

THE BALANCING ACT -- SETTING A STANDARD FOR ELECTRONYSTAGMOGRAPHY

By

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Introduction

"Treating dizziness is witchcraft...it is all soft and touchy-feely!"

"I get rid of dizzy patients as soon as I can!"

Have you ever heard statements like these? Many clinicians make these statements. Why are vestibular disorders held in such disdain by so many clinicians? Is it because dizziness is incurable? No. Almost all patients with dizziness get better. Is it something about the patients? Probably not. Dizzy patients can be a little strange, but are rarely unpleasant to deal with. In my opinion, the main reason that some clinicians don't like dizziness is that they have difficulty tolerating ambiguity.

There is lots of ambiguity in dizziness. Dizziness is subjective. Our tests are indirect. We don't agree on criteria for diagnosis. Good treatment is currently more art than science. The science void makes the field ripe for charlatans and quacks. One of the roles of the physician treating dizzy patients is to make as much order from the ambiguity as possible. Vestibular practitioners require a continuum from ambiguity to art to science. Part of this continuum must involve agreement on standards.

Science or Art?

There is a general medical belief that science is always better than art. This is understandable, but "junk science" is worse than good art. The ambiguity of dizziness makes it just as vulnerable to junk science as it is to quackery. Perhaps there is no difference between junk science and quackery. For example, vestibular research has more than its share of papers that report "signs" that turn out to be inconsistent and/or clinically meaningless. In vestibular research, it seems that the need to apply a number is so great that it seems that any number will do, even if it has no meaning. Vestibular practice needs more science, but it must be science that yields reliable treatments.

How many times have you seen an electronystagmogram (ENG) report that calls an unfamiliar eye movement a "central sign?" Actually very few eye movement findings have been clearly identified as reliable "central signs." This report often results in the ordering of tests, procedures, MRI scans (always normal) and chronic, unwarranted worry by patients. This is junk science. Yet, there is no foundation to criticize these practices. Until recently an ENG could be performed and interpreted in any way. The only way that one interpretation can have validation is to have consensus or standards.

ENG is an old-fashioned test but is still the most widely used clinical vestibular test. While "all" of us know what an ENG is, it turns out that what we know is different (See Figure 1).

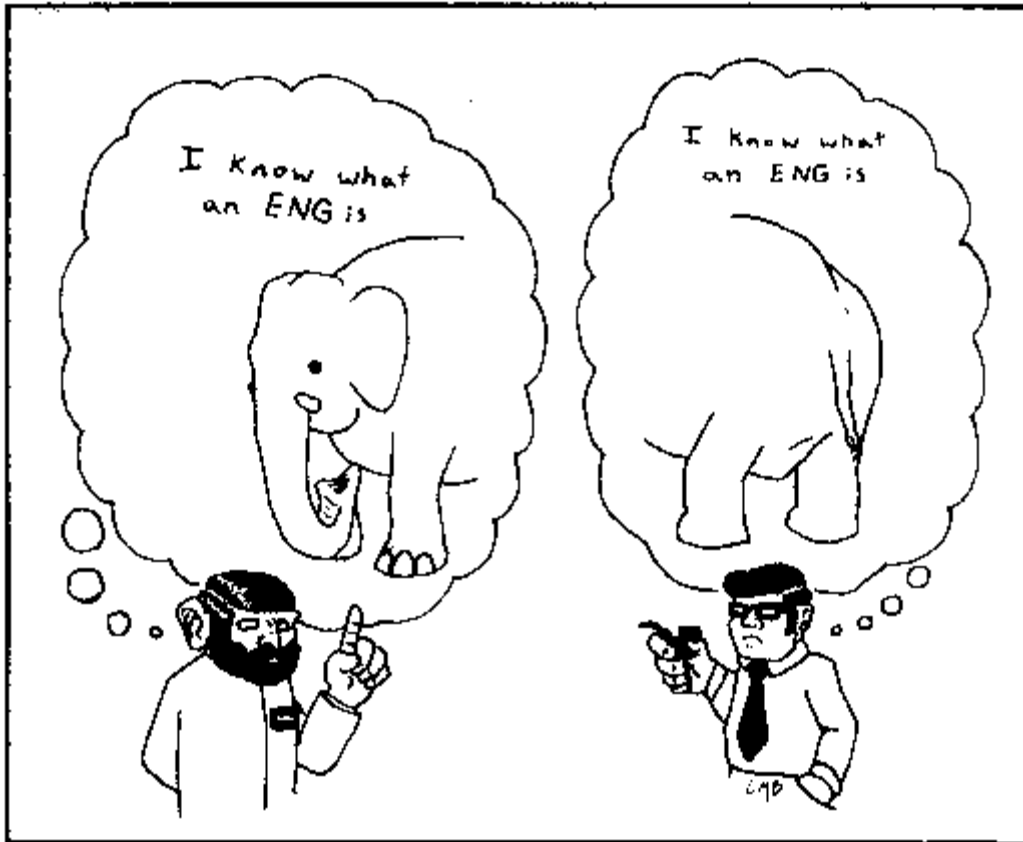


Figure 1. Heads or Tails -- Does everyone agree what an ENG is?

Brief History of ENG Standardization

In 1985 the Committee on Hearing, Bioacoustics, and Biometrics (CHABA) of the National Research Council (NRC) was formed with the purpose of specifying standards for basic evaluation of human vestibular function. In 1992 their findings were published in *Aviation Space and Environmental Medicine* 63 (2) Suppl A1-A34. The American National Standards Institute (ANSI) based the first draft of the standard called S3.45 on this work. ANSI prefers to have consensus among voters to establish a standard and the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) has one vote.

The process of establishing any standard took many years. The technology that had been state-of-the-art such as strip chart recordings and electro-oculography (EOG) recordings with surface electrodes has been replaced by newer technologies such as computerized digital recording and analysis with video or infrared measurements. The ANSI committees' membership changed over the years but few clinicians were included. The membership generally consisted of researchers and persons with acoustical and/or engineering backgrounds. Frankly, most committee members were not qualified to comment on clinical practice, much less develop standards for it. The utility of tests for clinical purposes seemed to be of secondary importance to accurate measurement of eye velocity. To make matters worse qualified clinicians did not want to get involved. In the future we will see many of these clinicians complain that they had no input. Manufacturers can have an important perspective on the design of ENG testing but they were not consulted either.

Many clinical testing centers have adopted techniques that they staunchly defend as the "best way". There is no way to include many of these techniques and still have a standard. We know that acceptance of any standard will not be universal. After years of work by several committees striving for consensus, we have a standard that needs improvement. There was a desire to have a standard, even a flawed one, that could be changed later. After much discussion, two articles in AAO-HNS publications, and an open meeting for members, the AAO-HNS Subcommittee on Balance Disorders decided to accept the ANSI proposal in September 1999 with the understanding that it be reconsidered by the year 2004 to try to resolve differences. Hopefully, changes in the ANSI and other committees will not mean that this understanding will be ignored.

Summary of the Standard

The complete version of the ANSI S3.45-1999 standard can be purchased from ANSI for \$75 for those who wish, but a summary seems reasonable here. There are many curious inclusions and exclusions. Nevertheless, the standard represents the collected wisdom of several committees and it is a serious attempt and a good starting point for establishing a standard.

General recording parameters:

Among the recording specifications are the use of electro-oculography recording with 5 (2 vertical, 2 horizontal and one ground) electrodes 12 mm or less in diameter and less than 10 kW impedance. The sampling rate must be 100 Hz or greater for digitized systems (strip chart recorders are allowed). Amplifiers must have a common mode rejection of 100 dB, minimum 60 dB gain and Bessel filters shall be used. Accuracy of displacement of ± 1 degree and velocity of ± 2 deg/s. Saccade targets should be yellow-green rather than red.

In summary an ENG will consist of the following:

1. **Calibration.** This is to be performed using $\pm 20^\circ$ horizontal and $\pm 10^\circ$ vertical targets and appropriate correction factors.
2. **Spontaneous Nystagmus Test.** Involves measurement while fixating in the light, with eyes closed and also with eyes open in the dark.
3. **Gaze Test.** Involves measurement under the same conditions as spontaneous nystagmus, with horizontal gaze positions of 30° left and right and 25° up and down.
4. **Saccade Test.** Uses 20° vertical and horizontal targets, holding positions for 1 second.
5. **Pursuit testing.** May use either sinusoidal (0.2 and 0.4 Hz) or triangular stimuli displacement of 40° and peak velocity of $20^\circ/s$. For sinusoidal stimuli the phase and gain are the considered outcome measures or gain only if the system does not permit phase calculations.
6. **Hallpike Test.** This is performed in a darkened room with Frenzel's glasses measuring eye movements for 20 s in head hanging right, left and midline positions.
7. **Positional testing.** This is conducted with eyes closed and head turned to right, left and extended, then body lateral left and right.
8. **Caloric Tests.** Warm and cool tests are required with water at 44° and 30°C for 40 s at a flow rate of 200 cc/min for open loop testing. Closed loop testing is also allowed with 27°C for cool water and flow rate of 350 cc/min. Fixation suppression is tested at 100 s. The Jongkees formulae for unilateral weakness and directional preponderance are used.
9. **Information from a specific worksheet is required.**

Some controversial issues and the response of the AAO-HNS equilibrium subcommittee include:

1. Electro-oculography is the eye movement recording technique in the standard. EOG has been used for decades and is standard procedure. Newer technologies for measuring eye movements such as video and infrared techniques are not considered.
2. Only water calorics are permitted. Either closed or open loop techniques are acceptable, but air calorics are not included.
3. No normal values are included. Apparently this was considered to be a matter of interpretation rather than how the test was to be performed.
4. Pursuit testing is to be quantified with phase and gain measurements. Phase and gain have a firm foundation in electronics, but not pursuit testing. The papers that offer these parameters assume that phase and gain must apply to any system.
5. A standard work sheet and report form is required.
6. There is some inconsistency in the definition(s) of nystagmus. For calorics, five beats are to be averaged; for other sections, three beats define nystagmus.
7. Some engineering parameters such as the use of Bessel filters and AC versus DC recording are questionable.
8. Possibly the most problematic requirement is that digital sampling for caloric testing be done at 100 Hz. if a computer is used. The problem is that some of the currently available commercial hardware samples at 30-50 Hz so that new software and possibly new hardware is needed. Should everyone buy new equipment? Video and infrared cannot sample at 100 Hz without special engineering. So, what sampling rate should be used?

There are many considerations that enter into the decision of which sampling rate should be used. The most important determinant of sampling rate for digital systems is the frequency content of the response of interest. Figure 2 shows the effect of sample rate for a pure sine wave. If sampling is performed at the same frequency as the signal, the response will appear to be a straight line. If sampling is two times the frequency, then most of the information is preserved. The Nyquist theory indicates that sampling should be done at least at twice the frequency of the highest frequency of interest in the signal. In clinical situations filtering is needed so that sampling should occur at least twice the upper cutoff of the filter.

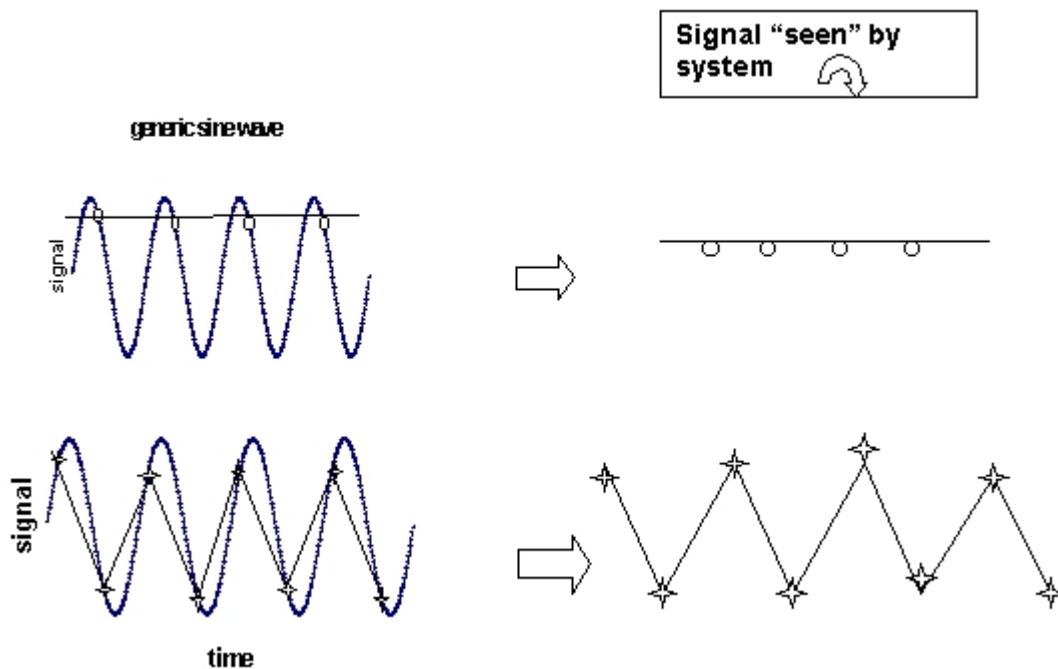


Figure 2. As more points are available the definition of the signal becomes clearer. In the top trace sampling occurs at the same frequency as this sine wave. The waveform appears to be a straight line or constant. In the bottom, the sampling rate is twice the frequency of the sine wave and better resolution of the sine wave is seen. Of course the maximum number of points give the best definition of the waveform. The original waveform was sampled at 100 times the frequency of the wave.

If we must sample at 100 Hz then there must be frequencies in a slow phase eye movement¹ of the caloric response up to 30-50 Hz. This has never been reported in the literature. What might the minimum duration of a recognizable slow phase be? A quarter of a second (250 ms)? If we believe that 100 ms is the absolute minimum duration then the maximum frequency of interest for slow phase would be 10 Hz. Even if we double this and make this our upper frequency cutoff we are still well within current recording rates of 50 Hz.

Where Do We Go from Here?

We have a standard for ENG that is a starting point. For decades the strategy was to achieve consensus whereas now the strategy is to accept a standard and revise it. The standard needs to be re-examined again with the above thoughts in mind. Manufacturers and customers should keep these requirements in mind when designing or purchasing ENG systems. The current standard should probably be viewed as a "strong guideline." If some of the issues are not resolved after inclusion of the stakeholders (clinicians and manufacturers and others) the AAO-HNS may have to withdraw support for the ANSI standard.

¹Fast phases certainly require a sampling rate of 100 Hz to quantify accurately, but in the caloric response, these are unwanted noise to be removed.

References

1. Jongkees LBW and Philipszoon AJ (1964). Electronystagmography. *Acta Otolaryngol (Stockh)* Suppl 189.
2. American National Standard *Procedures for testing basic vestibular function*. ANSI S3.45-1999. Publ by Acoustical Society of America, New York, NY, 1999.

Biography

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Dr. Blakley is Chairman of the Department of Otolaryngology and Director of the Vestibular Laboratory at the University of Manitoba, Winnipeg. He received his undergraduate training and his Doctorate in Medicine at the University of Saskatchewan. He completed his residency in Otolaryngology in 1984 and his Ph.D. in Otolaryngology in 1989 from the University of Minnesota. Dr. Blakley's research has emphasized the clinical assessment and treatment of balance disorder patients. He has written extensively, including a book for the lay public on dizziness entitled *Feeling Dizzy: Understanding and Treating Dizziness, Vertigo and other Balance Disorders*. Dr. Blakley serves as Chairman of the American Academy of Otolaryngology-Head and Neck Surgery Equilibrium subcommittee.