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Visual acuity in unilateral cataract

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Abstract

***Background*—Patching the fellow eye in infancy is a well recognised therapy to encourage visual development in the lensectomised eye in cases of unilateral congenital cataract. The possibility of iatrogenic deficits of the fellow eye was investigated by comparing the vision of these patients with untreated unilateral patients and binocularly normal controls.**

***Methods*—Sweep visual evoked potentials (VEPs) offer a rapid and objective method for estimating grating acuity. Sweep VEPs were used to estimate acuity in 12 children aged between 4 and 16 years who had had a congenital cataract removed in the first 13 weeks of life. The acuities of aphakic and fellow phakic eye were compared with the monocular acuities of similarly aged children who have good binocular vision, and with children with severe untreated uniocular visual impairment. Recognition linear acuities were measured with a linear Bailey–Lovie logMAR chart and compared with the sweep VEP estimates.**

***Results*—A significant difference was found between Bailey–Lovie acuity of the fellow eye of the patient group and the right eye of binocular controls, and the good eye of uniocular impaired patients (one way ANOVA, $p<0.01$). However, this was not evident for a similar comparison with sweep VEP estimates. There was no significant difference between the right and left eye acuities in binocular controls measured by the two techniques (paired *t* test).**

***Conclusion*—A loss of recognition acuity in the fellow phakic eye of patients treated for unilateral congenital cataract has been demonstrated with a logMAR chart. This loss was not apparent in children who have severe untreated uniocular visual impairment and may therefore be an iatrogenic effect of occlusion. An acuity loss was not apparent in the patient group using the sweep VEP method. Sweep VEP techniques have a place for objectively studying acuity in infants and in those whose communication difficulties preclude other forms of behavioural test. The mean sweep VEP acuity for the control groups is 20 cpd—that is, about 6/9. When acuities higher than this are under investigation—for example, in older children, slower transient VEP recording may be more appropriate, because higher spatial frequency patterns are not as visible at higher temporal rates (for example, 8 Hz used in sweep VEP recordings).**

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Visual acuity is the most commonly used clinical measure of visual function. Most ophthalmological centres assess linear letter recognition acuity in adults, and single letter or picture recognition acuity in preschool children. Resolution acuity is assessed in younger, preverbal infants with forced choice preferential looking techniques using gratings or vanishing optotypes.[1–3] These tests depend upon the identification of looking behaviour which can be particularly difficult to determine when a child is active or has an oculomotor disturbance—for example, oculomotor apraxia or nystagmus. The possibility of an objective and rapid assessment of vision using visual evoked potentials (VEPs), therefore, is particularly attractive for the paediatric population.

It is known that resolution and recognition acuity can be differentially affected by pathological visual degradation. By stimulating peripheral retina, preferential looking acuity can underestimate the depth of amblyopia in a strabismic eye, or in a case of foveal abnormality.[4,5] The VEP predominantly reflects activation of the macular pathway and the foveal representation at the occipital pole. It can provide an objective indication of visual pathway function and theoretically could provide a more accurate indication of interocular acuity differences. Transient VEPs to pattern reversal or onset stimulation have been used in the past to assess the quality of vision.[6–11] Subtleties of transient waveform interaction[12] are hidden in the steady state VEP as the responses merge and appear like a sine wave. However, the steady state VEP offers the strong advantage over transient recording in that the much faster response acquisition time suits the limited attention span of an infant. The sweep spatial frequency VEP is a steady state response to a range of spatial frequencies sequentially presented with fast counterphase, typically between 8 to 16 reversals per second.[13,14] An extrapolation to zero response amplitude gives an estimate of visual resolution. We have compared the swept spatial frequency VEP acuity estimates, made in older children with unilateral aphakia, with those of normally sighted controls.

There are few patients with unilateral congenital cataract in the literature who have achieved 'good' (6/6–6/24) visual acuity in the aphakic eye.[15–18] The success in these cases appears to depend upon 'early' cataract extraction and optical correction—that is, within 12 weeks, and upon the degree of compliance patching the fellow eye. Patching of the good, phakic eye is an essential part of the amblyopia treatment in unilateral aphakia. Occlusion per se is amblyogenic and it is not clear at present what long term effect it is having on the fellow eye.

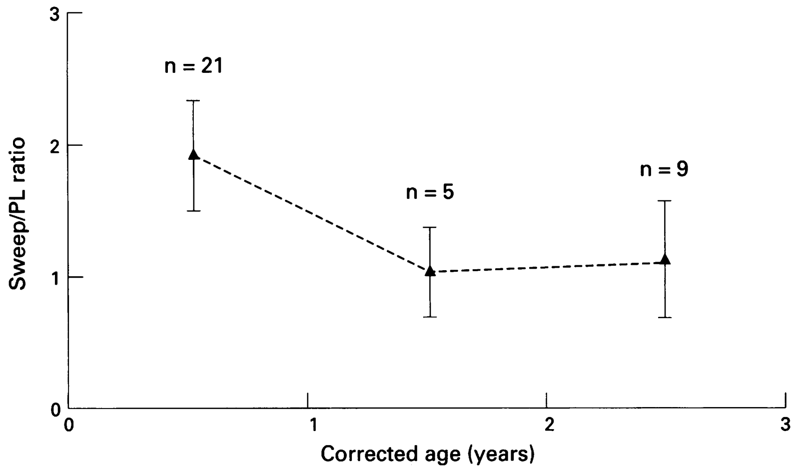

Figure 1 Comparison of binocular acuities measured in a group of clinically normally sighted infants using Keeler forced choice preferential looking and sweep visual evoked potential (VEP) techniques. The sweep VEP method overestimates acuity in the first year, the agreement is closer over the next 2 years.[20] (There is a significant correlation between the two measures accounting for 60% of the variance.)

We currently use interocular resolution acuity differences measured by forced choice preferential looking (FCPL) techniques to modulate the patching regime in the clinical follow up of preverbal infants with unilateral aphakia.[19] We established the relation between the acuity estimates made with FCPL and sweep VEP acuity estimates, obtained with a VENUS Neuroscientific program, in a group of 35 ophthalmically normal infants aged 4 weeks to 3 years,[20] (Fig 1). In agreement with other authors we found that the sweep estimate exceeded the PL estimate in infants under 1 year of age, but became closely correlated after this time.[21] In older children and adults preferential looking acuity is correlated with optotype acuity, but overestimates typically by 1–2 lines of Snellen (about 1 octave).[16–22] Sweep VEP estimates of acuity have also been correlated with recognition optotype acuities.[23 24] In a retrospective study Gottlob *et al*[25] suggested that the sweep VEP estimates made in infancy were predictive of single optotype acuity in early childhood.

We have become interested in the visual function of the phakic eye in infants following unilateral cataract removal.[26] Patching during the developmentally sensitive period places the fellow eye at risk of occlusion amblyopia. This becomes particularly relevant as surgical intervention may now occur within days of birth. Deleterious effects of patching on visual performance of the fellow eye, however, are considered rare and to be associated with full time occlusion.[27 28] Such effects, measured with either VEP techniques[29 30] or preferential looking,[31] have been claimed to be reversible. Indeed there is some debate as to whether there is an acuity deficit in the fellow eye following unilateral cataract removal and whether this is iatrogenic.[18–26 32–35]

To address this issue we have measured linear recognition acuity, with a Bailey–Lovie logMAR chart, in a group of older children who had unilateral congenital cataracts removed as infants, and compared this with acuity estimates obtained by a sweep spatial frequency VEP technique. These children had followed an occlusion regime of patching the phakic eye for 50% of waking hours in the first year of life, irrespective of interocular acuity differences. This study has enabled us to compare sweep VEP acuity with recognition acuity in older children and to assess its utility in a clinical population who may have amblyopia and may have latent nystagmus.

Methods

The letters on a Bailey–Lovie linear letter recognition test,[36] have approximately equivalent legibility, and the letter size and line spacing vary systematically in a logarithmic progression. Visual acuity can be recorded as a logMAR score (minimum angle of resolution): each letter read has a score of 0.02 logMAR which contributes to the line score of 0.1. We used a matching template for two of the children in our sample—both were 4 years old. The template was large enough and the letter spacing such that the ceiling for acuity was the wall chart and not the match template.

Swept spatial frequency VEPs were measured from an active electrode placed at Oz referred to Cz; an electrode at Fz was connected to the earth. This montage gave VEPs of good size and compared with a reference sited at Fz, reduced the contamination of raw data by eye movements and periocular myogenic activity. The amplifier bandpass was set at 0.1–100 Hz. Horizontal black and white sine wave gratings, of 80% contrast, were counterphases at 8Hz (16 reversals per second). Closed circuit television was used to monitor fixation throughout the recording. A sweep was stored only if fixation was deemed to have occurred throughout the 8 second presentation period. If fixation deviated, attention was drawn again to the stimulus and the sweep restarted. Individual sweeps were stored and at least four sweeps vector averaged for subsequent analysis. A horizontal grating orientation was selected in order to minimise the adverse effects of nystagmus.[37] Every second the pattern size became smaller and typically eight pattern sizes were presented within the range 0.5–36 cpd. The second harmonic of the response was extracted by discrete Fourier transform, and its amplitude and phase displayed as a function of spatial frequency. Linear regression was used to extrapolate from the highest amplitude response to the zero amplitude baseline. This intersection with the baseline determined the sweep VEP estimate of acuity. Phase data are used to distinguish reliable amplitude data. The phase is expected to show a progressive lag as spatial frequency increases and to have narrow confidence limits. Figure 2 is an example of the graphical display of the data and the regression in cpd (cpd/30 gives the Snellen equivalent). The VEP amplitude tends to be large in young infants and to diminish towards adulthood, with pathological factors such as amblyopia and nystagmus. Extrapolation to a zero amplitude is a relative measure of amplitude change

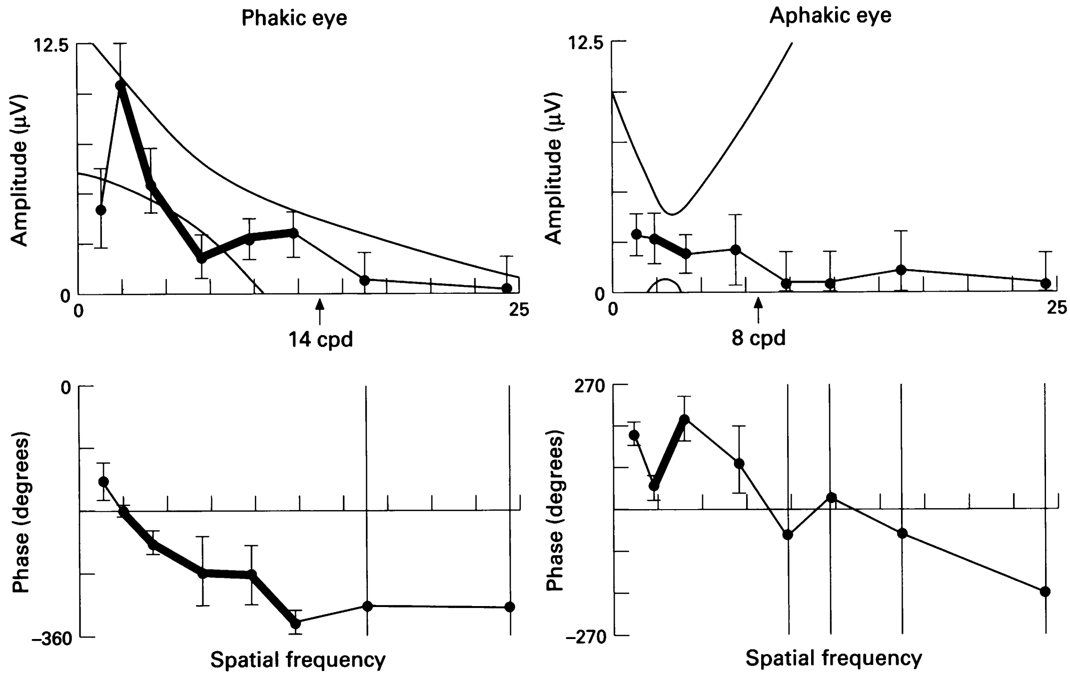

Figure 2 An example of the sweep data to illustrate the regression estimate of acuity in a 6-year-old patient who had a left cataract extraction aged 8 weeks. His Bailey–Lovie linear acuity is right eye 0.26, left eye 0.56, approx 6/10 right eye and 6/24 left eye.

and the acuity estimate is mostly independent of absolute VEP amplitude.

Subjects

Twelve children, aged between 4 and 16 years of age, who had been treated for unilateral congenital cataract were recalled. The children had been operated on in the first 13 weeks of life and the fellow phakic eye was patched for at least 50% of waking hours in the following 9–12 months. The fellow eye was deemed clinically normal on ophthalmic examination. All of the patients had squints and 50% had latent nystagmus which was evident on electro-oculogram and video recording. The patient group was compared with two groups of similarly aged children. The first were 12 binocularly normal children (mean age 9.3 years), 'the binocular control group', the second group was comprised of nine children, (mean age 8.5 years), who had a severe untreated unilateral condition (including six with persistent hyperplastic primary vitreous (PHPV) one dense cataract, one unilateral retinoblastoma, and one unilateral optic atrophy, 'the uniocular control group'.

Results

Sweep VEP acuity estimates were expressed as logMAR (minimum angle of resolution) for direct comparison with the Bailey–Lovie data (Snellen = d/D, MAR = D/d, cpd 30/MAR). In the binocular control group there was no significant difference between the acuities of right and left eyes, measured by either technique and the right eye estimates were compared with the fellow eye of the other groups. Phakic eye acuity was significantly better that aphakic eye acuity in the patient group (paired t test $p<0.001$ for both sweep VEP estimates and Bailey–Lovie acuity). Mean recognition acuity for the fellow eye was 0.26 logMAR ≅ 6/10 and aphakic eye acuity was 1.3 logMAR = 6/120. Sweep fellow eye acuity was 0.24 logMAR ≅ 6/10 and aphakic eye acuity was 0.64 logMAR ≅ 6/30. A comparison of Bailey–Lovie estimates from phakic, fellow eyes with control eyes demonstrated a significant difference (one way ANOVA, $p<0.01$). This was not evident for similar comparisons using the sweep VEP estimates of acuity. Figure 3 highlights the mean acuity difference for patient and control groups. This also demonstrates that latent nystagmus was not confounding the results, because removal of these data from the patient group reveals similar group mean differences.

Sweep VEP acuity estimates and Bailey–Lovie acuity were correlated significantly when data from all groups were considered; $R^2=0.4$, the gradient of the regression was 1.5 (Fig 4). Thus when Bailey–Lovie acuity is high the sweep acuity estimate is lower. This discrepancy between the two forms of testing is also seen when the effects of defocus are assessed. That the sweep VEP is vulnerable to defocus indicates that pattern/contrast sensitive mechanisms are involved in producing the electrophysiological response, but the rate of acuity fall off with blur is less than for subjective testing with recognition acuity, suggesting that sweep acuity is less sensitive to high spatial frequencies.[38] Figure 5 illustrates representative data from one experienced adult observer and demonstrates the effects of defocus on both forms of acuity test.

Discussion

Our findings demonstrate that fellow, phakic eye acuity measured with a linear Bailey–Lovie chart is reduced significantly compared with control eyes of binocular subjects and untreated monocular subjects, most of whom had similar conditions; the majority had PHPV. The chart design tends to diminish effects of

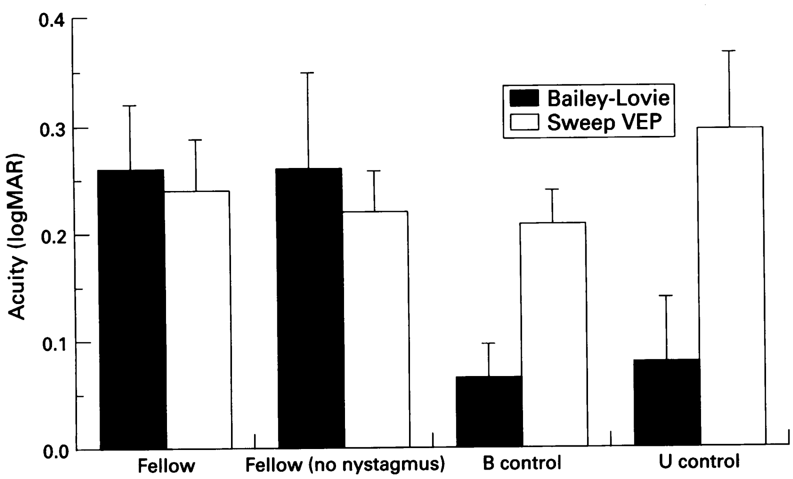

Figure 3 A graphical display of the mean Bailey–Lovie letter and sweep visual evoked potential (VEP) acuity (+1 SEM) for all groups treated. This illustrates the significant difference between Bailey–Lovie letter acuity in the fellow eyes of aphakic patients and the monocular acuities of the control groups. The sweep VEP estimates are not significantly different between the groups. The groups are referred to as follows: fellow (n=12) data from all patients; fellow (no nystagmus) (n=6) excludes data from patients exhibiting latent nystagmus; B control (n=12) right eye estimates from binocularly normal controls; U control (n=9) visual acuity from the good eye of children with severe unilateral ocular dysfunction.

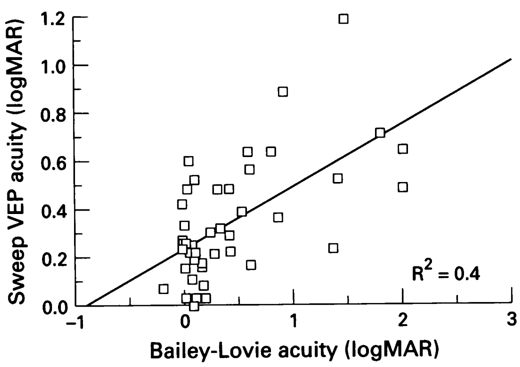

Figure 4 The correlation between the two acuity measures in the whole population accounted for 40% of the variance. The gradient of the regression is 1.5.

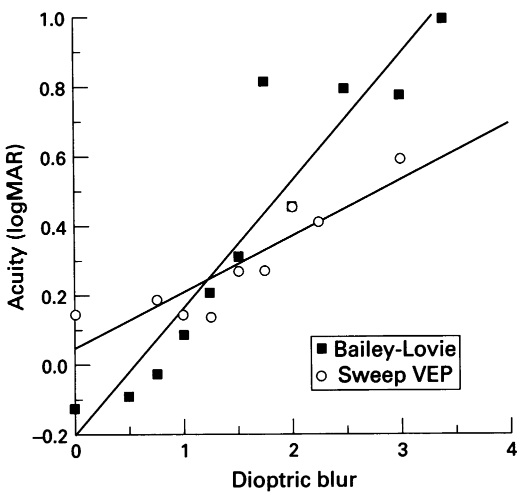

Figure 5 This demonstrates a dissociation of acuity measures when the effects of defocus are studied in an experienced adult observer.

test scoring criteria (for example, scoring a line of acuity if the majority of letters are read), which could hide a subtle deficit and the logarithmic progression of letter size removes the sampling gaps inherent in the Snellen range. Bailey–Lovie acuity is a recognition task which requires the perception of static, high spatial frequencies. In contrast, the sweep VEP uses high temporal frequencies which are suboptimal for the highest spatial resolution, but allow easier detection of low spatial frequencies.[39] A high spatial frequency deficit therefore may not be apparent in the sweep VEP estimates despite its predominantly macular representation at the striate cortex. The lesser effect of defocus on sweep VEP acuity is readily understandable in this context.

It is valuable to know the extent and robustness of the relation between objective and subjective acuity testing particularly when testing paediatric populations, or older children and adults who cannot respond conventionally. A significant correlation was found between sweep VEP estimate and Bailey–Lovie acuity accounting for 40% of the variance in the data. The sweep VEP estimates tend to be lower than Bailey–Lovie acuity when the latter is high, but tend to be higher at lower Bailey–Lovie acuities. This implies that the sweep estimate is slightly more resistant to amblyogenic factors—that is, an amblyopic deficit is not revealed or present at high temporal rates in older children.[40–42] Crowding occurs in normal individuals, but is more pronounced in amblyopia and a higher recognition acuity may be measured with single letter or symbol presentation. This may account for the greater correlation reported when single letter recognition acuity has been compared with sweep VEP estimates.[25] In younger (under 3 years), clinically normally sighted children a greater correlation is obtained when sweep VEP estimate is compared with spatially similar minimal resolvable grating PL acuity.[20]

It is possible that the good progress initially reported in the early years following removal of unilateral congenital cataract may be a consequence of the relatively low behavioural acuity of infants, coupled with the methods of acuity assessment and the wide range of 'normal' acuity, sometimes spanning 2 octaves. The fall off in success, or asymptotic visual development,[43] as the infant matures may be attributed in part to the occurrence of strabismus and latent nystagmus at a time when acuity tests which are more sensitive to the high spatial frequency deficits associated with amblyopia can be used.

Latent nystagmus is not normally apparent under binocular viewing conditions, but develops during monocular viewing. It appears to be characterised by an absence of binocular vision development during the sensitive period of binocular function.[44] Latent nystagmus was noted in 50% of the clinical population studied, but removal of these data did not alter the difference in mean acuity between fellow eyes (Fig 3) In the uniocular control group those who had profound uniocular visual deprivation from birth were noted to have symmetrical optokinetic nystagmus (OKN). In contradistinction, OKN was asymmetrical for the uniocular aphakic group; retaining the immature characteristic of a weaker response in the nasotemporal direction. It appears that a lack of early interocular rivalry may determine symmetrical OKN.[45]

Conclusion

Bailey–Lovie recognition acuity is reduced in the fellow eye of patients operated on for uniocular congenital cataract compared with controls. When compared with sweep VEP acuity estimates a significant correlation is found, but the gradient of the regression indicates that at lower Bailey–Lovie acuity the sweep acuity tends to be higher. Sweep VEPs acuities for the right and left eyes of a normally sighted individual show a close correspondence, within 1 octave. This lends support for the use of the technique as an objective monitor of interocular acuity difference and amblyopia therapy, particularly in the preverbal infant and child. In older children the high temporal rate used in sweep VEP recording may diminish its sensitivity at detecting high spatial frequency losses.

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