Original Article

Evaluation of distance and near stereoacuity and fusional vergence in intermittent exotropia

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Aim: To evaluate the role of distance and near stereoacuity and fusional vergence in patients with intermittent exotropia [X(T)] and their change after surgery.

Materials and Methods: This prospective interventional institution-based clinical study included 31 cases of X(T) requiring surgery and 33 age, sex-matched controls. All subjects underwent complete orthoptic assessment including near stereopsis (Randot stereogram) and distance stereopsis by polaroid stereo-projector apparatus using special paired slides and fusional vergence assessment at distance and near prism bar at baseline and one week, one month, three months and six months after surgery in X(T).

Results: The successful surgical alignment rate was 74.2%. Preoperatively, cases demonstrated significantly poor distance and near stereoacuity, compared to controls ($P < 0.001$). Mean distance stereoacuity (sec of arc) in normals, (X)T preoperatively and postoperatively was 344.8 ± 139.5, 1149.2 ± 789.4 and 450.1 ± 259 while mean near stereoacuity was 34.7 ± 9.5, 68.7 ± 31.1 and 47.4 ± 22.6 respectively. Postoperatively at six months, significant improvement in stereoacuity was observed both at near and distance ($P < 0.05$). Mean distance fusional convergence (in prism diopter) in normals, X(T) preoperatively and postoperatively was 20.7 ± 4.7, 18.0 ± 3.3 and 21.4 ± 3.6 respectively, mean near fusional convergence was 27.8 ± 6.3, 24.1 ± 5.5 and 29.1 ± 5.5 respectively. There was good correlation between fusional vergence amplitudes for distance and near indicating any one would suffice.

Conclusion: Early detection of abnormal stereoacuity (near and if possible distance) and near fusional vergence amplitudes may help to decide proper timing of surgery in X(T).

Key words: Fusional vergence, intermittent exotropias, polaroid stereo-projector for distance stereopsis, stereoacuity

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Introduction

Intermittent exotropia [X(T)] affects nearly 1% of the general population.[1] It begins as an exophoria which progresses to X(T) and then may deteriorate into a constant exodeviation in up to 75% of cases.[2] Although progression is common, not all cases are progressive and some may remain stable or may even improve.[3-5] There are various opinions regarding the appropriate timing of surgery in a patient with X(T). Early surgery is fraught with the risk of consecutive esotropia, which in the visually immature child of less than five years of age can lead to amblyopia.[6] On the other hand undue delay can lead to suppression and loss of binocularity even after surgical correction.[7]

Previous studies[8-10] have demonstrated that most patients with X(T) have a normal near stereoacuity, but distance stereoacuity is grossly reduced or absent when tested on instruments like the Mentor B-VAT visual acuity tester.[8-10] Surgical correction of exodeviation leads to significant improvement in distance stereoacuity, which however does not return to normal levels.[8-10] We used the relatively simple twin polaroid stereoprojector system to measure the distance stereoacuity in X(T) patients and normal subjects.

Fusional vergences are disjunctive ocular movements responsible for maintaining normal ocular alignment and control of deviation in X(T). However, measurement of fusional amplitudes in X(T) patients has not been done previously. As stereoacuity is an indicator of sensory status and fusional vergences are concerned with motor alignment, we evaluated the possible relationship between these two parameters before and after surgery and with surgical results in patients of X(T).

Materials and Methods

The study was a prospective, interventional institution-based clinical study which included 31 cases of intermittent X(T) and 33 asymptomatic age and sex-matched controls recruited from the outpatient department as well as some attendants. Consecutive cases diagnosed as X(T) and symptomatic for manifest deviation for distance and or near were admitted for surgery and were included in the study. Written and informed consent of patients or parents and healthy controls was obtained prior to inclusion in the study. The study was approved by our institutional review board.

All cases with amblyopia, >2 diopters (D) of anisometropia, incomitance in the horizontal or vertical deviation, significant

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vertical deviation of ≥5 prism diopters (PD) or significant oblique muscle overactions were excluded. Cases with previous history of strabismus surgery were also excluded. Controls were emetropic or ametropic <0.5 D without anisometropia or intermittent or manifest deviation.

All subjects underwent a complete ophthalmic and orthoptic assessment including cycloplegic refraction and full correction of the refractive error if any. Measurement of the angle of deviation was obtained in all patients at distance (6 m) and near (33 cm) in primary position with fixation on accommodative targets employing the alternate prism bar cover test (PBCT) with appropriate spectacle correction based on retinoscopy. In patients with near distance disparity in measurements, they were repeated after unilateral patching for 6 h and using +3D lenses in front of each eye to distinguish true disparity from false and then to classify them according to Kushner's classification[11] of X(T).

Near stereoacuity was measured by Random dot, Randot Stereotest (Stereo Optical Co, Chicago, IL) with subjects wearing polaroid spectacles. Test stereogram was held at a distance of 40 cm from the subject during testing. Patients with refractive errors wore their spectacles under their polaroid lenses. Patients were asked to determine which circle in each successive group appeared to "pop out of the page". This procedure was repeated until two mistakes were made successively. Threshold stereoacuity level was recorded in seconds of arc.

Distance stereoacuity was measured with polaroid stereoprojector apparatus (Pradovit, Germany) using special paired slides, with the patient standing at 6 m from the screen and wearing polaroid glasses. Slides used for measuring distance stereoacuity have five geometrical shapes each of a different level of distance stereo disparity of 200, 400, 660, 800 and 933 arc seconds respectively [Fig. 1]. Slides in pair are placed in the carousel of the stereoprojector. Polaroid dissociation stereoprojector [Fig. 2] is a twin projector instrument used to dissociate the two eyes by using the phenomenon of polarization of light. The twin projectors are provided with polaroid filters, which convert the non-polarized light into polarized light of particular orientation. The orientation of polarization is vertical in one projector and horizontal in the other. The image by polarized light falls on the highly polished aluminum screen, which retains the polarized nature of the light. The image is seen with polaroid glasses in which the polarized filters of appropriate orientation are incorporated. Thus the polarized glasses (filters over the projector and polaroid goggles) allow the image carried by light in a particular polarization and cut off the other image and provide the dissociated images to the two eyes, despite the two eyes being open.

The fusional vergences were measured for both distance (6 m) and near fixation (33 cm) with prism bar, after neutralization of deviation. Prism strength was increased slowly and stepwise and patient was asked to report when the fixation object appears double. The prism power was noted as the break point and this was confirmed with the observation of the eye deviating out. The prism power was then reduced again slowly and stepwise and the point at which the patient regained single vision was noted. This was recorded as the recovery point. Both convergence and divergence breakup and recovery points were measured.

All patients underwent conventional strabismus surgery, consisting of either a bilateral lateral rectus (LR) recession (12 cases) or a monocular recession-resection procedure (17 cases) and two cases had unilateral LR recession. The amount of surgery was based on type and amount of exodeviation. All surgeries were performed by a single surgeon (PS). For the true divergence excess cases (2) and children operated under general anesthesia (10), bilateral LR recession surgery was done. In all basic cases under peribulbar anesthesia (17) monocular recession-resection was done. Unilateral LR recession was done if deviation was less than 18 PD (2).

All subjects were examined at one week, one month, three months and six months after surgery. A minimum follow-up period of three months was required for inclusion in the study. However, all patients could complete six months follow-up. The following measurements were repeated: ocular deviations, stereoacuity and fusional vergences for both distance and near. Surgical outcome was defined as successful in motor terms if the postoperative deviation was less than 8 PD on PBCT, with patient wearing required optical correction.[12]

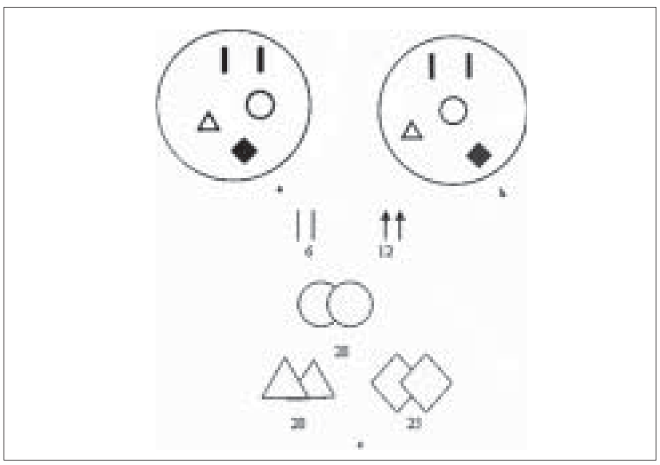

Figure 1: Photo of stereoprojector used in this study

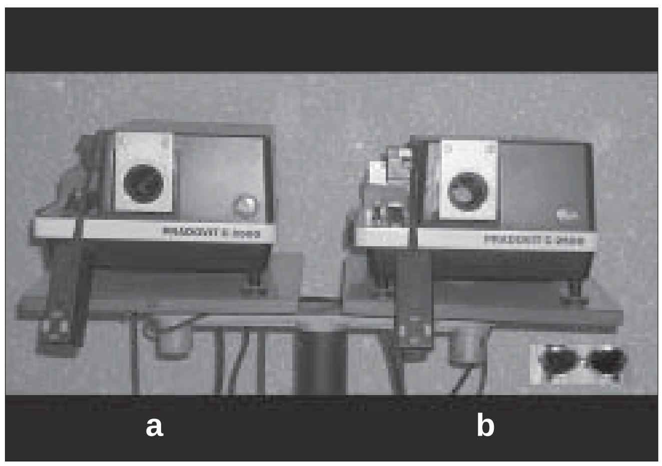

Figure 2a and b: Photo of stereoprojector paired slides. The disparity (in mm) between the two similar images governs the extent of stereopsis measured. The stereopsis levels measured by the paired slides are given

Statistical analysis

Statistical analysis was performed using SPSS 10 statistical software (PC version, USA). Probability value (*P* value) less than 0.05 was regarded as statistically significant. Descriptive analysis like mean, median, confidence intervals and standard deviation was done for all the parameters. Independent sample student's t-test or Mann-Whitney U test whenever applicable was used for comparison of various parameters between cases and controls. Pearson's or Spearman's correlation coefficient was measured whenever applicable to determine the relationship between different parameters. To see the changes over a period of time Friedman test was used.

Results

Thirty-five consecutive cases of intermittent X(T) were approached and 31 cases were included in our study. Four patients were excluded due to previous surgery (2) and significant vertical deviation (2). Thirty-three age and sex-matched controls were evaluated. The mean age of cases was 19.6 ± 9.0 (range, 6 to 42) years and that of controls was 19.5 ± 8.6 (range, 8 to 40) years ($P = 0.9$). There were 15 males (48.4%) and 16 females (51.6%) in the X(T) group and 18 males (54.5%) and 15 females (45.5%) in the control group ($P = 0.9$). Mean amount of deviation (PD) in patients with X(T) was 39 ± 10.4 (range, 18 to 71) at distance and 37 ± 9.6 (range, 25 to 71) at near.

Patients with X(T) performed significantly worse for both distance and near stereoacuity than normal subjects. Table 1 shows the stereoacuity data for normal subjects and patients with X(T). The mean distance stereoacuity of patients with X(T) was poorer than that of normal subjects ($P < 0.001$). Preoperatively out of 31 cases, 12 (38.7%) were unable to demonstrate any distance stereoacuity. For statistical purposes they were assigned a value of 2100 sec of arc. Because it is not biased by the extremes, median value might be a more valid measure for comparison between two groups. Postoperatively, significant improvement was seen in distance stereoacuity ($P < 0.001$). The improvement in stereoacuity was significant up to four weeks after which no significant improvement was seen. Preoperatively only three out of 31 cases (9%) demonstrated fine distance stereoacuity of 200 sec of arc. Postoperatively 12 cases (39%) with X(T) were able to demonstrate this level of distance stereoacuity. Of 31 patients distance stereoacuity improved in 27 (87.1%), did not change in two (6.5%). Worsening was seen in two patients of which one patient developed consecutive esotropia of 14 PD. These two patients worsened from 600 and 200 sec of arc to 933 and 600 sec of arc respectively. The first patient was a 25-year-old male who had surgical motor success from 25 PD to 6 PD of X (T) and the other patient was a nine-year-old girl who developed consecutive esotropia of 14 PD from 35 PD of X (T). The amount of esotropia remained same and was given prism therapy subsequently.

The X(T) patients in our study demonstrated poor near stereoacuity, when compared with normal subjects, both preoperatively ($P < 0.001$) and at six months postoperatively ($P = 0.004$). The X(T) patients did show a significant improvement in near stereoacuity ($P < 0.001$). Friedman test showed a significant improvement at all the visits up to six months ($P < 0.05$) but the final level achieved was not the same as normals ($P = 0.04$). Preoperatively 25 X(T) patients (80.7%) had near stereoacuity poorer than 40 sec of arc and at six months, only 13 (42) patients had near stereoacuity poorer than 40 sec of arc.

The relationship between near and distance stereoacuity for cases and controls was evaluated using Spearman's correlation coefficient. There was a significant correlation between near and distance stereoacuity in normal subjects ($r = 0.560$, $P < 0.001$) as well as in X(T) preoperatively ($r = 0.365$, $P = 0.04$) and postoperatively ($r = 0.532$; $P = 0.002$). The correlation between preoperative and postoperative stereoacuity level was better for near ($r = 0.791$, $P = 0.000$) than for distance ($r = 0.544$, $P = 0.002$).

Table 2 shows fusional vergence amplitudes of patients with X(T) and normal subjects, at near and distance fixation. Preoperatively, X(T) patients demonstrated poor convergence and divergence amplitudes ($P < 0.05$), when compared with normal subjects. Although both convergence and divergence amplitudes were adversely affected, convergence was affected to a greater extent in patients with X(T). Convergence recovery point was found to be more adversely affected than break point. After surgery, improvement was seen in fusional vergence amplitudes of patients with X(T) and at six months, no significant difference was present among the two groups.

We tried to determine the relationship between fusional vergence amplitudes and stereoacuity. We did not observe any significant correlation between stereoacuity and fusional vergence amplitudes for distance or near in both X(T) patients and normal subjects (correlation coefficient varied between –0.104 to 0.227, *P* value 0.2 to 0.9)

We defined surgical success as postoperative deviation less than 8 PD (exo/eso).[12] Surgical success in motor terms was

Table 1: Levels of stereoacuity (in sec of arc) for normal subjects and patients with X(T)

	Normal subjects (sec of arc) (a)	X(T) patients preoperatively (sec of arc) (b)	*P value a *vs.* b	X(T) patients postoperatively (sec of arc) (c)	*P value a *vs.* c	*P value b *vs.* c
Mean distance stereoacuity	344.8 ± 139.5	1149.2 ± 789.4		450.1 ± 259		
Mean near stereoacuity	34.7 ± 9.5	68.7 ± 31.1		47.4 ± 22.6		
Median (range) distance stereoacuity	400 (200-660)	800 (200-2100)	<0.001	400 (200-933)	0.2	<0.001
Median (range) near stereoacuity	30 (20-50)	70 (25-140)	<0.001	40(20-100)	0.04	<0.001
Correlation between near/distance stereoacuity#	0.560 ($P < 0.001$)	0.365 ($P = 0.04$)		0.532 ($P = 0.002$)		

*using Mann-Whitney U test. #Using Spearman's correlation coefficient, X(T) - exotropia

Table 2: Fusional vergence amplitudes (in prism diopters) of patients with X(T) and normal subjects, at near and distance fixation

Fusional vergence amplitudes		Normal subjects	X(T) patients preoperatively (*P* value compared to normals)	X(T) patients postoperatively (6 months) (*P* value compared to normals)
Near	Convergence breakpoint	27.8 ± 6.3	24.1 ± 5.5 (P = 0.01)	29.1 ± 5.5 (P = 0.3)
	Convergence recovery point	22.2 ± 5.5	17.9 ± 2.5 (P < 0.001)	22.6 ± 4.1 (P = 0.7)
	Divergence breakpoint	10.3 ± 2.0	9.4 ± 1.7 (P = 0.04)	10.5 ± 1.5 (P = 0.6)
	Divergence recovery point	8.1 ± 1.9	6.5 ± 1.5 (P < 0.001)	8.0 ± 1.4 (P = 0.8)
Distance	Convergence breakpoint	20.7 ± 4.7	18.0 ± 3.3 (P = 0.009)	21.4 ± 3.6 (P = 0.5)
	Convergence recovery point	17.4 ± 3.9	14.6 ± 2.5 (P = 0.001)	17.4 ± 2.9 (P = 0.9)
	Divergence breakpoint	7.6 ± 1.5	6.5 ± 1.6 (P = 0.004)	7.7 ± 1.7 (P = 0.7)
	Divergence recovery point	5.6 ± 1.5	4.3 ± 1.5 (P = 0.001)	5.6 ± 1.7 (P = 0.9)

X(T) - exotropia

achieved in 23 patients (74.2%). Seven patients had residual exodeviation, while one patient developed consecutive esotropia. Comparison of stereoacuity was done between successful and failed group. Successful patients had a significantly better near stereoacuity both preoperatively and at six months postoperatively ($P < 0.05$), compared with failed patients. Mean distance stereoacuity was also found to be more adversely affected in failed cases than in successful cases but it did not reach statistical significance, both preoperatively and postoperatively.

Discussion

Strabismus surgery is frequently required to treat patients of X(T) with poor control of deviation.[13-16] The decision to perform surgery is often based on the subjective determination of the increasing frequency of manifest strabismus and a few objective criteria like deteriorating control of deviation, poor stereoacuity.[11,17] The X(T) almost always affects distance stereoacuity more than near stereoacuity as the manifestation of deviation is more and earlier for distance. O'Neal and associates have demonstrated that diminished distance stereoacuity is an objective measure of loss of control in X(T) and even with excellent postoperative alignment, the distance stereoacuity, especially with random dot testing, does not recover fully.[10]

Findings in our study agree with those of previous studies.[18-23] Distance stereoacuity in patients with X(T) was found to be very poor and surgical realignment led to improvement in distance stereoacuity.[24] At six months postoperatively mean distance stereoacuity of patients became similar to that of normal subjects (P = 0.2) in our study.

At present distance stereoacuity is usually evaluated using Mentor B-VAT System and vectographic contour circles test. Though Mentor B-VAT is a very sophisticated instrument, there are certain drawbacks associated with it, in addition to the high cost. Patient has to wear binocular liquid crystal shutter spectacles (connected to a microprocessor) and is presented with disparate images alternating at high frequency. It is suggested that in patients with X(T) who are having a very tenacious fusional control over their deviation, wearing of shutter spectacles can cause latent deviation to become manifest and hence patient will exhibit poor or absent distance stereoacuity on this test.

In our study, we have used twin polaroid stereoprojector apparatus with special paired slides for measuring distance stereoacuity. This instrument produces dissociation of two eyes using the principle of polarization of light. Since both the eyes are open during this test, it appears to be a more physiological and less dissociating test available for measuring distance stereoacuity. It is a relatively inexpensive setup which can be developed with two slide projectors, a pair of polaroid filters, a pair of polaroid glasses and a highly polished aluminum screen. Stereoacuity which we measured ranged from 933 to 200 sec of arc.

One surprising finding of our study was that, even near stereoacuity was found to be significantly poor in X(T) patients compared to normal subjects both preoperatively and after surgical correction. Surgical realignment led to significant improvement in near stereoacuity, but even at six months postoperatively mean level was still poor compared to that of normal subjects. This contrasts with earlier reported[25] normal near stereoacuity. One possible explanation for this can be that patients report at a later stage of the disease process (criterion for surgery for this study being frequent manifestation of deviation for distance and/or near). Diminished near stereoacuity is thus an indicator of more advanced effect of prolonged X(T) on binocular vision. Hence a more aggressive approach in managing these patients is needed and may yield better functional outcome. Also, this suggests that near stereoacuity measurement definitely has got a role in monitoring the progression of patients with X(T), at least in the absence of instrument for distance stereoacuity measurement. Near stereoacuity is easily measured on an outpatient basis using simple equipment (RANDOT, TNO or Titmus), which is cheap and readily available and can be performed very easily even in young children. Our study found a good correlation in distance and near stereoacuity levels in normal subjects. Unfortunately, near stereoacuity tends to be affected much later in the clinical course of patients with X(T) as the manifestation of deviation is more and earlier for distance. Hence relying only on near stereoacuity measurement for monitoring sensory status of patients with X(T) can lead to undue delay in surgical intervention.

This correlation was modest preoperatively in X(T) patients but showed improvement at six months postoperatively.

This possibly was due to a greater deterioration of distance stereoacuity compared to near stereoacuity seen in X(T), which is corrected after surgery.

It was found that successful candidates demonstrated much better preoperative and postoperative stereoacuity levels at near and distance compared to failed cases and suggests early intervention on the basis of deterioration of distance and near stereoacuity.

Fusional vergences play a vital role in maintaining normal ocular alignment. To the best of our knowledge, no study has been undertaken to measure fusional vergence amplitudes in these patients, though central and peripheral fusion has been evaluated.[26] We measured fusional vergence amplitudes in normal subjects and X(T) patients using prism bar and accommodative targets. It was found that X(T) patients had poor convergence and divergence amplitudes preoperatively when compared with normal subjects. Surgical realignment led to significant improvement in both convergence and divergence amplitudes of patients, almost to normal levels. Convergence amplitude for distance was found to be more adversely affected than that for near. This may be an explanation why these patients manifest their deviation usually first at distance fixation.

There was good correlation between break points and recovery points in normal subjects and X(T) patients (postoperative better than preoperative). Also both convergence and divergence values for distance correlated very well with values for near. Thus it seems that performing fusional vergence amplitude measurements at near fixation alone can provide sufficient information for managing these patients.

We tried to determine the relationship between stereoacuity and fusional vergence amplitudes in X(T) patients and in normal subjects. No correlation was seen between these two parameters in either of these groups. This indicates that while fusional vergences have a vital role to play in maintaining motor alignment it appears that they do not have any direct influence on the sensory status of the eyes.

To conclude, our study describes a simple test for distance stereoacuity, which is an early indicator of decreased binocularity and a useful criterion for the optimal timing of surgery in patients with X(T). Short of that, near stereoacuity and near fusion vergences can also be helpful and better outcome is expected if the cases are operated before distance or at least near stereoacuity gets affected. We may suggest the cutoff thresholds for near and distance stereoacuity as 40 arc sec and 400 arc sec respectively, till more studies establish more definite norms.

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