

Electroretinography in a Paediatric Setting: A Useful Diagnostic Tool

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ABSTRACT

Assessing visual behaviour in young children is a challenging task. When children present with poor vision, nystagmus, photophobia or nyctalopia, it can be difficult to determine the cause. The electroretinogram (ERG) plays an important role in the diagnosis and management of paediatric retinal eye conditions and can be a useful diagnostic tool for the paediatric ophthalmologist. The ERG records electrical activity of the retina in response to ocular stimulation with either a light or pattern source.

Patients are referred to the visual electrophysiology clinic when a diagnosis is uncertain or when the ERG result will

help confirm a diagnosis. When a diagnosis is confirmed the ERG can be used to monitor progression of the disease. These results, along with genetic counselling, allow patients and their families to be informed on prognosis and progression of retinal disease and its impact on vision.

A retrospective review of patients attending The Children's Hospital at Westmead for ERG assessment over a two-year period from 2007 to 2009 was carried out. This paper discusses methods of paediatric ERG assessment, indications for testing and common paediatric retinal dystrophies.

Keywords: electroretinogram, paediatrics, retinal dystrophy

INTRODUCTION

The electroretinogram (ERG) is utilised as part of a group of tests which assess visual and retinal function. These tests include visual acuity, colour vision, contrast sensitivity, visual fields, fundoscopy and other electrodiagnostic testing. The ERG records electrical activity from the retina in response to ocular stimulation via either a light or pattern source. It is used to investigate rod and cone photoreceptor retinal function as well as inner and outer retinal function.

Paediatric ophthalmological investigation is hindered in young infants and children by the limited number of objective diagnostic tests available, and the patient's inability to communicate symptoms and subjective visual responses. Fundoscopy examination in young infants is not always conclusive and may reveal a normal-looking retina initially, even in cases of severe retinal dystrophy.¹ The ERG is a useful tool in the paediatric population as it is objective, and although it does require some co-operation from the patient to enable adequate positioning of both the patient and the electrodes during

the test, it requires minimal participation and interaction throughout the test.

The role of the ERG in paediatric ophthalmology is crucial in the diagnosis and management of paediatric retinal eye conditions. The benefit of the ERG in providing a diagnosis should not be underestimated as it can impact the patient's visual rehabilitation with low vision training and support from low vision services, schooling choices and future employment possibilities.

TYPES OF ERG ASSESSMENT

There are three types of ERG assessment. These are the full field, pattern and multifocal ERG. The full field ERG (ffERG) is used to assess the retina with light stimulation. It investigates rod and cone photoreceptor function and inner and outer retinal function. It requires minimal patient interaction and can be assessed while the patient is asleep or under sedation. It is recorded in a minimum of five stages in scotopic and photopic conditions to isolate rod, mixed rod and cone, and cone stimulation in the retina. It is useful in diagnosis of retinal dystrophies such as retinitis pigmentosa, Leber's congenital amaurosis, congenital stationary night blindness and cone dystrophies.

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The ffERG waveform is comprised of a series of peaks and troughs known as the a, b, c and d waves. It is analysed by the amplitude and timing of the first initial negative trough – the a wave, and the subsequent positive peak – the b wave (Figure 1). The a wave originates from the photoreceptor layer of the retina, the rods and cones, while the b wave originates from the Muller and bipolar cells. Differences in the electrical potential caused by hyperpolarisation of the

apical membrane of the retinal pigment epithelium (RPE) and hyperpolarisation of the distal end processes of the Muller cells result in the c wave. This is a slow positive wave that follows the b wave but is not always identifiable. The d wave is a positive response that occurs after the b wave when the retinal illumination is turned off in the light adapted eye. It is produced by the interactions of the on (depolarising) and off (hyperpolarising) bipolar cells.

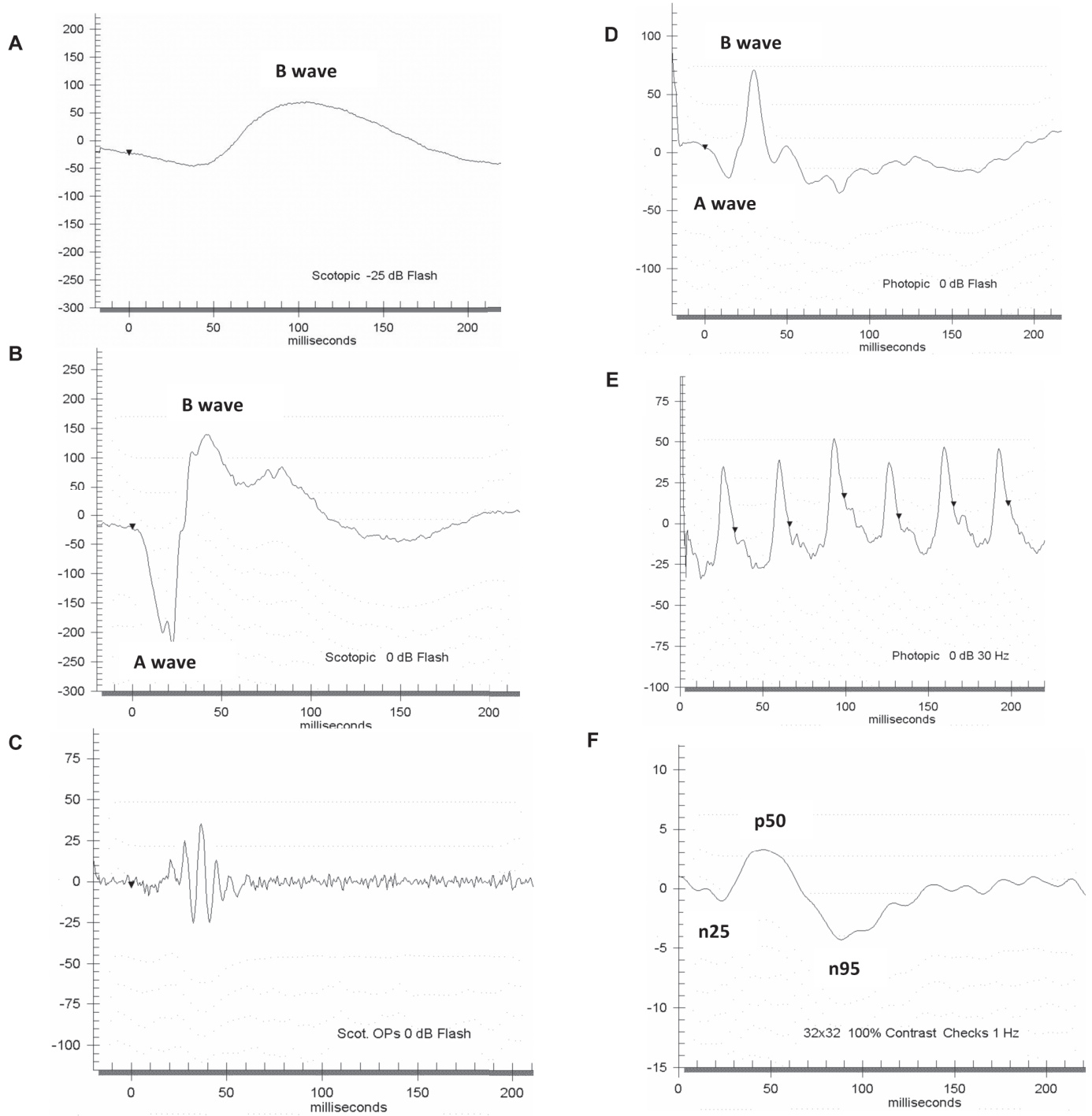


Figure 1. A normal full field ERG recording and pattern ERG recording. (A) scotopic rod response, (B) scotopic combined rod cone response, (C) scotopic oscillatory potentials, (D) photopic cone response, (E) photopic cone flicker response, (F) pattern ERG.

The pattern ERG (pERG) assesses ganglion cell function and is used to investigate macular function and maculopathies. It is recorded to pattern stimulation and is often performed in conjunction with a visual evoked potential (VEP) to differentiate between optic neuropathies and macular pathway dysfunction. It requires co-operation and steady fixation from the patient and therefore the patient can not be sedated during the test.

The pERG waveform is comprised of a negative trough at approximately 25 milliseconds, a positive peak at approximately 50 milliseconds and another trough at approximately 95 milliseconds (Figure 1).

The multifocal ERG (mfERG) is used to assess localised retinal lesions within the central 20 to 30 degrees of retina and is recorded with pattern stimulation. It is a cone initiated response and requires co-operation and central steady fixation from the patient and like the pERG the patient can not be sedated for the test.

ELECTRODES

There are different types of electrodes that can be used to record the ERG. Ocular contact electrodes record from the cornea or the conjunctiva. Corneal recording electrodes come in the form of a contact lens with or without a lid speculum – Burian Allen and ERG Jet respectively. Gold foil and DTL thread electrodes record from the conjunctiva (Figure 2). Skin electrodes are attached to the skin surrounding the eye (Figure 3).

The ERG result will differ in scale amplitude depending on the type of electrode used and the proximity of the electrode to the cornea. Skin electrodes record the lowest amplitude and Burian Allen electrodes record the highest. In comparison with a Burian Allen electrode the amplitude will be reduced to 89% when recorded with an ERG Jet electrode, 56% when recorded with a gold foil electrode, 47% when recorded with a DTL electrode and 12% when recorded with a skin electrode.² The waveform morphology when recorded with skin electrodes is similar to corneal contact electrodes, and after scaling responses, amplitudes are similar also.³ Skin electrodes have been proven to be an effective and reliable, non-invasive technique of recording the ERG in the paediatric population.^{4,5}

TESTING PROTOCOLS

The International Society for Clinical Electrophysiology of Vision (ISCEV) is an international body that establishes standard protocols for all visual electrophysiology testing. This includes the ERG as well as the VEP and electrooculogram (EOG). These international guidelines enable comparison of data amongst different recording centres and different recording equipment. The current ISCEV protocol for recording of the full field ERG includes

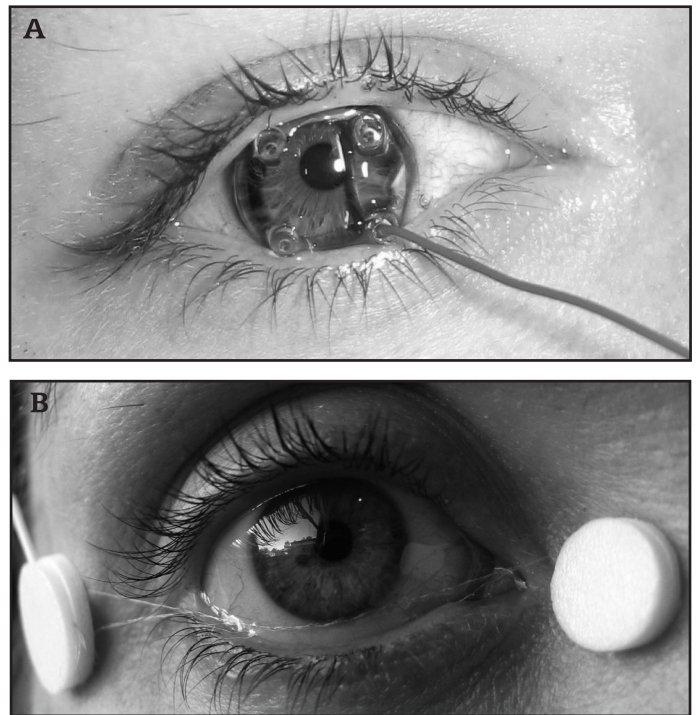


Figure 2. Two types of ocular contact electrodes (A) ERG Jet contact lens electrode, (B) DTL.

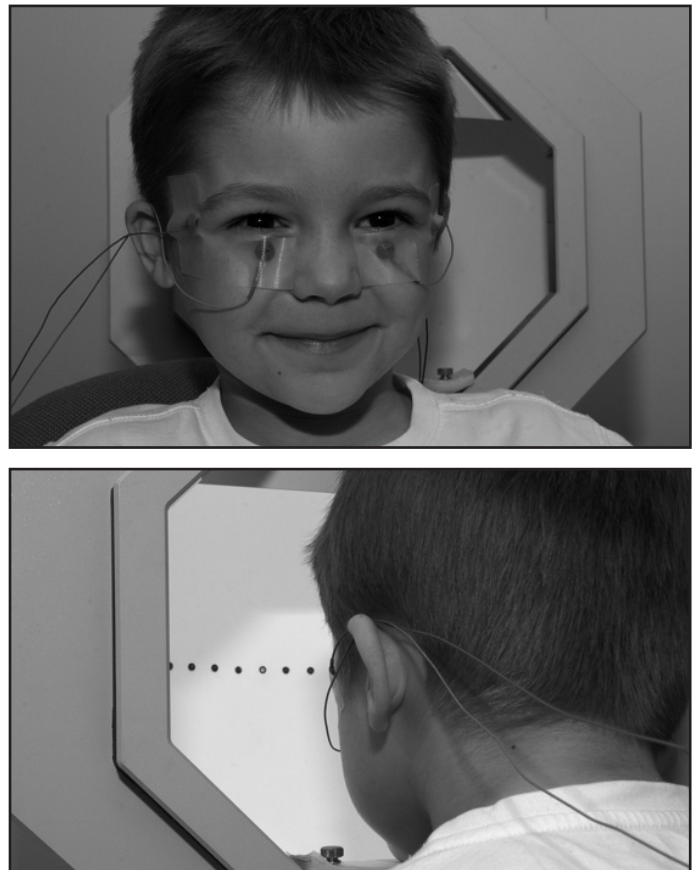


Figure 3. Child with skin electrodes at the Ganzfeld bowl.

the following responses, named according to conditions of adaptation and the stimulus (flash strength in $\text{cd}\cdot\text{s}\cdot\text{m}^{-2}$)⁶

1. Dark-adapted 0.01 ERG (Rod ERG)
2. Dark-adapted 3.0 ERG (Standard combined ERG)
3. Dark-adapted 3.0 (Oscillatory Potential ERG)
4. Light-adapted 3.0 ERG (Cone ERG)
5. Light-adapted 3.0 Flicker ERG (30Hz Flicker ERG).

ISCEV recommends a minimum of 20 minutes dark adaptation with maximal mydriasis prior to scotopic rod testing and a minimum of 10 minutes light adaptation prior to photopic cone testing.

PAEDIATRIC ERG ASSESSMENT

Recording of the ERG in a paediatric population can prove to be more difficult than in an adult population. This is due to limited co-operation and compliance from paediatric patients. Testing protocols are often adapted to combat these restrictions.

A paediatric ERG assessment will often be of longer duration, and will require interaction and skill from the technician recording the test. The testing environment may need to be adapted to allow it to appear less threatening and enable better co-operation from the child. Due to these challenges paediatric ERG assessments are a highly specialised area of electrophysiology with many centres not performing paediatric assessments on a regular basis.

In a recent survey of seventy-one visual electrophysiology centres worldwide, it was found that only 13 (21%) of the centres performed a high volume (more than ten patients per month) of paediatric ERG assessments in infants and young children less than 6 years of age, and only seven (11%) centres performed a high volume of ERG assessments on patients less than 12 months of age. Eighty-seven percent of respondents indicated that they rarely or never used sedation or anaesthesia. Twenty-nine percent of respondents used skin electrodes and 88% used ocular contact electrodes.⁷

MATERIALS

The Eye Clinic at The Children's Hospital at Westmead (CHW) provides a visual electrophysiology service where ERG, along with other visual electrophysiology tests such as VEP and EOG are performed. These tests are recorded either in the clinic or in operating theatres under sedation with a general anaesthetic. Patients are referred to the visual electrophysiology clinic when a diagnosis is being investigated, subnormal visual responses can not be explained, or if a patient with a known retinal dystrophy is being monitored for progression of the disease. All

patients are referred from an ophthalmologist or paediatric consultant.

The clinic services paediatric patients aged from birth to 18 years. Rarely an adult assessment will be undertaken. Testing of an adult will only occur during a genetic investigation in conjunction with the genetic eye clinic at CHW, or if an adult patient has a developmental delay and would benefit from being tested in a paediatric environment with specialised staff.

The visual electrophysiology clinic at CHW is led by orthoptists and a consultant ophthalmologist. It benefits from the help and support of the play therapy department within the hospital. Their expertise has been vital in establishing an environment that is non-threatening to the patient. This enables better compliance and co-operation during testing and has led to the ERG test being a more enjoyable experience for the majority of patients.

The ERG is recorded by an orthoptist and in most cases two orthoptists will be present during the test, one to operate the recording equipment and one to monitor the patient and encourage co-operation from the patient. This is achieved with toys, games and music.

Previously sedation and ocular contact electrodes were used routinely for ERG assessments at CHW. This proved difficult in many ways, being confronting for parents to observe and requiring additional nursing staff for patient observation. With new advances in technology and revised paediatric protocols including the use of skin electrodes and play therapy advice, sedation is now rarely undertaken and is never undertaken within the clinic. All attempts are made to have the ERG performed in the clinic. If this proves too distressing for the patient, or there are other complicating factors such as systemic disease or developmental delay the ERG may be performed under general anaesthetic administered by a paediatric anaesthetist in the operating theatres at CHW. Often the consultant ophthalmologist will be present to perform an examination under anaesthetic after the ERG is completed.

METHOD

The medical records of patients who underwent ERG testing either in the Eye Clinic or in operating theatres under a general anaesthetic, between January 2007 and January 2009 were retrospectively reviewed.

ISCEV standards were followed where possible. If a patient was unco-operative a shorter period of dark adaptation was used. All patients underwent a full orthoptic assessment prior to the ERG, including visual acuity, cover test, ocular motility, and if achievable colour vision, contrast sensitivity, visual fields and fundus photos.

The parents or guardians of the patient were present for the duration of the test. The Ganzfeld bowl light source was

always attempted initially. Younger children sat on their parent's lap and older children sat by themselves. Infants were swaddled and held into the bowl, lying in their parents arms. If recording was unnoticeable with the Ganzfeld, a hand held Kurbisfeld light source was used. The duration of the consultation lasted on average 60 minutes.

The type of electrode used for the ERG was determined by the age and co-operation of the child. Young children or older children who were unco-operative, were tested with skin electrodes. Older children and children who had been sedated were tested with an ocular contact electrode.

RESULTS

In total there were 131 patients reviewed and a total of 139 tests performed. Ages of the patients ranged from 10 weeks to 22 years with a mean age being 6.3 years (SD \pm 5.7). The two most common groups were patients older than 10 years at 27% (n=35), and those aged between 6 and 12 months 19% (n=25) (Figure 4).

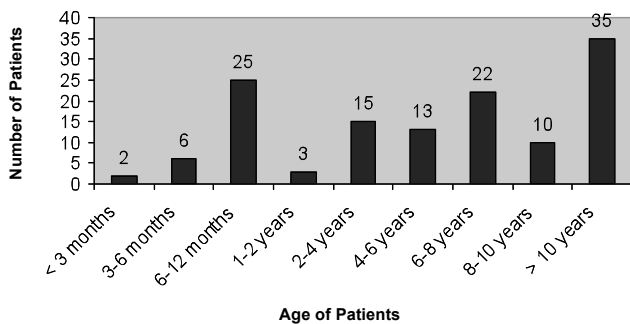


Figure 4. Distribution of ages of patients seen for ERG testing.

The most common type of ERG assessment was the ffERG. Eighty-six percent (n=119) of patients were assessed with this method. Nine percent (n=12) of these patients were

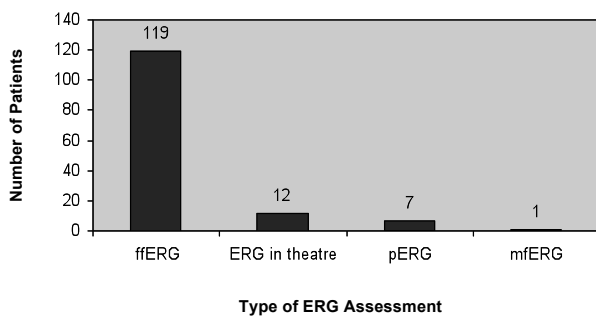


Figure 5. Distribution of types of ERG assessment performed.

assessed with a ffERG in operating theatres under sedation with a general anaesthetic. A much smaller proportion of patients were assessed with a pERG or mfERG, 5% (n=7) and 1% (n=1) respectively (Figure 5).

The most frequent electrode used was the skin electrode. This was used in 81% (n=113) of patients, by far the majority. ERG Jet electrodes were used in 14% (n=19) of patients, and all patients who underwent ffERG assessment under general anaesthetic in operating theatres were assessed with an ERG Jet electrode. Therefore seven patients were assessed with an ERG Jet electrode in the Eye Clinic without sedation. Gold foil and DTL electrodes were used in 3% (n=4) and 2% (n=3) of patients respectively. A corneal electrode was used for all pERG and mfERG recordings (Figure 6).

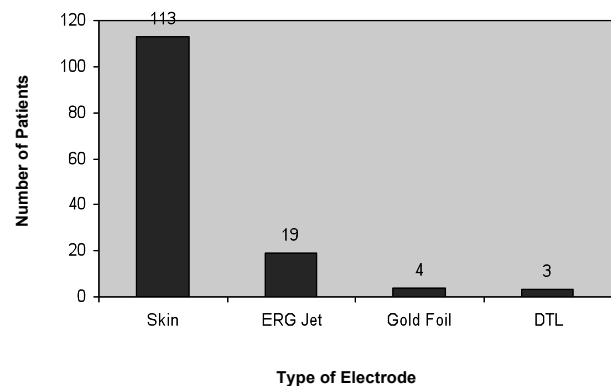


Figure 6. Distribution of types of electrodes used for ERG assessments.

All patients were referred for an ERG by an ophthalmologist. Subnormal visual acuity was the most common reason for referral 38% (n=53). This was followed by visual inattentiveness 22% (n=31), high refractive error 11% (n=15), and nystagmus 9% (n=13) (Table 1). All of these clinical features can occur with or without retinal dysfunction. If retinal dysfunction is detected alongside

Table 1. Reasons for referral		
Reasons for referral	Number	Percentage
Subnormal visual acuity	53	38
Visual inattentiveness	31	22
High refractive error	15	11
Nystagmus	13	9
Nyctalopia	7	5
Maculopathy	6	4
Functional vision loss	5	4
Optic nerve disease	3	2
Retinal toxicity to medications	3	2
Photophobia	3	2

these other clinical findings, it can help to either explain the clinical features, or diagnose the patients with a disease or syndrome.

Of the 139 ERG assessments performed on 131 patients, 34% (n=45) were normal, 10% (n=13) were diagnosed with Leber's congenital amaurosis and 17% (n=22) had a dysfunction of their photoreceptors (rod, rod-cone and cone dystrophies) (Figure 7). Eight percent (n=11) of patients were found to have a functional or non-organic visual problem (Table 2). The diagnosis of a patient with a functional vision problem is a diagnosis of exclusion. As the ERG is an objective test it is an accurate method of ensuring there is no underlying retinal pathology.

Diagnosis	Number	Percentage
No retinal dystrophy	45	34
Leber's congenital amaurosis	13	10
Functional	11	8
Cortical vision impairment	10	8
Cone dystrophy	10	8
Rod-cone dystrophy	10	8
Delayed visual maturation	8	6
Congenital motor nystagmus	6	5
Congenital stationary night blindness	5	4
Optic neuropathy	4	3
Maculopathy	3	2
Inconclusive	3	2
Rod monochromatism	2	2

DISCUSSION

GENETIC COUNSELLING

Retinal dystrophy is investigated by a comprehensive ophthalmological exam, electrodiagnostic testing and a thorough genetic pedigree. Electroretinography is not a tool used in isolation to provide a diagnosis for retinal dystrophies, nor does it determine the genetics of a retinal dystrophy. When a diagnosis is confirmed the ERG can be used to monitor progression of the disease. These results, along with genetic counselling, allow patients and their families to be informed on prognosis and progression of the disease and its impact on vision. This is useful for families as patients diagnosed with a retinal dystrophy benefit from low vision support services.

Prenatal diagnosis and medical genetics are 'traditional' genetic counselling roles. More comprehensive knowledge of genetic disorders has led to speciality areas developing in genetic counselling, such as cancer and ophthalmology.⁸

Patients with inherited eye disorders and their families have complex needs, which include clinical services for diagnosis and management, social and genetic counselling to help them cope with the disease. Specialist genetic eye clinics are set up to help meet these needs.⁹

CHW runs a Genetic Eye Clinic (GEC) which is held once a month. It is led by a clinical geneticist together with a consultant ophthalmologist who specialises in genetic eye disease. The team also comprises of a clinical geneticist fellow, a genetic counsellor, ophthalmology registrars and fellows, and orthoptists.

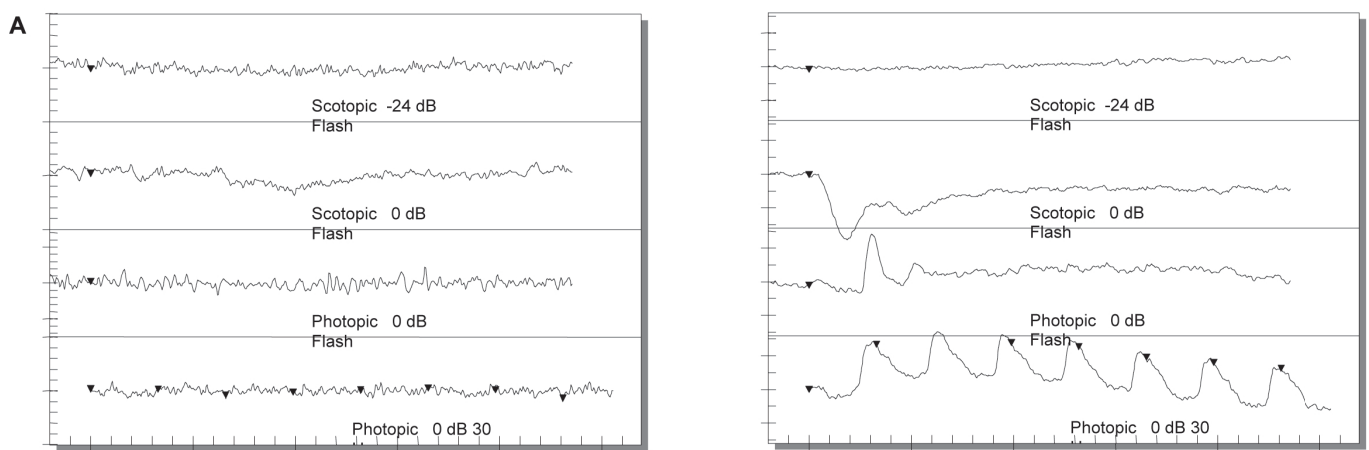


Figure 7. ERG results for (A) advanced rod-cone dystrophy and (B) congenital stationary night blindness. Note (A) shows extinguished responses for both photopic and scotopic stimuli, (B) shows an extinguished rod response on the dim -24dB flash and a negative b wave on the brighter 0dB flash with present photopic responses.

Each patient who attends the GEC along with their family may have tests performed such as visual acuity, orthoptic examination, colour vision, visual fields, fundus photography and electrophysiology. They will also have an ophthalmological examination, including cycloplegic refraction and fundoscopy performed when necessary. Genetic counselling and testing will also be carried out along with any necessary referral to other services, either internal or external to the hospital such as low vision services.

The GEC is invaluable to patients and their families in providing a comprehensive consultation regarding their genetic eye disease and will discuss in layman's terms their clinical diagnosis, family pedigree, patterns of inheritance, risk for future pregnancies as well as prognosis of vision. This enables patients and families to gain a better understanding of the implications of their inherited eye condition.

LOW VISION

Early intervention from a low vision service will better prepare patients and families with skills needed in the future. Awareness of a child's level of vision plays a vital role in the overall development of the child. For example if a child can not see, they will be less likely to learn how to reach for toys, roll to an object or understand their environment. Low vision specialists play an important role in teaching parents the necessary skills required to ensure their child continues to develop in all areas. A diagnosis aids the patient in registering for low vision services, which in turn, ensures they receive vital early intervention as soon as possible.

CONCLUSION

ERG assessment is an essential tool in diagnosing retinal dystrophies in paediatrics. Testing procedures may need to be adapted to suit the clinical environment where the test is being performed. Skin electrodes are an effective way of

assessing the ERG without causing discomfort to the patient. It is possible to accurately record the ERG in the majority of paediatric patients without the use of sedation, however this is reliant on the examiner's expertise and ability. Early electrophysiology has become a vital component to the paediatric ophthalmology clinic at CHW and is utilised well by both internal and external paediatric ophthalmologists.

The ERG assists in the early diagnosis of retinal dystrophies. This is vital in the patient receiving early intervention low vision services and enables development of the child in all areas in the presence of a vision impairment.

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