Principles and Practice of Clinical Electrophysiology of Vision

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A Year Book Medical Publishers imprint of Mosby-Year Book, Inc.

Mosby-Year Book, Inc.
11830 Westline Industrial Drive
St. Louis, MO 63146

1 2 3 4 5 6 7 8 9 0 CL CL MV 95 94 93 92 91

Library of Congress Cataloging-in-Publication Data
Principles and practice of visual electrophysiology / [edited by]
John R. Heckenlively, Geoffrey B. Arden.
p. cm.
Includes bibliographical references.
Includes index.
ISBN 0-8151-4290-0
1. Electroretinography. 2. Electrooculography. 3. Visual evoked response. I. Heckenlively, John R. II. Arden, Geoffrey B. (Geoffrey Bernard)
[DNLM: 1. Electrooculography. 2. Electrophysiology. 3. Electroretinography. 4. Evoked Potentials, Visual. 5. Vision Disorders—physiopathology. WW 270 P957]
RE79.E4P75 1991 91-13378
617.7 1547—dc20 CIP
DNLM/DLC
for Library of Congress

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Aging and Pattern Visual Evoked Cortical Potential

Emiko Adachi-Usami

The decrease in visual acuity and other visual functions with aging has been reported extensively. This decline of visual function has been attributed to anatomical aging changes in the eye and the visual pathway. Opacities of the crystalline lens and vitreous body, miosis, and a loss of neurons at both the retina and the visual cortex have been considered to be the factors responsible for the loss of function.

With the development of surgical techniques for cataracts and the prolongation of life, patients older than 90 years often have a visual acuity over 20/20. Are their cells and neurons in the visual pathway still functioning as in youth?

Visually evoked cortical potentials (VECP) to pattern stimulation have been known to reflect several visual functions related to neuronal function, and the effect of age on pattern VECP has been studied by a number of authors. There is general agreement that the P100 peak latency increases and amplitude decreases in the elderly. However, the ophthalmological findings described in the literature are not sufficiently clear. The present chapter deals with the aging effects on pattern VECPs mainly in elderly subjects.

GENERAL CHANGES IN VISUAL EVOKED CORTICAL POTENTIALS WITH AGE

Waveform

There have been a few reports that described the development of VECP waveforms.[3, 18, 24] Generally, the waveforms change from a single positive peak to a negative-positive complex with age. The pattern-onset response consists mainly of a single positive peak with a latency of about 150 ms until about 10 months, a negative component becomes recognizable at the age of 20 months, and the initial positive component splits into two positive waves at puberty.

Figure 53–1 shows the pattern-reversal VECP responses to three check sizes from one infant that were recorded at three different ages. At the age of 10 weeks, simple, large, slow positive peaks with a peak latency at about 150 ms are observed. At 15 weeks the peak latencies of positive waves become shorter—about 120 ms. At 19 weeks the positive peak and the negative troughs become sharp and clear. The check size that elicits the largest responses in amplitude is 80 min at 10 weeks but becomes smaller—40 min at 15 weeks and 20 min at 19 weeks. No obvious alternation of VECP waveforms was observed after that. This development of waveforms is concurrent with the anatomical development of the macula and myelin sheath as well as with synaptic development.

Amplitude Changes With Aging

There has been a variant of opinion regarding the aging effects on VECP amplitude. Halliday et al.[10] reported that there was no significant effect of age on amplitude. Celesia and Daly[6] also found no correlation between age and the amplitude of P100.

In contrast, Shaw and Cant[15] reported that the P100 amplitude was greatest in childhood, declined until the fourth decade, increased again, and then decreased after the sixth decade. Wright et al.[21]

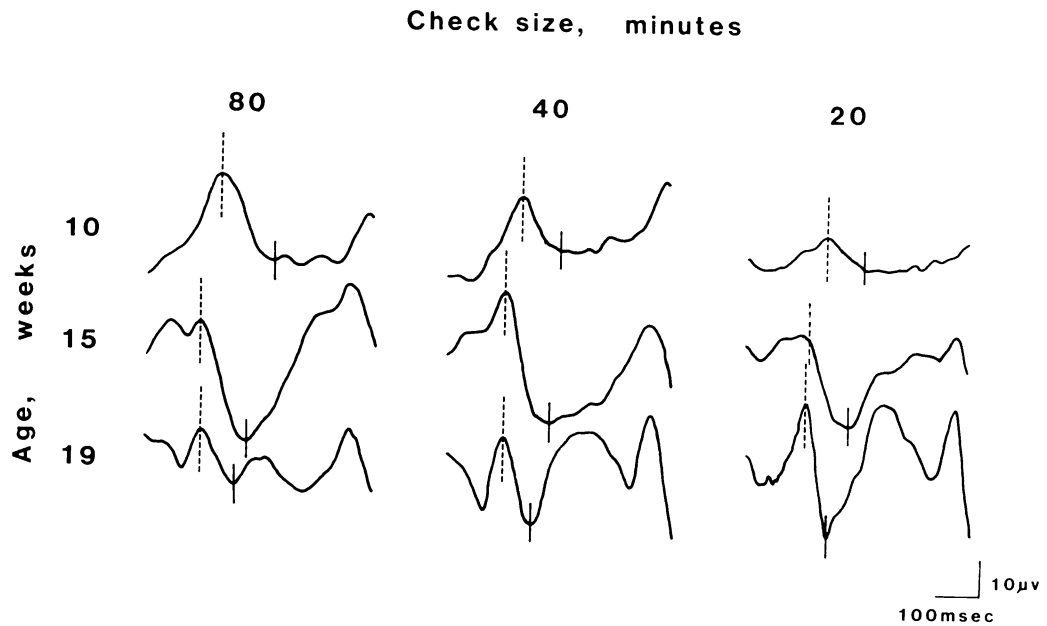

FIG 53–1.
Pattern-reversal VECP responses to three check sizes from one infant that were recorded at the ages of 10, 15, and 19 weeks after her birth.

found that the amplitude of the component of the pattern-reversal VECPs was very high in the teenage group but, once reduced, became constant from the twenties onward and showed no further consistent age changes.

We recently found that the P100 amplitude decreased with aging as shown in Figure 53–2. A progressive reduction in the amplitude of the P100 component with age for lower temporal frequency ranges was observed up to the ages of 30 to 39 years; however, the temporal tuning curve tended to shift toward lower frequencies with age after 30 years.

Peak Latency Changes With Aging

Most of the related literature refers to the increase in P100 latency in the elderly. However, a delay of the P100 is also known as an important criterion for diagnosing optic neuritis caused by multiple sclerosis. We have to be very careful when judging abnormal delay of the P100 because it can be found not only in the elderly but also in normal controls by changing the stimulus conditions such as lower vs. upper visual field, monocular vs. binocular viewing, luminance, defocusing, and spatial frequency of stimuli.

In 1975 Asselman and others[5] reported that the latency of the P100 was unaffected by aging until about 60 years but that thereafter there was a tendency for it to increase. In subjects under the age of 60 years the mean latency was 90.5 ms, but over the age of 60 years it was significantly longer at 97.2 ms.

Still later, in 1977, Celesia and Daly[6] reported a linear increase in mean latency with age. They showed an annual increase of 0.18 ms in the delay of the P100 during the age range from 15 to 70 years; it increased from 93 to 103 ms over that period. More precisely, Shearer and Dustman[17] stated that the rate of the P100 delay accelerates from young adulthood through the sixth decade. The rate of increase has been demonstrated to be greater for smaller than for larger check sizes.[7, 19, 22] Shaw and Cant[16] showed that the relationship between age and latency is influenced by pattern luminance and that at lower levels of luminance there is an increase in latency after the fourth decade.

In order to exclude the effect of senile opacity of the crystalline lens, we compared the P100 latency between phakic eyes and aphakic eyes with an intraocular lens (Fig 53–3). Peak latency changes by aging were similar in the two groups showing a significant delay in the age group beyond 70 years, suggesting that reduced transparency of the medium in the elderly was not the reason for the delay of the P100, but rather it was possibly due to senile changes in the neural pathway.

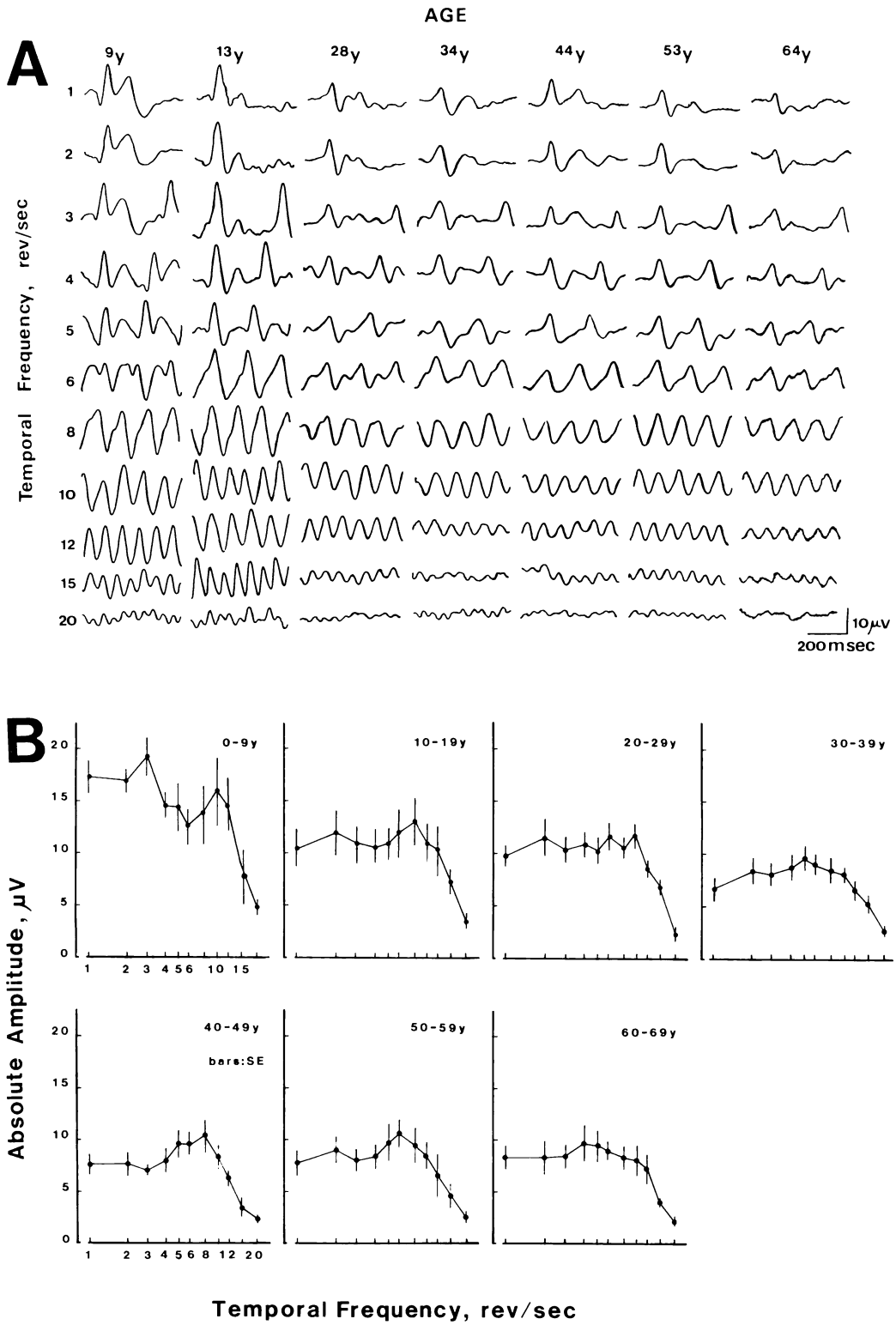

FIG 53–2.

A, pattern-reversal VECPs to 11 different reversal frequencies for seven age groups. **B,** P100 amplitude of the pattern-reversal VECPs vs. temporal frequency curves measured in seven age groups. Each age group contains ten subjects. Each point represents the mean ±1 SE. (From Adachi-Usami E, Hosoda L, Toyonaga N: *Doc Ophthalmol* 1988; 69:139–144. Used by permission.)

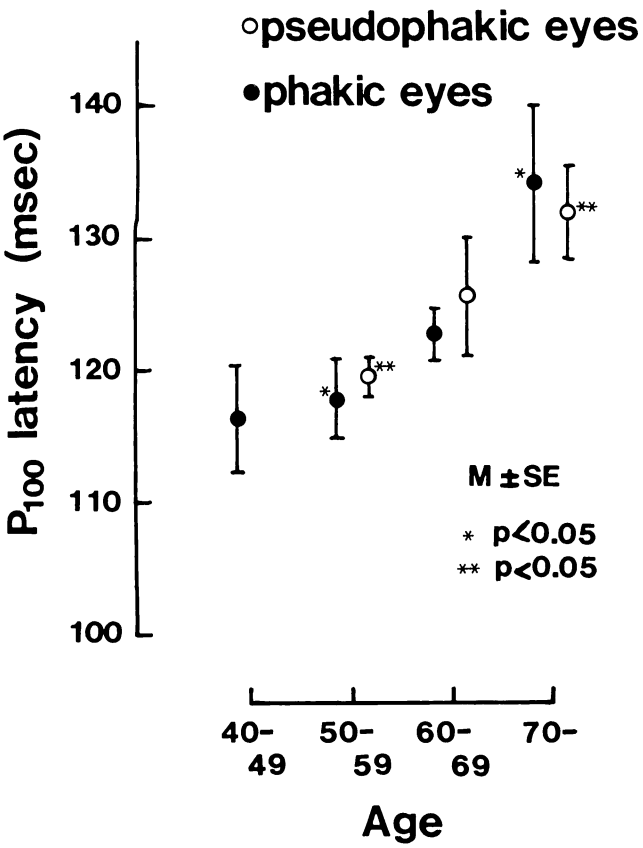

FIG 53–3.
Effect of age on P100 peak latency of pattern-reversal VECPs obtained from phakic and pseudophakic eyes.

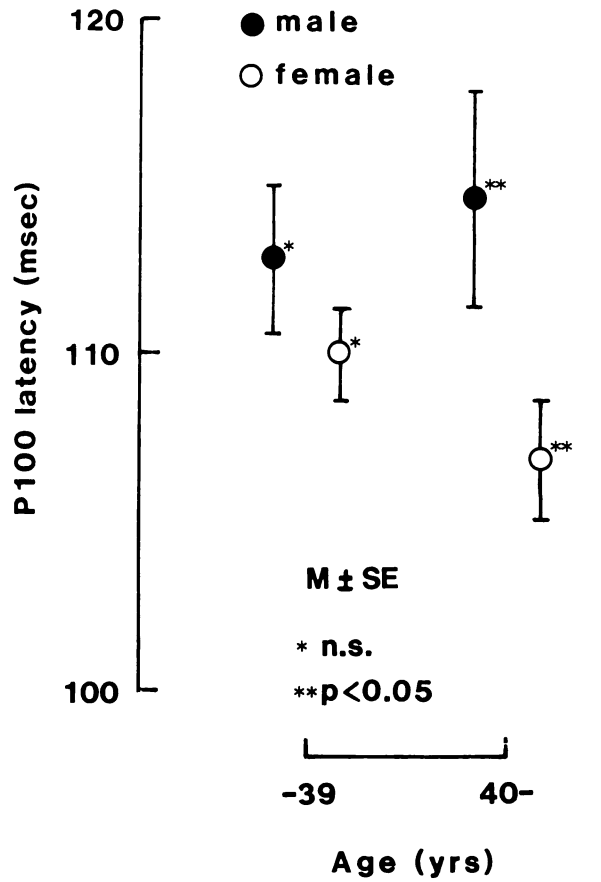

FIG 53–4.
Gender difference in P100 peak latency for young and elderly groups.

Some authors suggested a gender effect for the P100 increase in the elderly. Halliday et al.[10] found that the increase in mean latency from the age of 50 years was seen only for the female group. We also found shorter latencies in elderly females, although such a tendency has been observed throughout their life spans (Fig 53–4). On the contrary, Mitchell et al.[14] reported that a significant age effect (increasing values with age) was demonstrated, but none in relation to gender. Further studies on gender and age relationships are necessary.

In summary, it might be true that the increase in P100 latency with age begins rather late in life, over 60 years, and is uncertain at ages below 50 years.

TEMPORAL FREQUENCY CHARACTERISTICS

Few VECP studies have been performed on age-related changes in temporal frequency characteristics. Wright and Drasdo[21] found by psychophysical measurements that contrast sensitivity was significantly lowered with age, especially for high temporal frequency stimulation.

Adachi-Usami et al.[1] recorded pattern VECPs from 70 normal volunteers aged 4 to 70 years. Eleven reversal frequencies between 1 and 20 reversals per second (rps) were presented. A progressive reduction in the amplitude of the P100 component with age for lower frequency ranges of less than 10 rps was shown up to the ages of 30 to 39 years, and the temporal tuning curve followed a constant pattern after 40 years. However, there was a tendency for the maxima of the tuning curve to shift toward lower frequencies with age after 30 years. The youngest group, 0 to 9 years, had two peaks at 3 and 10 rps, contrary to the single peak found in older groups (see Fig 53–2).

CONTRAST THRESHOLDS

An increase in contrast threshold in spatial vision with age is well known.[4, 8, 12, 20, 21] Most of the stud-

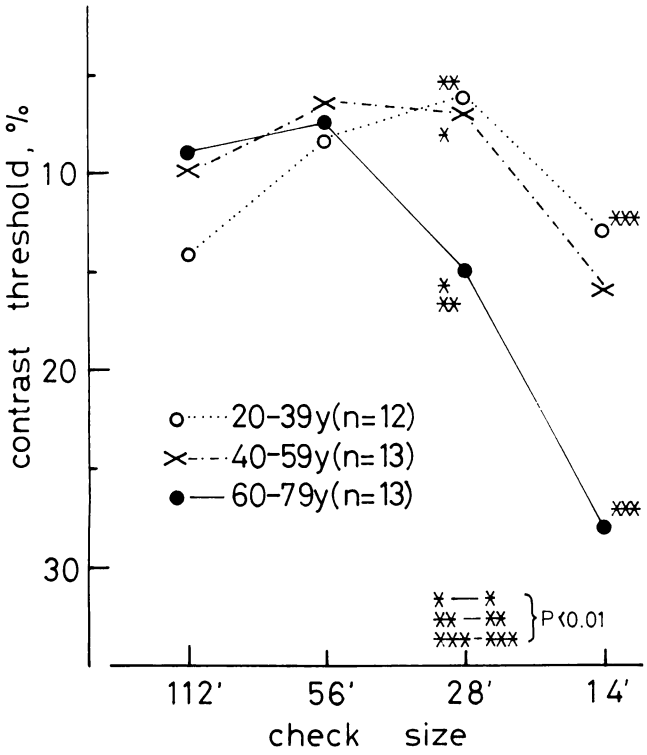

FIG 53–5.
Mean contrast thresholds for each check size in three age groups. The spatial frequency characteristics of the contrast thresholds are observed to be equally shaped in all groups. The contrast thresholds are significantly increased in the elder group with small check size stimuli ($P < .01$). (From Yamazaki H, Adachi-Usami E: *Acta Soc Ophthalmol Jpn* 1988; 92:1662–1665. Used by permission.)

ies were based on psychophysical measurements.

Our recent study[25] could verify this by means of pattern VECPs (Fig 53–5). The subjects, 38 normal volunteers ranging from 20 to 79 years old, were divided into three age groups. An artificial pupil of 3 mm was used to eliminate senile miosis effects. All patients' visual acuities were more than 1.0. With decreasing pattern contrast, the P100 peak latency decreased linearly as log contrast rose. The contrast threshold was determined by extrapolating the regression line of the line of the latency vs. log contrast to 140 ms for each check size. Contrast thresholds in elderly subjects were significantly higher than those of middle-aged or younger subjects at higher spatial frequency stimuli.

LUMINANCE THRESHOLD

The threshold levels for both rods and cones are significantly affected by age. However, the form of the psychophysically measured dark adaptation curve is the same for all age groups, although there is evidence that the amount of light reaching the retina is interfered with by the crystalline lens, which loses its transmittance with age, as well as by senile miosis. On the other hand, it is known that the decrease in pattern luminance increases the P100 latency of VECPs.[2, 11]

In order to determine the luminance threshold increase in the elderly by means of VECPs, the factors that interfere with the optical transmittance need to

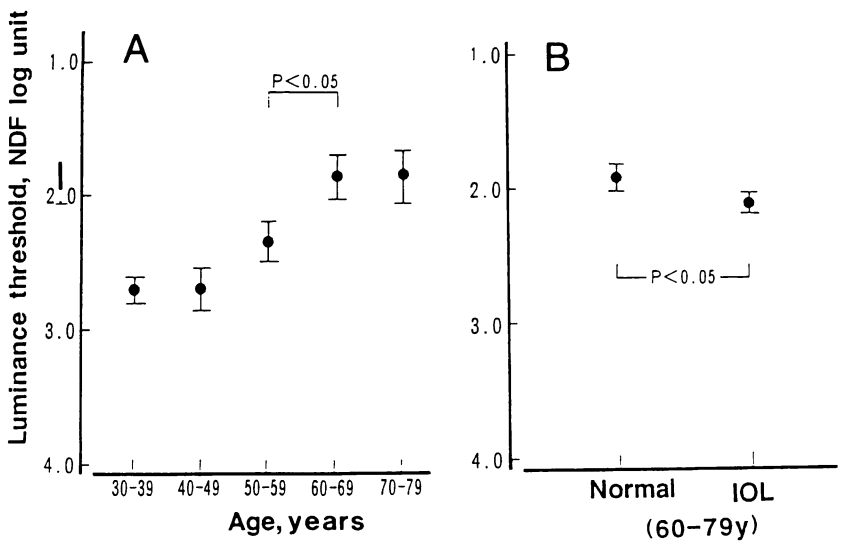

FIG 53–6.
A, aging effects on VECP luminance thresholds. Luminance thresholds increase with age. **B**, VECP luminance threshold in normal phakic subjects and pseudophakic eyes. (From Adachi-Usami E: *Jpn J Ophthalmol* 1990; 34:81–94. Used by permission.)

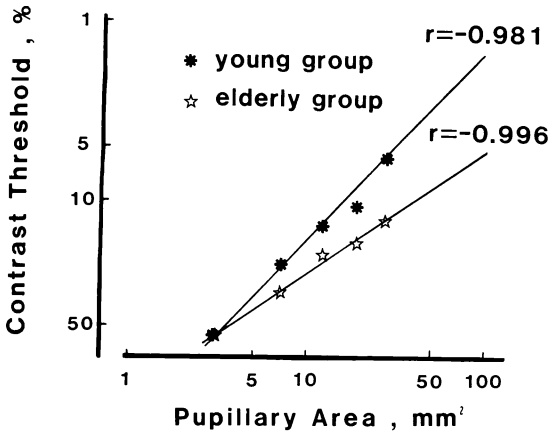

FIG 53–7.
Contrast threshold vs. pupillary area in a young group (aged 20 to 30 years) and an elderly group (55 to 70 years). (From Fujimoto N, Adachi-Usami E, Ito Y: *Acta Soc Ophthalmol Jpn* 1988; 92:1185–1189. Used by permission.)

be excluded. We therefore studied the luminance threshold in 39 normal phakic eyes and 25 pseudophakic eyes after posterior-chamber lens implantation.[26] The regression line was obtained from the VECP P100 amplitude vs. luminance data. Then, VECP luminance threshold was estimated by extrapolating to the light which produced a zero response. The threshold was seen to increase with age. The difference in thresholds between young subjects (aged 30 to 39 years) and elderly subjects (aged 60 to 79 years) was approximately 0.8 log units in neutral-density filter value (Fig 53–6,A). VECP luminance thresholds in pseudophakic eyes were a bit higher than those of the normal controls (Fig 53–6,B).

These results suggested that the increase in the luminance threshold in the elderly was not due to a lesser transparency of the crystalline lens but rather to aging changes of the neural pathway.

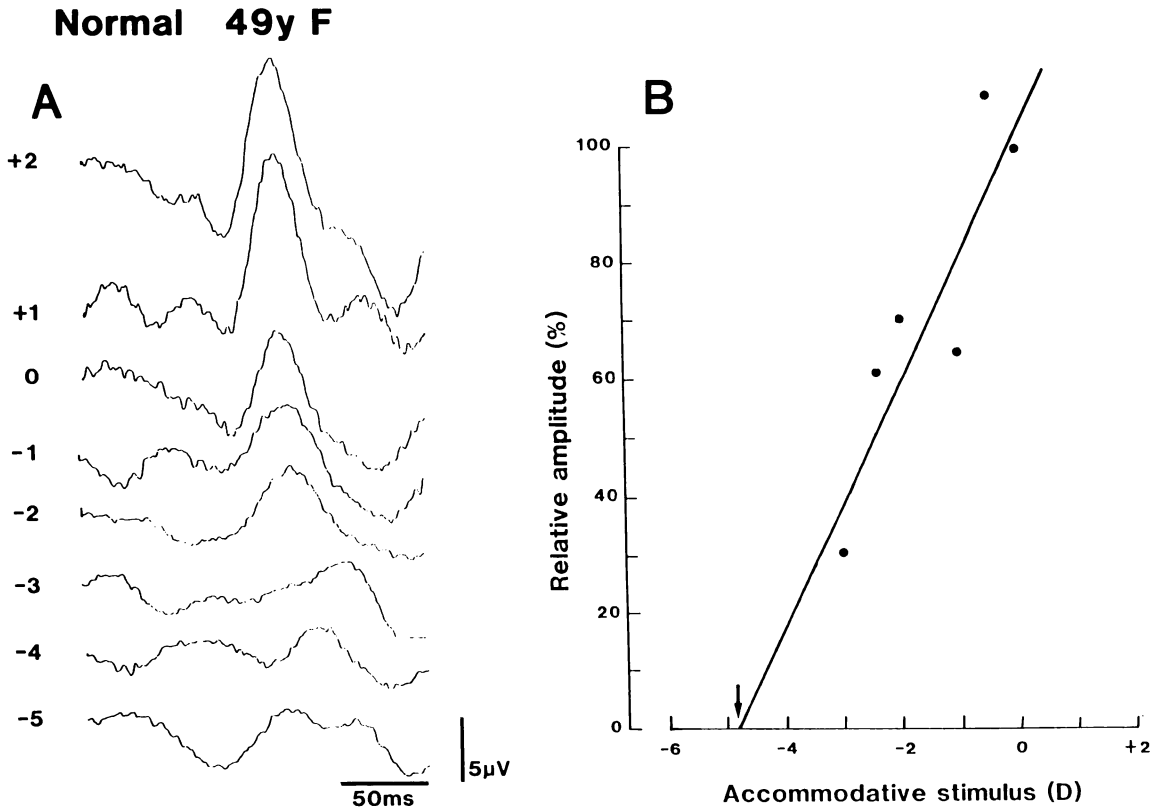

FIG 53–8.
A, pattern VECPs of a 49-year-old normal female. A minus-power lens was placed in front of the eye, and the power was increased in 1-D steps. **B,** the relative amplitude of P100 to the one for 0 D was plotted against lens power. The diopters of difference between −2 D and the lens power of the zero-amplitude point, defined by extrapolating the regression line *(dotted line),* were determined as the objective amplitude of accommodation. (From Yamamoto S, Adachi-Usami E, Kuroda N: *Doc Ophthalmol* 1989; 72:31–37. Used by permission.)

PUPILLARY SIZE

The pupil becomes smaller with age, which means that retinal luminance will be reduced to a certain extent. So the delay and reduction of the P100 in the elderly could be partly caused by miosis, not only by the senescence of the neural pathway.

According to Wright et al.[22] the mean pupil diameter decreased from 4.9 mm in the 10 to 19-year-old age group to 3.15 mm in the 70- to 79-year-old age group, with a difference in retinal luminance of 0.38 log units. Halliday et al.[11] and Adachi-Usami and Lehmann[2] found that a 1-log unit decrease in pattern luminance resulted in a 15 to 18-ms increase in P100 latency. According to our data,[25] a 0.38-log luminance decrease evoked an increase of 7 ms, whereas Wright et al.[22] calculated this increase to be 5.7 ms.

In an earlier section, the increase in luminance threshold in the elderly was described as being 0.8 log units, which could not be caused by the reduction in pupil size alone.

Therefore, we studied the effect of the pupillary area on contrast threshold based on the P100 latency in normal and young subjects (Fig 53–7).[9] The pupil was dilated with cyclopentolate, and VECP contrast thresholds were measured at pupil sizes of 2, 3, 4, 5, and 6 mm with the use of an artificial pupil. The VECP latency contrast threshold (T) was defined as the contrast necessary for obtaining a criterion latency of P100 from the upper limit of age-matched normal subjects with 4-mm artificial pupil size. The pupillary area was represented by A, and a relation of $\log T = -k \log A + C$ was found, where C is a constant. The contrast threshold obtained was higher in the elderly group than in the young group, but the differences were small with small pupil size. There were fewer differences in contrast threshold between the young and elderly groups with small pupils.

It was thus again proved that the increase in contrast thresholds in the elderly was not influenced by miosis.

ACCOMMODATION

The amplitude of accommodation decreases with age from about 20 D at 5 years to 0.5 D at 60 years.

Millodott et al.[13] applied steady-state pattern VECPs for objective measurements of accommodation and demonstrated its attenuation with advancing age. We[23] employed transient VECPs instead (Fig 53–8) and recorded them by increasing minus-power lenses in 1-D steps in front of the eye up to the range where no response was recordable. It was found that the amplitude of the P100 component was attenuated linearly with increased accommodation stimulus. The regression line was calculated from the pattern VECP amplitude vs. accommodation stimulus (in diopters) plots, and the accommodation power was determined by extrapolating the line to the 0-μV amplitude. The gradient of the regression line increased with age. The accommodation obtained when measured with pattern VECPs was attenuated significantly in the groups over 40 years of age (Fig 53–9), and there was also a remarkable delay in P100 peak latencies (see Fig 53–8).

The accommodation determined subjectively was found to be smaller at approximately 3 D than that obtained by the pattern VECP measurements.

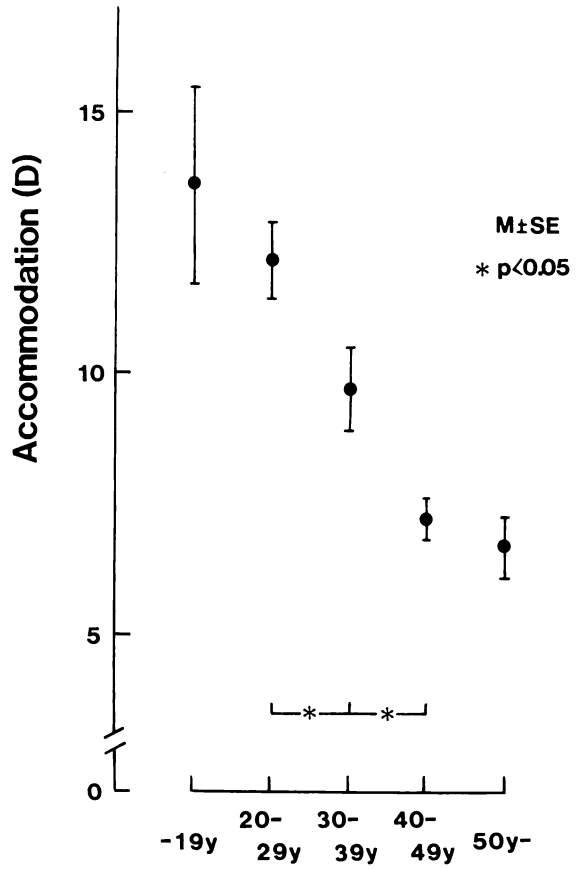

FIG 53–9.
The objective amplitude of accommodation as measured by patterns VECPs were averaged for each decade. Accommodation power was reduced significantly over 30 ($P < .05$) and over 40 years of age ($P < .05$). (From Yamamoto S, Adachi-Usami E, Kuroda N: *Doc Ophthalmol* 1989; 72:31–37. Used by permission.)

CONCLUSION

As mentioned above, there is no doubt that aging increases the latency of VECPs, and the effect is also clear in regard to amplitude. A more precise description is available in our latest work.[27]

Accordingly, we should evaluate the delay in latency with care and precision when diagnosing diseases. It is recommended that normative data for every age group be readily available in all clinical facilities.

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