In 33 patients with corneal or lens opacities, the VER delivered by the transscleral route (TVER). Based on the preoperative TVER characteristics, predictions of the postoperative acuities were made on a 1 to 5 scale. The predicted acuities were compared with those measured 6 months after surgery and showed that the TVER is a good predictor of postoperative acuity ($r = 0.8$). The criteria used for acuity estimates are presented.

Horowitz et al. have described a means for stimulating the retina by light delivered via an optical probe (light pipe) coupled to the lower lid, and subsequently recording the cortical evoked potentials elicited (transscleral VER, TVER). Dawson et al. have also reported the signal:noise ratios, variability, stimulus-response relationships, and subjective brightness aspects of transsclerally delivered stimuli in normal subjects. Since the VER is known to be biased for macular function, it was anticipated that the TVER might have potential value for predicting macular function in patients with opacities of the anterior segment dense enough to preclude full appreciation of the retinal state or potential acuity. The present study was undertaken to determine the prognostic value of the TVER, which has not been heretofore established.

**Methods.** Forty-one consecutive patients whose cornea and/or lens preoperatively was sufficiently opaque to preclude clear visualization of the posterior retina were selected for this study. The presence of obvious complicating eye diseases excluded patients, although some with macular degeneration or posterior uveitis were inadvertently included because the coexistence could not be recognized at the time of selection. In each case, the TVER was measured preoperatively with the stimuli described by Dawson et al. Briefly, the stimulating, transscleral probe was positioned at the lower lid, and cortical responses were recorded. Whenever possible, both eyes were tested, the second serving for comparison. Peak stimulus radiance at the probe tip was 340, 80, or 9 mw for white stimuli. A red stimulus ($\lambda > 627 \text{ nm}$) was also presented and had a peak radiance of 40 mw. Stimulation of each eye followed 4 min of adaptation to 0.2 troland (td). Where there was a functional fellow eye, the patient was asked to fixate a dim red light with it during the 4 min adaptation period. The lids of both the eyes were closed during flash delivery.

Preoperatively the best corrected Snellen acuity was recorded. Six to 12 months after surgical removal of the corneal or lens opacity, the visual acuity was determined once again. Of the initial 41 patients, postoperative acuity values were available in only 33.

The preoperative TVER was used to estimate the potential acuity without reference to the actual acuity data. The parameters used for the estimate from the TVER were the signal:noise ratio, the stimulus-response relationships, the amplitude of the response to red, the relationships to responses...
Fig. 1. Frequency distribution of acuity in 33 patients. Postoperative, above; preoperative, below. CF, Counts fingers; HM, hand motion; LP, light perception.

Fig. 2. Preoperative TVER signals for one patient, shown with the stimulus variables used for all patients. Acuity: preoperative OS, 20/20; OD, LP; postoperative (lens extraction OD), OS, 20/20; OD, LP. TVER preoperative predicted acuity rating: 4 (see Fig. 1).

of the normal eye (if present), and the absolute response amplitude. The "guesstimates" on an arbitrary 1 to 5 scale were compared with the postoperative acuity in the 33 patients.

**Results.** The upper portion of Fig. 1 shows the frequency distribution of acuities 6 to 12 months after surgery for the same 33 patients as in the lower part of Fig. 1. The acuities given are in five arbitrary acuity categories: ratings were "1" for a Snellen acuity of 20/20-20/100 to "5" for light perception—no light perception. In all cases, the operation performed was either a cataract extraction, a penetrating keratoplasty, or both.

There was no apparent relationship between the acuity result and the particular surgical procedure.

Fig. 2 gives an example of the typical TVER test results for a 64-year-old white man with severe opacifying keratopathy (bullous keratopathy secondary to Fuchs' endothelial dystrophy) of the right eye. White stimuli were delivered, and the cortical responses were averaged for three stimulus intensities ranging from 9 to 340 mw peak. A single set of recordings was taken during stimulation with a 40 mw red transscleral stimulus and a noise (unstimulated) record was made. Relative
"primary" response amplitude comparisons for white and red stimuli, signal-noise ratio, and response-stimulus relationships were made between OD and OS. Based upon these, the potential OD acuity was estimated to be 4 ("counts fingers"—"hand motion"). The actual postoperative (6 months) acuity at the time of testing was "light perception" OD, 20/30 OS.

Fig. 3 shows the distribution of preoperative, predicted potential acuities plotted against the actual postoperative acuity after 6 to 12 months in the 33 patients. Acuity is rated 1 through 5 as in the previously defined arbitrary categories. A nonparametric Spearman correlation coefficient was calculated for the two data sets showing that $\rho = 0.80$ ($p < 0.01$).

(Incidentally, in some patients, the VER was found to be present when the "bright flash" electroretinogram showed little or no response.)

Discussion. The sample of patients described included patients with both opacities of the anterior segment and (inadvertently) other eye diseases. Since progression of the pre-existing disease could alter the potential acuity after the prediction was made, thus tending to reduce any apparent accuracy, the results presented in Fig. 3 should prove to be conservative estimates of the potential acuity as predicted by the TVER procedure.

Shown in the results is the analysis of cortical signal amplitude of a single portion of the VER in the region of 70 to 100 msec. Although quantitative to some extent, they are strongly influenced by the examiner's subjective comparison of the many factors used to arrive at the final acuity estimate. Currently, of the five factors used, there is still insufficient experience to generate a truly objective quantitative means to predict acuity. In any case, several factors seem to be useful for prediction, and some were mentioned in the Results section.

The most important factor, by far, is the signal:noise ratio, but even that datum is of only limited value when it is considered alone. Whenever possible, the records from the normal (control) eyes must be used for comparison; there is simply too wide a variation among normal individuals in their VER production to enable firm reliance on one set of data. Thus, if the signal:noise ratio is extremely small in a single eye, one cannot predict function without comparing that to the normal (control) eye. (A great disparity between the eye in question and a normal eye is the basis for predicting a reduced acuity.) Moreover, when recording is done via bipolar scalp electrodes, the response is more susceptible to intersubject variation; their use assumes a specific potential field distribution and both the visual field representation, and the potentials generated probably are nonuniformly distributed among a random sample of normal humans. The use of a pseudomonopolar recording electrode, however, minimizes the intersubject differences, since the assumption of a specific signal dipole orientation is not so important.

The second major point in the TVER evaluation was the linearity of the response (or the distribution) between response amplitude and the stimulus power. The results from normative data show that there is a nearly linear relationship between the logarithm of stimulus power and response amplitude. Therefore the absence of such a linear response leads to a less favorable acuity prediction. Interestingly, the response to the red stimulus is greater in normal eyes than would be predicted for an equivalent white stimulus. As indicated in Fig. 2, the red stimulus at 40 mw frequently produces a response amplitude approximately equal to that elicited by the 80 mw white stimulus. A relatively low red response led to a less favorable acuity prediction.

Limited experiments with experimentally lesioned monkey retinas in our laboratory indicate that the red stimulus is more specific for central macula than the white stimulus, since the latter will still produce sizable cortical potentials when 1 or 2 degrees of the central retina have been destroyed by photocoagulation—not so with the red stimulus.

The fourth major factor in establishing an esti-
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-to-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