td>−0.100 ± 0.031</td>
</tr>
<tr>
<td>OC</td>
<td>0.450 ± 0.438</td>
<td>−0.429 ± 0.513</td>
<td>−0.063 ± 0.025</td>
</tr>
</tbody>
</table>

Target amplitudes ranged from 10° to 40° for the five groups and two saccadic directions considered. Data are mean degrees ± SE.
TABLE 4. Amplitude and Peak Velocity for 40° Downward and Upward Lid and Eye Saccades

<table>
<thead>
<tr>
<th>Group</th>
<th>Amplitude</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Downward Saccades</td>
<td>Upward Saccades</td>
<td></td>
<td></td>
<td>Peak Velocity</td>
</tr>
<tr>
<td></td>
<td>Lid</td>
<td>Eye</td>
<td>Lid</td>
<td>Eye</td>
<td>Lid</td>
</tr>
<tr>
<td>CB</td>
<td>24.3 ± 5.2</td>
<td>35.2 ± 2.6</td>
<td>22.9 ± 4.0</td>
<td>34.7 ± 1.8</td>
<td>291.1 ± 45.2</td>
</tr>
<tr>
<td>IB</td>
<td>32.7 ± 4.3</td>
<td>34.8 ± 2.5</td>
<td>31.3 ± 4.0</td>
<td>34.5 ± 2.1</td>
<td>348.9 ± 72.9</td>
</tr>
<tr>
<td>CLB</td>
<td>40.3 ± 3.5</td>
<td>36.4 ± 1.7</td>
<td>37.3 ± 3.5</td>
<td>35.7 ± 2.4</td>
<td>490.5 ± 152.4</td>
</tr>
<tr>
<td>YC</td>
<td>32.3 ± 5.4</td>
<td>36.9 ± 2.4</td>
<td>30.0 ± 4.7</td>
<td>35.4 ± 1.7</td>
<td>419.7 ± 143.7</td>
</tr>
<tr>
<td>OC</td>
<td>33.7 ± 5.3</td>
<td>35.9 ± 2.1</td>
<td>31.8 ± 4.3</td>
<td>35.0 ± 2.1</td>
<td>343.7 ± 72.6</td>
</tr>
</tbody>
</table>

Amplitude is expressed as mean degrees ± SD; peak velocity is expressed as mean degrees per second ± SD.
aponeurogenic blepharoptosis groups (Table 1). The lid saccades in the CLB group were, on average, larger and had higher peak velocities (Table 4).

**DISCUSSION**

Our data, obtained through search coil registration, showed clear differences in the eyelid metrics of patients with either congenital or aponeurogenic blepharoptosis. In addition, marked differences were found between the two forms of aponeurogenic blepharoptosis (involutorial and contact-lens-induced).

Aging affects the metrics of spontaneous blinks and vertical eye saccades. Our data confirmed aging’s effects on vertical eye saccades: reduced amplitudes with significantly lower peak velocities. Lid saccades also displayed a reduced peak velocity with age, albeit, with an increased amplitude. We may speculate that changes in the elastic properties of the levator muscle, its aponeurosis and the eyelid tissues, contribute to these effects of aging, because the elastic fibers become fewer and thinner with age.

Because age-related (involutorial) aponeurogenic blepharoptosis is assumed to be caused by disinsertion or laxity of the levator muscle aponeurosis, we expected to find a different amplitude and peak velocity in such patients with blepharoptosis compared with the age-matched control group. However, no differences between the two groups were found, which suggests that either the anatomic changes that cause aponeurogenic blepharoptosis do not affect eyelid motility proper, or they are compensated for, or our recording method may have been too insensitive to detect any differences in eyelid motility. This result partially concurs with a previous study by Fruch Musch who measured levator force and established no differences between the two groups were found, which may apply to lid movements, although the two were simultaneously recorded. Several clinical studies suggest that Hering’s law of equal innervation of the extraocular muscles may apply to lid movements, which may lead to over-elevation of an eyelid contralateral to a ptotic eyelid. Neuroanatomic studies in primates have shown that the motor neuronal pool for both levator palpebrae muscles lies within the unpaired central caudal nucleus. However, in eye movements Hering’s law probably results from nonconjugate adaptation to the effects of aging and disease. The bilateral control of lid saccades is much less conjugate than that of eye saccades. Probably, adaptation occurs only if a functional need arises, (e.g., to retain sight in both eyes). It is unclear from our study to what extent, if any, an equal innervation of the lid movements, similar to Hering’s law, affected our measurements.

We have demonstrated that search coil registration is of additional value in the examination of patients with blepharoptosis. However, we have not yet established its full clinical potential, notably on an individual level. The assessment of eyelid motility in other kinds of blepharoptosis would be of further interest.

**References**