Clinical Contrast Sensitivity Function in Patients with Infantile Nystagmus Syndrome Before and After Eye Muscle Surgery

Richard W Hertle¹,², Dongsheng Yang¹, Megan Cochran⁴ and Priya R Edward⁵

¹Children’s Hospital Vision Center, Akron Children’s Hospital, Akron, Ohio, USA
²The Northeastern Ohio Medical University, Rootstown, Ohio, USA
³Department of Ophthalmology, Hualiang Eye Hospital Chengsha, Hunan Province, China
⁴Robinson Memorial Hospital, Columbus, Ohio, USA
⁵Rainbow Babies and Children’s Hospital, University Hospital, Case Western Reserve University, Cleveland, Ohio, USA

Abstract

Purpose: To test the hypothesis that eye muscle surgery in patients with infantile nystagmus syndrome improves contrast sensitivity function.

Methods: This is a prospective, interventional case series analysis of clinical data before and after eye muscle surgery in 113 patients who had no previous surgical treatment. Outcome measures included: 1) Routine demography and clinical characteristics, 2) Binocular best-corrected visual acuity in the null position and 3) Contrast sensitivity function. All patients data was collected for this study immediately pre-surgery and 2 to 6 months after surgery. Parametric and non-parametric statistical analysis of outcome measure data collected for this study were performed using standard software on grouped data using computerized software.

Results: Age ranged from 4-43 years (average 14 years), in which 63% were male. After surgery Follow-up the patient with an average of 13.1 months, although the study data was collected as described above, 61% had associated afferent visual system disease, 71% had significant refractive error, 71% had strabismus, 62% had an associated anomalous head posture and 21% had associated (a) periodicity Cumulative data from 113 patients and separate data from patients with either best binocular visual acuity < 20/80 or > 20/100 showed significant improved CS across all spatial frequencies tested.

Conclusion: Infantile nystagmus patients have deficient constrast sensitivity which may proved a measure of visual system dysfunction. This report supports the hypothesis that contrast sensitivity improves after eye muscle surgery in patients with infantile nystagmus and may be a useful outcome measure for future interventional clinical trials.

Keywords: Contrast sensitivity; Eye muscle surgery; Nystagmus

Introduction

Infantile Nystagmus Syndrome (INS) is an oculomotor disorder of unknown etiology that presents in early infancy. Nystagmus has been classified in many ways, resulting in some confusion and disagreement among clinicians and scientists. The National Eye Institute sponsored workshop, Classification of Eye Movement Abnormalities and Strabismus (CEMAS), has attempted to resolve some of the confusion with a publication that defines the various types of nystagmus [1]. The published definition of INS by the CEMAS working group is used in this study [1]. The major clinical characteristics of INS with variable association include: Increased intensity with fixation, decreased intensity with sleep, variable intensity due to eye position in orbit or gaze (eccentric null position), changing direction in different positions of gaze (neutral positions), decreased intensity with convergence (damping), changing direction and/or intensity with monocular occlusion (“latent component”), anomalous head posturing, strabismus and dissociated horizontal and vertical deviations [1].

In addition to the above characteristics from 17% to 33% of patients with INS will have an inherent, rhythmic, periodic or (a) periodically changing nystagmus intensity and/or direction over time [2,3]. Most clinicians are familiar with this oscillation as acquired Periodic Alternating Nystagmus (PAN). Acquired PAN has a specific pattern identified by the presence of spontaneous nystagmus in the primary position, which beats horizontally in one direction for 1 or 2 minutes, followed by a quiet period, and then reappearance of the nystagmus in the opposite direction for a similar length of time. Infantile Aperiodic Alternating Nystagmus (IAPAN) has all the characteristics of INS except that the nystagmus direction and/or intensity changes in an irregular pattern over time. IAPAN also has the clinical characteristics of a dynamic, anomalous head posture and dynamically changing visual functions both over time and as a function of gaze [2,4].

Two broad areas of visual system treatment in infants and children with nystagmus and include treating their ametropia and oculomotor dysfunctions [5,6]. Common standard visual system treatment includes correction of refractive errors with spectacles, treatment of amblyopia, eye muscle surgery for strabismus, low vision devices, and sunglasses. Although treatment of refractive error is standard of care, the use of devices such as specialized contact lenses is often not included. Likewise, treatment of strabismus and amblyopia is common, but associated treatment of nystagmus and its consequences are rare.

Previous studies have shown that results for letter acuity, vernier acuity and contrast sensitivity in some, but not all, subjects with INS is poorer than in normal observers under conditions of comparable retinal image motion [7-10]. This implies that contrast sensitivity
may not be limited by the motion of the retinal image in some subjects with infantile nystagmus syndrome. There is psychophysical evidence that retinal motion may contribute to vision loss via an amblyopic component in patients with INS separate from ametropic and strabismic components [10]. High spatial frequency vision, i.e., Snellen acuity, may not be the best subjective measure of visual function in patients with disorders of the ocular motor system such as INS. Other subjective measures such as Contrast Sensitivity (CS), motion detection, gaze dependent visual acuity, visual reaction time, stereopsis, eye-hand and visual-vestibular coordination may more accurately represent measures that was affected by ocular motor disease and thus can be used as outcome variables in interventional clinical trials. This report details the outcome on contrast sensitivity after eye muscle surgery in the treatment of patients with INS after baseline spectacle correction.

Methods

All testing, data collection, analysis and reporting were approved by the Institutional Review Board of Akron Children’s Hospital, Akron, OH, USA and The Children’s Hospital of Pittsburgh of UPMC, Pittsburgh, PA, USA and Nationwide Children’s Hospital, Columbus, Ohio. All procedures observed the declaration of Helsinki and informed consent/assent was obtained from all patients/parents. Inclusion criteria included; INS (diagnosed by clinical evaluation and eye movement recordings), no prior treatment other than spectacles and not taking any medications known to affect the ocular motor system. Exclusion criteria included those patients with syndromic INS or patients in whom there were incomplete data or follow up less than 12 months.

The first step was to prescribe spectacle optical correction. Many patients presented either for the first time or for another treatment opinion who were not already in spectacle correction. The prescriptions fulfilled corrected myopia ≥ 0.75 diopters, astigmatism ≥ 1.50 diopters and anisometropia ≥ 1.00 diopters and either fully corrected or symmetrically under-corrected (by up to 1.50 D) hyperopia of ≥ +3.50 D (spherical equivalent). Spectacle-corrected distance visual acuity was measured at 3 meters in the patient’s habitual head position using the Amblyopia Treatment Study (ATS) HOTV protocol for patients ≤ 7 years and the ATS ETDRS protocol for patients > 7 years of age at least every 4 (± 1) weeks after spectacle wear until acuity remained at within 1 line from the prior visit [11]. This testing was accomplished in the patient’s eccentric null position if they did not have IAPAN and in primary position during the patient’s time of least intense nystagmus if they had IAPAN using the acuity testing protocols mentioned above [12-20]. The visit at which visual acuity remained stable became the baseline for all further measurements. All subsequent measures of visual acuity described below were obtained using the age-appropriate ATS protocol [11-20].

The goals of eye muscle surgery were to; simultaneously treat combinations of the patient’s strabismus, anomalous head posture and nystagmus with one operation. Standard methods of preoperative evaluation, anesthesia and fornix based eye muscle surgery were employed in the surgical treatment of all patients. The exact surgical procedure for each patient was based on the surgeon’s clinical experience and published reports detailing those used in the treatment of strabismus, anomalous head posture and nystagmus. The surgical procedures are outlined in Table 1.

Table 1: Percentage of patients who had each one of operations 1-9. These 9 operations describe a methodological approach to eye muscle surgery on patients with infantile nystagmus syndrome and are based on multiple previous publications. # - Number of patients; (%) - Percentage of patients; mm - Millimeters; reattach - Reattachment of muscle at original insertion with no recession or resection.

| Operation type (113 patients)                              | # (%) |
|------------------------------------------------------------|-------|
| Operation 1 - Horizontal head posture alone                | 25 (22) |
| Horizontal rectus recess and resect or renotomy + Reattach |       |
| Operation 2 - Chin down head posture (+/- Strabismus)      | 22 (20) |
| Superior rectus recess 5.0 mm + Inferior oblique myectomy  |       |
| Operation 3 - Strabismus alone                             | 15 (13) |
| Primary position deviation using at least two recti each eye|       |
| Operation 4 - Horizontal head posture + Strabismus         | 14 (12) |
| Fixing eye straightens head + Non-fixing eye straightens eyes|       |
| Operation 5 - Chin up head posture (+/ Strabismus)         | 8 (7)  |
| Inferior rectus recess 5.0 mm + Superior oblique tenectomy 5.0 mm |       |
| Operation 6 - No head posture, strabismus or vergence bamping |       |
| Horizontal rectus tenotomy + Reattach                     | 8 (7)  |
| Operation 7 - Multifacial head posture (+/- Strabismus)    | 8 (7)  |
| Transposition of recti + Combinations of oblique or recti recess |       |
| Operation 8 - Vergence damping alone (Artificial divergence)| 7 (6)  |
| Medical rectus recess 3.0 mm + Lateral rectus tenotomy + Reattach |       |
| Operation 9 - Torsional head posture alone                 | 6 (5)  |
| Horizontal transposition of vertical recti 1 tendon width  |       |

Outcome variables

Measures prospectively analyzed for this study was done immediately pre-surgery and 2 to 6 months after surgery and included: 1) Routine demography and clinical characteristics, 2) Binocular best-corrected visual acuity in the null position (BVA) and 3) Contrast Sensitivity Function (CS). Standard clinical monitoring of surgical complications and side effects were performed. While all clinical measures were obtained after each treatment modality, the reported baseline measures were being those measured immediately after adaptation to spectacle treatment and immediately prior to surgery. Post-treatment measures were obtained ≥ 2 to ≤ 6 months after the patient’s surgery.

Clinical and ocular motor evaluation

Demographic and clinical data reported in this series includes: Age, sex, AHP, ocular alignment, presence of IAPAN and refractive error. Ocular motor examination included a determination of heterophoria/tropia at distance (> 3 m) and near (33 cm) in all diagnostic positions of gaze. Cycloplegic refraction, tonometry, and examination of the anterior and posterior segments were performed on all patients. Clinical evaluation of the ocular motor oscillations included changes in the oscillation in primary position, at near, in all nine diagnostic positions of gaze, under monocular and binocular conditions and over time (~5 minutes) (Table 2).

Visual acuity testing at the null position

Best visual acuity was measured by a technician trained to perform the ATS visual acuity protocols and they were also masked to treatment status [11]. Visual Acuity (VA) testing was performed with the patient’s full optical correction in place using the electronic ATS protocol.
| PT# | Age  | STRAB | (A)PAN | EYE DX | Refractive Error |
|-----|------|-------|--------|--------|------------------|
| 1   | 43.1 | XT-HT | No     | Amblyopia | (+3.00 +2.50 x 90 OU) |
| 2   | 17   | None  | No     | None    | (+4.00 +0.75 x 75OD, +1.00 x 100 OS) |
| 3   | 6    | ET    | Yes    | Amblyopia | (+3.00 +4.50 x 90 OU) |
| 4   | 8.1  | ET    | No     | OCA    | (+0.50 +3.75 x 90 OU) |
| 5   | 6.7  | None  | No     | None    | (+2.00 +4.00 x 120 OD and x 60 OS) |
| 6   | 8.5  | ET    | No     | DVM    | (+2.00 OD, +2.75 OS) |
| 7   | 7.5  | ET    | No     | OCA    | (+2.25 +2.75 x 90 OU) |
| 8   | 16.6 | ET    | No     | RD     | (+2.00 +0.00 x 45 OD, +1.25 +0.75 x 35 OS) |
| 9   | 42.3 | None  | No     | None    | (+75 +1.75 x 90 OU) |
| 10  | 25.1 | ET    | No     | OCA    | (+3.00 +1.50 x 90 OU) |
| 11  | 41.2 | None  | No     | None    | (+3.00 +3.50 x 90 OD, +2.00 +2.75 x 90 OS) |
| 12  | 11.2 | ET    | No     | OCA    | (+3.00 OU) |
| 13  | 17   | ET    | No     | None    | (+3.00 +0.75 x 90 OU) |
| 14  | 12.1 | None  | No     | None    | (+1.50 +2.50 x 90 OU) |
| 15  | 59.2 | XT    | No     | RD     | (+4.00 +2.50 x 150 OD, +4.00 +1.25 x 65 OS) |
| 16  | 27.4 | None  | No     | None    | (+5.00 +7.50 x 90 OD) |
| 17  | 34.7 | None  | No     | None    | (+4.00 +0.75 x 135 OD, +4.75 +1.00 x 180 OS) |
| 18  | 31.5 | XT    | Yes    | None    | (PL +4.50 x 90 OD, PL +5.00 x 90 OS) |
| 19  | 38   | ET    | No     | Amblyopia | (+1.00 +4.50 x 45, -0.75 +3.00 x 135 OS) |
| 20  | 42.7 | None  | No     | None    | (+1.00 +2.00 x 90 OU) |
| 21  | 31   | ET    | Yes    | OCA    | (+3.00 +6.50 x 45 OD, +135 OS) |
| 22  | 6.5  | ET    | No     | None    | (PL +5.50 x90 OU) |
| 23  | 27.2 | None  | No     | OCA    | (+5.00 +1.00 x 135 OD, +45 OS) |
| 24  | 3.1  | ET    | Yes    | None    | (+2.50 +4.50 x 125 OD, +60 OS) |
| 25  | 16.8 | None  | No     | None    | (+7.50 +2.25 x 90 OU) |
| 26  | 38.6 | ET    | Yes    | RD     | (+1.00 +3.75 x 60 OD, +120 OS) |
| 27  | 7.2  | None  | No     | None    | (+4.50 +1.25 x 90 OD, +135 OS) |
| 28  | 18   | ET    | No     | FOV HYP | (+3.00 +3.00 x 90 OD, +3.75 +4.00 x 135 OS) |
| 29  | 4.3  | XT    | No     | None    | (+4.75 OU) |
| 30  | 10.2 | None  | Yes    | RD     | (+7.50 +1.00 x 90 OU) |
| 31  | 4.1  | None  | No     | None    | (+5.75 OD, +5.00 OS) |
| 32  | 13   | XT    | No     | OCA    | (+8.50 +2.50 x 90 OU) |
| 33  | 5.7  | XT    | No     | Amblyopia | (+3.50 +4.50 x 110 OD, +70 OS) |
| 34  | 33   | None  | No     | None    | (+1.25 +4.25 x 90 OU) |
| 35  | 4.5  | ET    | No     | None    | (+2.00 +4.00 x 45 OD, -2.25 +3.25 x 110 OS) |
| 36  | 13   | ET    | No     | None    | (+2.25 OU) |
| 37  | 15   | ET    | Yes    | Aphakia | (+1.50 +4.00 x 90 OD, +120 OS) |
| 38  | 6    | ET    | No     | OCA    | (+5.00 +3.50 x120 OD, +4.00 +4.00 x 60 OS) |
| 39  | 17   | None  | No     | None    | (+2.75 OU) |
| 40  | 4    | ET-HT | Yes    | Amblyopia | (+0.50 +1.75 x 175 OD, +10 OS) |
| 41  | 5    | None  | No     | None    | (+0.75 +2.50 x 140 OD, +1.00 +3.00 x100 OS) |
| 42  | 11   | ET    | Yes    | FOVE HYO | (+5.50 +2.00 x 90 OD, +5.75 +2.00 x 10 OS) |
| 43  | 8.5  | None  | No     | OCA    | (+2.00 +1.00 x 90 OU) |
| 44  | 15   | ET    | No     | OCA    | (+5.00 +4.00 x 135 OD, +85 OS) |
| 45  | 10   | None  | No     | CVI    | (+3.00 +0.75 x 85 OD, +4.50 +1.00 x 100 OS) |
| 46  | 6.5  | ET    | No     | None    | (+2.00 +2.50 x 90 OU) |
| 47  | 7    | ET    | Yes    | Amblyopia | (+75 +2.75 x 90 OU) |
| 48  | 9.5  | ET    | No     | None    | (+4.00 +1.00 x 90 OD, +1.00 +0.50 x 90 OS) |
| 49  | 5    | ET-HT | No     | OCA    | (+4.00 +3.00 x 90 OU) |
| 50  | 8.3  | None  | Yes    | DVM,CVI | (+0.50 +7.50 x 160 OD, +20 OS) |
| 51  | 12.5 | None  | No     | None    | (+0.50 +2.50 x 90 OU) |
| 52  | 8.5  | ET    | Yes    | RD     | (+6.50 OD, +1.75 +1.75 x 140 OS) |
| 53  | 8.5  | XT-HT | No     | FOV HYP | (+6.25 +1.25 x 90 OD, +100 OS) |
| 54  | 8.5  | ET    | No     | OCA    | (+2.00 +4.50 x 45 OD, +135 OS) |
| No. | Age | Diagnosis | Eye Surgery | Refraction Details |
|-----|-----|-----------|-------------|--------------------|
| 55  | 3.5 | None      | Yes         | None (-2.50 ± 0.50 x 90 OD, PL +1.00 x 90 OS) |
| 56  | 5.4 | ET        | No          | None (-1.25 ± 2.75 x 45 OD, -0.50 ± 1.00 x 135 OS) |
| 57  | 3.0 | ET        | No          | None (+6.00 ± 1.75 x 105 OD, +5.75 ± 1.75 x 90 OS) |
| 58  | 7   | None      | None        | None (-3.50 ± 1.75 x 80 OD, -4.75 ± 1.00 x 180 OS) |
| 59  | 4   | XT        | Yes         | None (-3.00 ± 2.00 x 90 OU) |
| 60  | 3.4 | None      | None        | None (+2.50 ± 4.50 x 90 OU) |
| 61  | 57  | None      | None        | None (+1.00 ± 4.00 x 45 OD, -1.50 ± 0.50 x 135 OS) |
| 62  | 4.5 | None      | None        | None (-5.00 ± 0.00 x 80 OD, -3.00 ± 3.00 x 75 OS) |
| 63  | 47  | ET        | Yes         | Amskia (+14.50 ± 2.75 x 120 OD, -15.25 ± 3.25 x 60 OD) |
| 64  | 35  | ET        | No          | None (+6.00 ± 2.50 x 115 OD, -4.50 ± 1.75 x 110 OS) |
| 65  | 16  | None      | None        | None (+4.50, OD +3.25 OS) |
| 66  | 8.5 | ET        | No          | FOV HYP (+4.00 ± 3.50 x 80 OD, -4.00 ± 4.00 x 90 OS) |
| 67  | 14  | ET        | Yes         | Amblyopia (+6.75 ± 2.25 x 90 OU) |
| 68  | 44  | None      | None        | None (-3.00 ± 1.00 x 185 OD, -3.50 ± 1.50 x 170 OS) |
| 69  | 4   | None      | None        | None (-4.25 ± 3.25 x 60 OD, +2.75 ± 3.50 x 120 OS) |
| 70  | 8   | XT-HT     | No          | RD (-2.50 ± 5.75 x 15 OD, -1.50 ± 6.00 x 125 OS) |
| 71  | 42  | XT        | No          | Amblyopia (+3.00 ± 3.25 x 45 OD, -3.50 ± 2.75 x 135 OS) |
| 72  | 6.6 | XT        | No          | Amblyopia (-1.00 ± 2.25 x 115 OD, -2.50 ± 4.25 x 90 OS) |
| 73  | 35  | ET        | Yes         | OCA (+6.00 ± 3.00 x 120 OD, -2.50 ± 3.25 x 60 OS) |
| 74  | 23  | None      | None        | None (-3.75 ± 4.00 x 90 OD, -3.25 ± 4.00 x 90 OS) |
| 75  | 7.1 | ET        | Yes         | DVM, CVI (+3.50 ± 4.75 x 70 OD, +3.75 ± 5.00 x 110 OS) |
| 76  | 33.5| ET-HT     | No          | None (-1.20 ± 0.00 x 180 OD, -7.50 ± 4.25 x 120 OS) |
| 77  | 11  | ET        | Yes         | Amblyopia (+6.50 ± 2.00 x 90 OD, +3.75 ± 1.75 x 110 OS) |
| 78  | 8   | ET        | No          | OCA (-6.50 ± 4.25 x 115 OD, -7.75 ± 3.50 x 110 OS) |
| 79  | 4.5 | None      | None        | None (-4.00 ± 0.75 x 180 OD, -4.75 ± 1.00 x 180 OS) |
| 80  | 7   | ET        | No          | Amblyopia (+6.75 ± 2.75 x 90 OU) |
| 81  | 9.5 | ET        | Yes         | OCA (+4.50 ± 1.00 x 90 OD, +3.00 ± 5.00 x 90 OS) |
| 82  | 5   | ET        | No          | None (-4.00 ± 3.00 x 90 OU) |
| 83  | 8.3 | None      | None        | None (-0.75 ± 0.75 x 160 OD, x 20 OS) |
| 84  | 12.5| None      | None        | None (-4.50 ± 2.50 x 90 OU) |
| 85  | 8.5 | ET        | Yes         | FOV HYP (+6.50 OD, +1.75 ± 1.75 x 140 OS) |
| 86  | 8.5 | XT-HT     | No          | OCA (+6.25 ± 2.50 x 90 OD, x 100 OS) |
| 87  | 3.6 | XT        | No          | RD (+6.25 ± 4.75 x 70 OD, +3.75 ± 5.00 x 110 OS) |
| 88  | 5.8 | XT        | No          | None (-3.00 ± 2.00 x 90 OU) |
| 89  | 26  | ET        | No          | Amblyopia (PL +3.50 x 90 OD, +1.75 ± 3.00 x 90 OS) |
| 90  | 13  | ET        | No          | None (+5.25 ± 1.25 x 90 OU) |
| 91  | 31  | ET-HT     | No          | OCA (-6.50 ± 1.00 x 45 OD, x 135 OS) |
| 92  | 6.3 | XT-HT     | No          | FOV HYP (+2.00 ± 4.00 x 90 OU) |
| 93  | 6.3 | XT-HT     | Yes         | FOV HYP (+2.00 ± 4.00 x 90 OU) |
| 94  | 7   | None      | None        | None (+0.75 ± 2.75 x 90 OU) |
| 95  | 9.5 | ET        | No          | Amblyopia (+4.00 ± 1.00 x 90 OD, +3.00 ± 5.00 x 90 OS) |
| 96  | 5   | None      | None        | None (-4.00 ± 3.00 x 90 OU) |
| 97  | 8.3 | ET        | Yes         | ONH (-0.75 ± 7.5 x 60 OD, x 20 OS) |
| 98  | 12.5| None      | None        | None (-0.50 ± 2.50 x 90 OU) |
| 99  | 8.5 | None      | None        | None (+6.50 OD, +1.75 ± 1.75 x 140 OS) |
| 100 | 8.5 | XT-HT     | No          | RD (+6.25 ± 1.25 x 90 OD, x 100 OS) |
| 101 | 31.5| XT        | No          | OCA (PL ±4.50 x 90 OD, PL ±5.00 x 90 OS) |
| 102 | 38  | ET        | No          | Amblyopia (+1.00 ± 4.50 x 45 OD, -0.75 ± 3.00 x 135 OS) |
| 103 | 42.7| XT        | No          | OCA (+1.00 ± 2.00 x 90 OU) |
| 104 | 51  | ET        | Yes         | ONH (+3.00 ± 6.50 x 45 OD, x 135 OS) |
| 105 | 6.5 | ET        | No          | OCA (PL ±5.50 ± 90 OU) |
| 106 | 27.2| None      | None        | None (-5.00 ± 1.00 x 135 OD, x 45 OS) |
| 107 | 3.1 | ET        | No          | ONH (+2.50 ± 4.50 x 125 OD, x 60 OS) |
| 108 | 16.8| None      | None        | OCA (-7.50 ± 2.25 x 90 OU) |
| 109 | 8.6 | ET        | No          | Amskia (+18.00 ± 3.75 ± 60 OD, x 120 OS) |
Table 2: Clinical characteristics of 113 patients with INS.

| Surgical procedure | Number of Patients | Percentage |
|--------------------|--------------------|------------|
| Strabismus correction | 113 | 100% |
| Amblyopia correction | 89 | 78.2% |
| Albinism correction | 7 | 6.1% |
| Delayed visual development correction | 7 | 6.1% |
| Other procedures | 8 | 7.0% |
| Total | 113 | 100% |

Results

From 2006-14, 113 patients were recruited and are the subjects of this study. They ranged in age from 4-43 years (average 14 years), 63% were male. Follow-up, after surgery, ranged from 9-48 mos (average 13.1 mos), 61% had associated afferent visual system disease (22% with visual pathway, optic nerve or retinal disease, 43% with amblyopia and 27% with albinism), 71% had significant refractive error, 71% had strabismus, 62% had an associated anomalous head posture and 21% had associated (a) periodicity (Table 2).

Surgical procedure

The method used to approach surgery on the extra ocular muscles of both eyes is represented in table 2. 22% had operation 1, 20 % had operation 2, 13% had operation 3, 12% had operation...
Contrast Sensitivity (CS)

Tables 3-5 shows changes in CS at all cycles per degree (cpd) stimuli for baseline and post-surgery. CS was statistically significantly better at all cpd stimuli after treatment cumulatively and also when analyzed as a function of better (> 20/80; logMar 0.60) or worse (< 20/100; logMar 0.70) BVA (p=0.001).

Discussion

Visual function in patients with INS is affected by unpredictable combinations of ocular motor (eccentric null zones, damping with convergence, monocular intensity changes, periodicity, strabismus, poor smooth pursuit, OKN and attentional changes) and sensory system defects (ammetropia, amblyopia, photosensitivity, loss of contrast sensitivity, poor motion perception, decreased temporal luminance, impaired contour interaction, light interference and pre-chiasmal, chiasmal, post-chiasmal and maldevelopment) [22-27]. Visual functions directly affected include high spatial acuity vision, contrast sensitivity, motion detection, visual recognition time, gaze and time dependent vision, depth, stereopsis, smooth pursuit, vestibular and proprioceptive functions [23,28-32]. Tests of these visual based functions are usually not part of routine eye evaluations and are more commonly used in research settings but may be important measures of visual function outside the office. It may be that some of all of these visual functions contribute to the subjective improvement in visual “well-being” described by these patients and their families after treatment.
Traditional visual system treatment of patients with INS includes spectacles, routine ambylopia and strabismus management. In the classroom, preferential seating, lighting, computer assisted devices and handouts of board written content are helpful aids.

There is no cure for many of the visual sensory system deficits that are associated with INS. Treatment directed specifically at the nystagmus would have as its goal to increase the quality and quantity of foveation periods, thereby, increasing the potential for more time and gaze angles during which best visual function could take place [25,33]. There is a large body of data supporting the hypothesis that foveation periods occurring during each beat of nystagmus can be lengthened or increased by therapeutic interventions (i.e., medicines, surgery, contact lenses, etc.) [12-20]. Quantitating these foveation periods is accomplished with accurate, calibrated, eye movement recordings using various foveation programs. The improvement in INS applies both to patients with and without associated sensory-system defects. Ocular motor and visual system benefits have been shown to be consistently observed in patients who undergo eye muscle surgery for INS, even if the purpose was to decrease torticollis or improve strabismus [12-20].

Several reports suggest it is clinically reasonable to measure CS to assess visual system disability in patients with multisystem vision disease [21,34-37]. Anatomical and electrophysiologically anomalous found in human albinos are reflected by reduced contrast sensitivitiy. Testing of CS in patients with INS has repeatedly shown it to be abnormal [21,34-37]. High astigmatic errors, nystagmus and other retinal/neural anomalies may result in abnormal meridional differences in sensitivity. Previous reports have also shown an increase in peak CS in INS patients while using telescopes and other low vision aids.

The approach outlined in table 1 to eye muscle surgery in INS1 patients was developed as a result of a need to improve multiple preoperative ocular motor and/or visual system abnormalities in the patient population with INS [14,17,18]. This 9-operation system allows the clinician to maximize surgical intervention by performing one procedure to address all possible indications, e.g., eye position, head/face position and nystagmus characteristics. This surgical algorithm is based on standard eye muscle surgical techniques and is easily applicable in most clinical situations. The data from this study add to others that have shown that INS patient’s strabismus and anomalous head posture can be improved after eye muscle surgery in the same way as other populations of patients with strabismus.

**Study Limitations**

There are several limitations of this case series. This is not a randomized clinical trial comparing an isolated intervention to a known treatment or placebo. There are no randomized clinical trials evaluating surgical treatments of INS thus clear evidenced based guidelines including indications and risks of treating visual system anomalies associated with INS are based on historical face validity and case/cohort series such as this one. Although all patients had INS, we included patients of all ages, varied baseline visual systems and associated eye diseases. There can be, in children, an age and repeated performance related improvement in clinical testing. In order to minimize these effects two things were included in the study protocol; 1) Outcome measure testing was obtained within 6 months of surgery limiting an age related effect and 2) Specific acuity and contrast sensitivity protocols have been demonstrated to have good test re-test reliability.

Although the patients reported here consist one of the largest prospective treatment cohorts of INS patients, this remains level 2-3 evidence at best. The data reported in this study showed significant improvements in BVA and CS from baseline to post surgery, suggesting that these measures of visual function can be improved in patients with INS after surgical treatment. Although group means showed improvement in visual acuity, individual patient acuity may have varied +/- 0.1 logMar based on chance alone. This is inherent in the testing methodology and age of the patients involved in this report and the reason we chose to perform group mean analysis. These surgical procedures are not novel, and also the treatment of the visual system of patients with INS. This study has shown that the use of standard surgical treatments of patients with INS significantly improves their contrast sensitivity function.

**References**

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**Table 5:** 44 Patients acuity < 20/100 (logMar 0.70) CS pre and post-operatively.

| Frequency/Exam | Mean +/- SD | Minimum | Maximum | P Value * |
|---------------|-------------|---------|---------|-----------|
| 3 cpd*        |             |         |         |           |
| Preop         | 0.53 ± 0.21 | 0.4     | 1.01    | 0.001     |
| Postop        | 1.46 ± 0.43 | 0.68    | 1.95    | 0.001     |
| 6 cpd         |             |         |         |           |
| Preop         | 0.71 ± 0.27 | 0.6     | 1.22    | 0.002     |
| Postop        | 1.59 ± 0.33 | 1.11    | 1.88    | 0.01      |
| 12 cpd        |             |         |         |           |
| Preop         | 0.78 ± 0.39 | 0.3     | 0.91    |           |
| Postop        | 1.01 ± 0.24 | 0.87    | 1.61    |           |
| 18 cpd        |             |         |         |           |
| Preop         | 0.13 ± 0.08 | 0.09    | 0.2     |           |
| Postop        | 0.98 ± 0.29 | 0.41    | 1.33    |           |
