How Someone with INS "Sees" the World and How to Clinically Assess Therapeutic Improvements in Visual Function

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Early research into infantile nystagmus syndrome (INS, aka congenital nystagmus) (1) made it clear that assessment of visual function in such patients required more than merely taking a visual acuity measurement in primary position, or even in the "null" position (2-5). As far back as 1974, Dr. J. Lawton Smith recognized the implications of this research and the changes that should be made by the ophthalmologist in the office. In one of his classic tapes he remarked, "You ought to measure their vision, let's say, straight ahead, to the left, and to the right" (6). Others have also come to the same conclusion (7). There is no doubt that for accurate, repeatable diagnoses of childhood nystagmus, for determination of the most effective therapeutic approach, and to objectively assess therapeutic efficacy, eye-movement recordings are necessary; that has been evident since the first ocular motor study of INS surgery (8).

The single factor most responsible for the lack of progress in the medical care of nystagmus patients over the past 30 years is the failure of the ophthalmological community to encourage the establishment of at least one ocular motor laboratory in each major city despite overwhelming evidence supporting their necessity for the highest standard of medical practice. It is also in many ways responsible for the widespread misunderstanding of INS and the near absence of adequate teaching of the subject in ophthalmologic residency programs. There is simply no excuse for a patient or parent in the 21st century to hear from their physician (as they still do), "You have nystagmus, there is nothing to be done," or even worse, "Your child has nystagmus, he may be blind." Such misstatements and dire predictions were common in the 1940's (personal knowledge); in light of what we now know, they reflect ignorance of the condition and are unconscionable. In an attempt to overcome the excessive inertia in the ophthalmological community, the following clinical assessment methods are presented below. Although not a substitute for accurate eye-movement data, they should at least help the INS patient obtain more effective therapy.

First, it is important for the physician to appreciate exactly how INS affects visual function. Shown below are photos representing what an INS patient sees as he directs his gaze to the left and right of the region of highest visual acuity (i.e., the region of peak NAFX). Note that these photos do *not* represent visual fields; the acuity simulated is for each gaze angle when the patient looks at a particular person in the photo while keeping his head still in primary position. Thus, they represent *foveal vision* at each gaze angle.

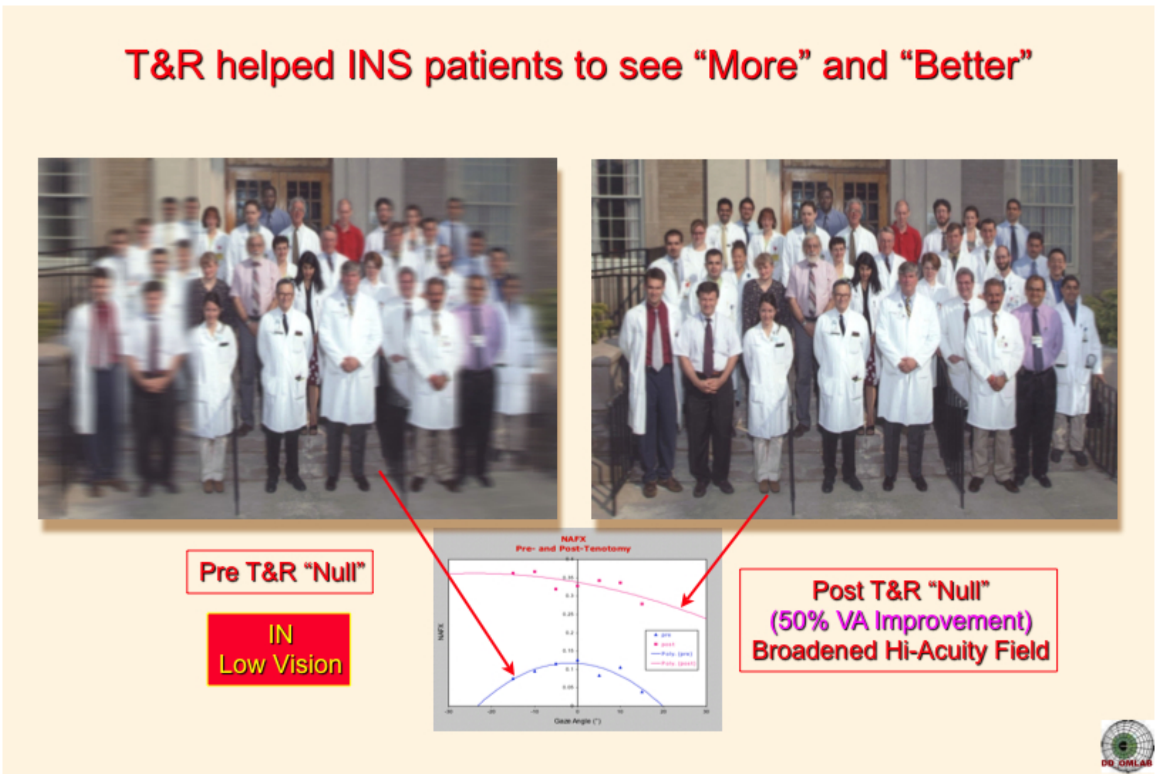

Figure 1. Photos simulating pre- and post-T&R foveal vision at different gaze angles and pre- and post-T&R plots of the NAFX function vs. gaze angle for an INS patient with poor primary position visual acuity.

Figure 1 simulates both what an INS patient with low primary-position acuity sees and shows the corresponding NAFX vs. gaze angle curves. The pre-tenotomy and reattachment surgery (T&R) photo shows the limited range of gaze angles for which acuity is maximal, albeit poor (i.e., the patient must look through this narrow 'window' of best acuity by constantly redirecting his head to point at each new target/person. The post-T&R photo shows both a *broadening* of the range of gaze angles with approximately peak acuity (broader NAFX curve peak)—he sees 'more'—and an *improvement* in the peak visual acuity region (peak NAFX)—he sees 'better.' Now, the patient has a much broader 'window' of high acuity and can rapidly make saccades to each target/person without repositioning his head.

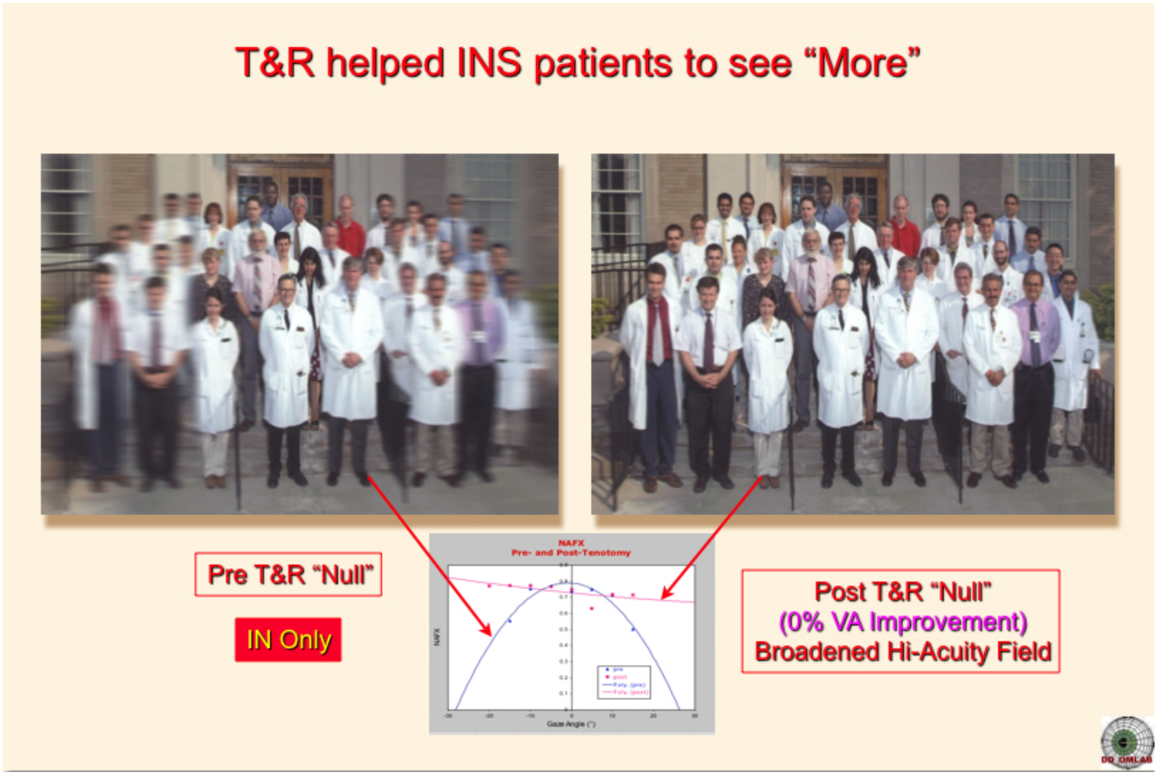

Figure 2. Photos simulating pre- and post-T&R foveal vision at different gaze angles and pre- and post-T&R plots of the NAFX function vs. gaze angle for an INS patient with good primary position visual acuity.

Figure 2 simulates both what an INS patient with high primary-position acuity sees and shows the corresponding NAFX vs. gaze angle curves. The pre-T&R photo shows the limited range of gaze angles for which acuity is high (i.e., the patient must look through this narrow 'window' of high acuity by constantly redirecting his head to point at each new target/person. The post-T&R photo still shows a *broadening* of the range of gaze angles with approximately peak acuity (broader NAFX curve peak)—he sees 'more'—but shows *no improvement* in the previously high peak visual acuity region (peak NAFX) Again, the patient has a much broader 'window' of high acuity and can rapidly make saccades to each target/person without repositioning his head.

In the office, all nystagmus patients should have their visual acuity recorded at lateral gaze angles in addition to primary position. That will provide baseline curves of visual acuity vs. gaze angle that will mimic the NAFX curves shown since the NAFX is linearly proportional to decimal visual acuity. Recording only primary-position visual acuity does not provide any measure of the broadening effects of EOM surgery and will mislead the physician, in cases like that shown in Figure 2, into the false conclusion that the surgery did not improve the patient's visual *function*. The patient will report that he sees 'better' (he actually sees 'more') but the physician will not have the necessary data to understand why and may incorrectly conclude that the surgery did not help the patient.

How can a visual acuity curve be generated in the office? Simply have markers placed on the floor at gaze angles of 10°, 20°, and 30° to each side of primary position (also marked as 0°). Then, with the patient's head restrained to the straight-ahead position, take acuity measurements after rotating the chair to each gaze angle. For binocular patients, binocular acuities are sufficient. For those with strabismus, the procedure must be repeated twice, once for each eye while the fellow eye is occluded. In this latter case, the curves will not match each other since the fixating eye influences the position of peak acuity (aka the 'null' position) in INS. If the patient has fusion maldevelopment nystagmus syndrome (FMNS, aka latent/manifest latent nystagmus), higher acuities will be in *adduction* of the fixating eye due to Alexander's law variation of the FMN. Comparing these pre-surgical curves to those taken post-surgery will provide data demonstrating two of the factors shown to improve with EOM surgery—broadening and raising the visual acuity peak. Post-surgical improvements in target acquisition time are more difficult to measure in a clinical setting.

If the INS patient has an eccentric "null," the Figures would be the same except that the position of the maximal-acuity regions (peak NAFX values) would appear at the eccentric position. Any *four-muscle* surgery to rotate that peak to primary position should have the same effects as those shown in the Figures. That is, a Kestenbaum resect and recess procedure or an Anderson plus T&R (i.e., two agonist muscles recessed and the two antagonist muscles undergoing a T&R) procedure. To date, there is no eye-movement evidence that an Anderson procedure alone (two recessions only) will have either the same or any broadening of the NAFX peak. In INS cases where the patient is binocular and the INS damps with convergence, the best approach is the bimedial recession surgery which will have the same effects as the above Figures show; convergence improvements are usually greater than gaze-angle improvements in patients with both eccentric peaks and vergence peaks in their NAFX.

To assess visual function improvement post-surgery:
1) determine the percent increase in the longest foveation domain (LFD), given by

$$\%\text{Improvement} = 100[\text{LFDpost} - \text{LFDpre}]/\text{LFDpre}$$

where LFD = the range of gaze angles where the NAFX is ≥0.9[NAFXpeak] (i.e., the range of gaze angles for which the NAFX is within 10% of the peak value;
2) determine the percentage improvement in visual acuity, given by

$$\%\text{Improvement} = 100[\text{VApost} - \text{VApre}]/\text{VApre}.$$

As stated above, this gives the physician two static measures of visual function improvement, how much 'more' and how much 'better' the patient sees. Measuring improvements in target acquisition time (i.e., how 'fast' the patient can acquire a new target) requires eye-movement data; these data have documented that the T&R procedure (and, therefore, all four-muscle procedures) allows patients to see 'more,' 'better,' and 'faster" (9-12).

The reason visual function improvement is best expressed in terms of percentages rather than either lines (acuity) or degrees (gaze-angle range) is that percentages more accurately reflect the changes in visual function. It should be noted that a 100% improvement in a patient's visual acuity from 20/400 or 20/200 will make a more dramatic improvement in a patient's life than a 100% improvement from 20/40.

Measuring visual acuity at various gaze angles in addition to primary position provides the clinical data necessary to determine the improvements in visual function following therapy. However, only eye-movement recordings can eliminate the misdiagnoses that occur in patients with strabismus and nystagmus.

There is one other topic that is relevant to this report, the *primary outcome measure* of studies of INS therapies. As should be evident from the above considerations, the commonly used clinical measure of peak visual acuity (usually with head, and therefore, gaze angle uncontrolled) is neither an adequate nor a scientifically valid measure of EOM surgery or non-surgical therapies of INS. First, because some INS patients will have waveforms with excellent foveation quality (i.e., high NAFX) at their preferred gaze angle, no therapy will improve that measure despite improvements in other measures of visual function. Thus, such studies will be flawed by false negative results. Second, because increasing the breadth of the NAFX vs. Gaze Angle curve, thereby increasing the range of gaze angles with the highest visual acuity, results in a more useful increase in visual function than simply increasing peak acuity by a line or two, using peak acuity as the primary outcome measure will miss this more important measure. Third, just as a motor measure (ocular alignment) is the primary outcome measure of strabismus surgery (a motor therapy), the primary outcome measure of nystagmus surgery (a motor therapy) should also be a motor measure (i.e., waveform foveation quality as measured by the NAFX). Fourth, both ocular alignment (for strabismus surgery) and the NAFX (for nystagmus surgery) are *direct measures* of the therapy whereas binocular acuity (for strabismus surgery) or measured visual acuity (for nystagmus surgery) are tertiary measures subject to many intervening, idiosyncratic, confounding factors.

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