mated acuity in an opaque eye is the relative response of the other (normal) eye. When no comparison eye is available, it is easy to be misled by a low TVER (indicating a poor visual prognosis), since occasionally the TVER response from a normal eye is indeed low. (Most frequently, this is found in patients over the age of 60.) Thus the least reliable signal aspect is the absolute amplitude of the response from one eye.

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The transscleral VER: normal responses. WILLIAM W. DAWSON, MELVIN L. RUBIN, and CAROL LYLE.

Normative data taken on a sample of 10 eyes indicate that transscleral visual evoked response (TVER) stimulation of the cortical evoked response with a range of lights and at lower adaptation levels produces replicable, low-variance responses which may be of sufficient quality for the clinical evaluation of retinal and visual pathway condition. Response amplitudes were related to the radiant peak-power of white stimuli but were greater for red stimuli. Attenuation of the subjective brightness of the stimulus delivered through the inferior lid and sclera was about 0.4 log units compared to corneal delivery. Typical signal: noise ratios were 5:1.

The sensitivity of the human cortical evoked response to light stimulation of the eye, particularly of the central retina, is well established.\(^1\) \(^2\)

Horowitz et al.\(^3\) have used transscleral stimulation to produce a visual evoked response (TVER) which may be valuable in estimating the residual visual function in patients having opacities of the anterior segment. This report illustrates the results of transscleral stimulation of normal eyes with normal visual pathways. It describes stimulus-signal relations and response variability, and measures the subjective brightness loss created by TVER stimulation as compared to more standardized stimulation through the transparent cornea.

Methods. Ten eyes were studied in subjects 16 through 24 years old who had clinically normal visual pathways. All were correctable to 20/20 or
better. Immediately following 4 min of light adaptation of the eyes by a ganzfeld to 0.2, 2, or 272 trolands (td), stimuli were delivered through closed eyelids at various lid sites by a system utilizing a light guide-probe described earlier. Peak stimulus power at the probe tip was calibrated by a PIN light diode. A filter box provided for neutral density or spectral filters. Powers available at the surface of the lid were 8, 80, and 340 mw peak. These stimuli had the typical blue-white appearance of a xenon arc discharge. In addition, a red stimulus was delivered via the same probe by means of a filter with a rapid cut-on beginning at 627 nm. The red stimulus power was 40 mw. Durations were approximately 6 μsec, and delivery rate was 2 Hz for all stimuli.

Responses were recorded by a differential input amplifier (passband 3 db points, 0.2 to 50 Hz) where the active Beckman miniature electrode was placed 2 cm above the inion on the midline and the reference electrodes were linked, earclips attached to each earlobe. The ground electrode was at the forehead. Electroencephalogram electrode paste was used. The input configuration provides a pseudomonopolar cortical recording which retains noise rejection advantages but requires fewer assumptions about polar distribution of the signal than a "true" bipolar input. Positive-going cortical signals produced "positive-up" records. The stimulus-locked responses were averaged by computer, and the results were stored as an ink record; 64 responses were averaged in each case. System noise comparisons were made by averaging the same number and frequency of signal pulses but with the probe tip held near the ear rather than the eye.

The psychophysical method of magnitude estimation was used to determine the relative loss of stimulus brightness between the TVER stimulus and the same stimulus delivered 1 cm before
were specified to them as brightness standard "10" and brightness "1." Intermediate intensity stimuli were created by neutral density filters. The subjects' task was to estimate the subjective magnitude of the intermediate ("test") stimuli relative to the two reference stimuli on a scale of 1 to 10. In one set of measures the reference stimuli and test stimuli were all delivered by the transscleral route, probe on the inferior lid, eyes closed. In the second set of measures, the reference stimuli were delivered as before, but the test stimuli were presented with the lid open and the probe before the cornea. The intermediate level stimuli were presented in random order until 10 judgments were accumulated at each stimulus level. After each fifth intermediate stimulus, the reference stimuli were again presented for comparison.

**Results.** Fig. 1 shows TVER signals recorded from a typical subject adapted for 4 min to 0.2 td; his eyes were closed just before stimulation. The arrows indicate the early negative and subsequent positive TVER peaks, which are quantified in the subsequent figures. When the stimulus site was at the outer canthus, there was a marked increase in response variability. The data to be presented were produced at the 0.2 td preadaptation level with the stimulation delivered at the superior and inferior lids. Adaptation at 2 or 270 td caused no major changes except reduced signal:noise ratios.

Fig. 2, A, shows group TVER amplitudes (means for 10 eyes of the TVER "primary" signal component measures indicated in Fig. 1) for the two stimulus sites, eyes closed and preadapted at 0.2 td. Fig. 2, B, shows the response for the same two sites, but with the lid remaining open during the stimulation series. Mean responses to red stimuli are indicated as circled R's. Limit marks are ± one standard error of the mean (S.E.M.). The shaded area at the bottom describes the average, peak-to-peak noise signal amplitudes ±1 S.E.M. which were recorded at the end of each set of measures (see Fig. 1). TVER stimulation after 15 min of dark adaptation (eyes closed) produced about a 30% increase in signal amplitude but no great change in variance. Fig. 3 provides a group summary comparison of low and high adaptation conditions and viewing (lid) conditions for the maximum stimulus at 0.34 watts. A lid-open state of an increased adaptation level served to reduce response amplitude.

The results of the subjective magnitude experiment show that when more intense test stimuli were delivered through the lid, they must contain approximately 0.4 log unit more power than a stimulus delivered through the cornea, for equivalent estimation of brightness. At lower intensities the differences were less.

The relatively linear distribution of amplitudes with stimulus power was not reflected in the latency data. Latencies to the N1 portion of the primary response were 65, 66, and 76 msec, respectively, for the 340, 80, and 9 mw. white stimuli. Corresponding latency S.D. was plus or minus 15, 10, and 30 msec for white stimuli. For the red stimulus, variance ± 1 S.D. was 11 msec.

**Discussion.** The results presented indicate that transscleral stimulation of the retina in normal eyes is an efficient means of producing VER signals which have an acceptable variance. The power of the stimulus light in the range of 9 to 340 mw was nearly logarithmically related to the peak-to-peak amplitude of the primary cortical response which could be identified in all of the normal subjects. The position of the probe is of moderate importance in obtaining low response variation. The inferior lid probe position appears to be a convenient choice for low variance and high signal:noise ratio. The adaptation level of the eye alters the response amplitude. Moderate light adaptation may produce signals 50% lower than in eyes which have been in darkness for 15 min, but partial dark adaptation seemed to increase variance. The amplitude of the response to red was greater than would be expected on the basis of peak stimulus power. However, the greater effectiveness of long wavelength stimuli for cortical evoked response production seems well established for the central retina, even when various stimuli are of matched intensity. Attenuation of stimulus subjective brightness by the filtering of the tissues was less than might have been expected.

Within a normal group, cortical responses may be evoked by TVER eye stimulation and yield signal:noise ratios of 4 or greater at moderate adaptation levels and high stimulus intensities. The primary signal component was identified and easily quantified for each subject. TVER stimulation is recommended where adaptation is in the 0.2 td region and stimuli are coupled to the lower lid with peak power exceeding 9 mw. This procedure may prove of value in clinical evaluations of medial opacity cases.

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The relationship between the volume of an intraocular gas bubble and the area of retina covered by the bubble was studied with the use of both a transparent model and a mathematical model of the vitreous cavity. The arc of contact of intraocular bubbles was calculated for vitreous cavities of various diameters. A 0.28 cm³ bubble will cover 90 degrees of retina and be of sufficient size to manage many of the problems for which an internal retinal tamponade would be useful. Larger retinal tears require disproportionately large increases in bubble volume to achieve modest increases in the area of retina covered. Estimating bubble size by observing the height of the bubble meniscus in the dilated pupil is subject to errors induced by small shifts in the angle of observation. A correct evaluation requires that the plane of observation be adjusted so that it coincides with the plane of the meniscus.

In 1938, Rosengren of Sweden described a technique for the treatment of retinal detachments that used a bubble of air to tamponade the retinal break against the pigment epithelium. The operation was displaced by the advent of scleral buckling in the next decade. The introduction of sulfur hexafluoride and other long-lasting gases has renewed interest in the use of intraocular gas bubbles for the management of selected retinal detachments. The ability of any gas to act as an effective internal retinal tamponade depends on having sufficient volume to cover the area of the retinal break. Thus it would be of value to know the relationship between bubble volume and the area of retina covered by the bubble. The present communication is intended to delineate this relationship.

**Method.** A glass model of the vitreous cavity was constructed with an internal diameter of 21 mm and a volume of 4.8 cm³ reflecting the dimensions and volume of the average vitreous cavity. The sphere was filled with water and other fluids. Gas bubbles of measured volume were inserted. The shape of the resultant bubble was observed with parallax controlled, and the angular extent of its arc of contact, designated θ, was measured (Fig. 1). When it became apparent that for clinically useful