Practical Visual Electrophysiological Examination

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Preface

Visual electrophysiology has been applied in clinical practice for more than 70 years. Many related books, focusing on detailed principles and clinical cases, have been published worldwide. However, this monograph aims to cover the elementary theory of visual electrophysiology practice for clinicians, researchers, and technicians. The contents include the concept of the visual electrophysiological, hardware composition, standardized operation and clinical cases, with step-by-step explanation and hand-to-hand guidance. All follow the international standards of ISCEV. Typical examples are highlights of this book, which can help physicians and technicians quickly understand the meaning underlying different waveforms. In addition, visual electrophysiology studies on animals are also involved in this book. The clinical cases listed in the book are from Peking Union Medical College Hospital and Hebei Eye Hospital. Professor Dezheng Wu was invited to review the book, and we are grateful to her.

We hope this "desk book" provides a valuable reference of fundamental visual electrophysiological application for clinicians, technicians, and researchers.

What we've done still leaves much to be desired. Suggestions and comments are welcome. Timely revision and supplements will be made to the book when it is reprinted.

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He graduated from Beijing Medical University in 1999 and joined Gaush in 2004. He has been in charge of product training, market promotion, and pre-sales and after-sales service of Roland visual electrophysiology and Kowa series fundus cameras. He possesses rich knowledge of Roland visual electrophysiological products, clinical operation and related clinical applications. He participated in the compilation and translation of "Roland Visual Electrophysiology Test Methods and Clinical Application Atlas" edited by professor Dezheng Wu. In addition, he edited an internal training book "Guidelines for the Clinical Application of Standard Visual Electrophysiology with Roland system," which was printed 8 times and published over 2000 copies. He organized more than 50 visual electrophysiology training courses and workshops. He is also a lecturer in the Roland global distributors training and user training courses.

Minglian Zhang, M.D. Professor and Dean of Hebei Eye Hospital; Director of Key Ophthalmic Laboratory of Hebei Province; Vice President of Xingtai Association for Science and Technology. He is a deputy director for academic societies and a co-editor for several books and journals. He has 35 years of clinical experience in ophthalmology, visual electrophysiological examination, and traditional Chinese medicine and especially in the treatment of complicated ocular fundus diseases, uveitis, and dry eye with combined western medicine and traditional Chinese medicine. He developed several new Chinese herbs formula and was awarded patents. He also won several provincial science and technology progress awards and was funded by National Natural Science Foundation. More than one hundred papers were published by his team. He gained Hebei Province outstanding professional and technical personnel honour.

List of Abbreviations

AMD	Age-related macular degeneration
AZOOR	Acute zonal occult outer retinopathy
BVMD	Best vitelliform macular dystrophy
CRT	Cathode ray tube
CSNB	Congenital stationary night blindness
DOA	Kjer-type dominant optic atrophy
DR	Diabetic retinopathy
EEG	Electroencephalogram
EOG	Electrooculogram
ERG	Electroretinogram
FFA	Fundus fluorescein angiography
ffERG	Full-field electroretinogram
FVEP	Flash visual evoked potential
ISCEV	International Society for Clinical Electrophysiology of Vision
LCD	Liquid crystal display
LED	Light-emitting diode
LHON	Leber hereditary optic neuropathy
mfERG	Multifocal electroretinogram
mfVEP	Multifocal visual evoked potential
NAION	Nonarteritic anterior ischemic optic neuropathy
OMD	Occult macular dystrophy
ON/OFF ERG	On/off electroretinogram
ON/OFF PVEP	Onset/offset pattern VEP
PERG	Pattern electroretinogram
PhNR	Photopic negative response
PVEP	Pattern visual evoked potential
RP	Retinitis pigmentosa
RPE	Retinal pigment epithelium
S-Cone	Short cone
SLO	Scanning laser ophthalmoscope
STR	Scotopic threshold response
VEP	Visual evoked potential
XLRS	X-linked juvenile retinoschisis

Visual Electrophysiology Summary

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1.1 Visual Electrophysiology Basic Mechanism and Features

1.1.1 Basic Principle

Visual electrophysiological examination is applied to record the bioelectrical signals from different parts of the visual pathway after the subject's visual system receives a stimulation, such as a flash or a pattern. Assorted electrodes are used to collect the bioelectrical signals and then waveforms are processed by biological amplifiers and computers (Fig. 1.1).

1.1.2 Clinical Importance

Visual electrophysiology is an objective test of visual function, which can assess retinal and optic nerve functions. Visual electrophysiological examination is widely used in the clinic, and abnormal waveform may reflect ocular disease conditions. Besides, some retinal and optic disorders have specific changes. However, the diagnosis of diseases should be based on the electrophysiological examinations and combine the clinical manifestation and other ophthalmological data. For children who could not cooperate with the subjective visual functional

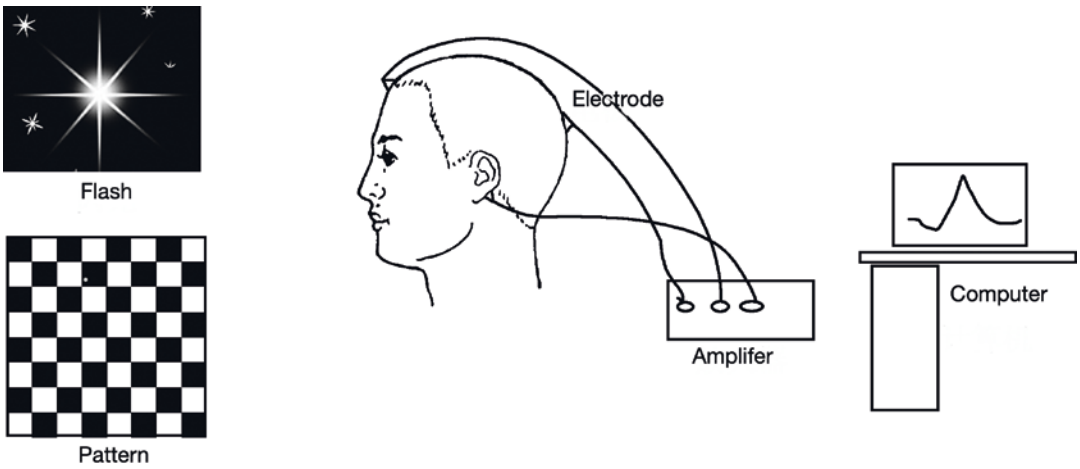

Fig. 1.1 Schematic diagram of visual electrophysiological examination testing and recording

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test or those who do not cooperate reasonably with the trauma evaluation, electrophysiology of vision is the only way to objectively measure the visual function without the subjective cooperation of the examinee. It is challenging to make a precise diagnosis of a variety of hereditary retinopathy, such as congenital stationary blindness and achromatopsia. Visual electrophysiological examination is one of the diagnostic criteria. Visual electrophysiological assessment can guide treatment and prognosis prediction for retinal vascular diseases, such as diabetic retinopathy. Moreover, visual electrophysiological examination plays an irreplaceable role in the diagnosis and follow-up of optic neuropathy, such as acute optic neuritis and multiple sclerosis. Furthermore, visual electrophysiology can also be used for screening for early glaucoma and preoperative retinal function assessment for cataracts.

1.2 Classification of Visual Electrophysiology

1.2.1 Basic Classification

According to the time of clinical application, software, hardware, and calculation methods, visual electrophysiology is generally divided into two groups: traditional visual electrophysiology and multifocal visual electrophysiology. Traditional visual electrophysiology includes electroretinogram (ERG), visual evoked potential (VEP), and electrooculogram (EOG). The phrase "traditional visual electrophysiology" appeared after the birth of multifocal visual electrophysiology. In order to distinguish from multifocal visual electrophysiology, the original visual electrophysiology was classified as traditional electrophysiology (also called conventional electrophysiology). Multifocal visual electrophysiology contains multifocal electroretinogram (mfERG) and multifocal visual evoked potential (mfVEP).

1.2.2 Classification of Traditional Visual Electrophysiology

According to different stimulating methods, VEP and ERG in traditional electrophysiological are divided into two types: flash (flash electroretinogram, FERG; flash visual evoked potential, FVEP) and pattern (pattern electroretinogram, PERG; pattern visual evoked potential, PVEP). EOG is induced by eye movement with two fixation points without stimulus and therefore no further classification.

ERG mainly reflects the function of the retina. FERG, also known as full-field electroretinogram (ffERG), reveals the massive function of the retina. ffERG is the international standard name for flash ERG, which is used in this book. PERG reflects macular photoreceptor and ganglion cell function. VEP demonstrates the whole visual pathway's function. EOG exhibits the function of retinal pigment epithelium and retinal photoreceptor cells.

1.2.3 Classification of Multifocal Visual Electrophysiology

Both mfERG and mfVEP require particular stimulators and software programs. The mfERG assesses the local ERG from different regions of the central retina. The mfVEP enables simultaneous recording from multiple regions of the visual field. However, due to significant variation, it is rarely used in clinical practice.

The above Sects. 1.2.1, 1.2.2 and 1.2.3 classification are shown in Fig. 1.2.

1.3 Visual Electrophysiology Clinical Application Principles

1.3.1 Overall Check

The visual electrophysiological examination should be as comprehensive as possible. Each

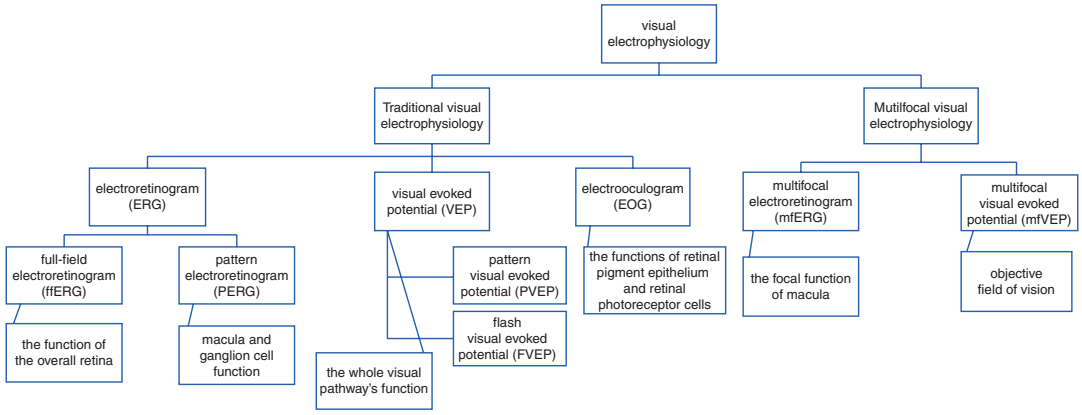

Fig. 1.2 Schematic diagram of visual electrophysiological classification

examination item has its unique value and cannot be substituted for each other.

At present, PVEP and FVEP are commonly used for visual electrophysiological examination. PVEP and FVEP generally are recommended at least twice as repetitions. If there is good repeatability, then it is reliable. FVEP has a significant variation, which is only detected in patients with poor vision and unable to cooperate to the gaze fixation point. In addition, FVEP itself has significant variation, which requires more repeatable results than PVEP to support the corresponding conclusions. If necessary, it can be used to determine whether the results are abnormal or not based on high-frequency steady-state FVEP. High-frequency steady-state FVEP refers to the FVEP with stimulus frequency greater than 7 Hz, and its amplitude value is stable with small variation.

ffERG is also widely used and reflects more clinical information.

mfERG is used to evaluate retinal function in macular-related diseases.

1.3.2 Combined with Other Clinical Results

Visual electrophysiological examination results should be combined with clinical symptoms and other ophthalmic or general examination results for analysis. The results of the visual electrophysiological examination are the results of retinal or optic nerve function evaluation, which are sometimes inconsistent with other clinical manifestations and require comprehensive analysis and judgment by clinicians.

1.3.3 Binocular Contrast

Visual electrophysiological examination results vary greatly, and every examination should be binocular control, which is more objective and convenient than the reference value control. If the difference of double eyes' visual electrophysiological result is more than 30%, the worse eye will be considered abnormal, and even the result is within the normal reference range.

1.4 Visual Electrophysiology International Standards

1.4.1 ISCEV Standards

Founded in 1958, the International Society for Clinical Electrophysiology of Vision (ISCEV) is an authoritative academic organization for Vision Electrophysiology. The association's primary function is to develop and update the international

standards of visual electrophysiology examination regularly and hold the international academic conference of visual electrophysiology once per year to promote the standardization of examination results of different equipment and different examination rooms. So far, ISCEV has published the international standards of ERG, VEP, PERG, EOG, and mfERG, respectively, and specified the inspection methods and parameters. Each examination room shall conduct each clinical examination under the above standardized international standards so that the results of different examination rooms may be cross-referenced. ISCEV website is https://iscev.wildapricot.org, information about the association introduction, a variety of standards and conferences can be downloaded free of charge. ISCEV's official academic journal is *Documenta Ophthalmologica*, https://link.springer.com/journal/10633. Most of the documents can be downloaded for free for ISCEV members.

1.4.2 Revision of the ISCEV Standards

The ISCEV ERG standard was first formulated in 1989 and then revised five times in 1994, 1999, 2004, 2008, and 2015. The first edition of the ISCEV VEP standard was developed in 2004, and it has been revised twice since 2009 and 2016. In 1996, ISCEV released the PERG guidelines, which were upgraded to the first version of the standard in 2000, and then revised twice in 2007 and 2012. The first edition of the ISCEV EOG standard was formulated in 1993 and revised in 1998, 2006, 2010, and 2017. ISCEV mfERG developed the guideline in 2003, revised them into the second edition guideline in 2007, and upgraded them to the first edition standard in 2011, and in 2021, the second edition standard was published.

1.4.3 The Relation Between the Book and ISCEV Standards

Examination items specified in international standards are clinical essential examination items, and operation steps of Chap. 5 of the book "visual electrophysiological equipment installation, operation steps" are written following the latest standard. In the book, the concept, naming, examination items, and application scope are also based on the latest edition of the standard to make results more scientific, more accurate, and more convenient. On this basis, each examination room can also carry out special extended examination items other than those in international standards according to their clinical and scientific research needs. These special examination items are also mentioned in the above ISCEV standards and the several related extended protocols in 2018 and 2019.