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Pilot Study Assessing the Effect of Exam Room Length on the Measurement of Strabismus

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ABSTRACT

Purpose: Our study aims to investigate the effect of decreasing distance from the patient to the fixation target on the measurement of strabismus with a known distance-near disparity.

Methods: Strabismus measurements were taken by one pediatric ophthalmologist at our standard distance of 18 feet and compared to those taken at 16, 14, 12, and 10 feet from the fixation target. A clinically meaningful difference was defined as >2.5 prism diopters (PD), since a difference of that magnitude may alter surgical planning.

Results: Thirty-nine subjects, including 22 exotropes and 17 esotropes, were included in this study. Mean prism diopter difference (PDD) in the exotrope group at lengths of 16, 14, 12, and 10 feet compared to 18 feet were 1.3 (SD 1.9, range 0–6), 1.3 (SD 2.2, range 0–8), 1.7 (SD 3.2, range 0–14), and 2.8 (SD 4.4, range 0–14), respectively. Among esotropes, the mean PDD at the same distances were 1.1 (SD 1.9, range 0–7), 2.1 (SD 2.6, range 0–7), 3.9 (SD 4.9, range 0–19), and 4.3 (SD 5.1, range 0–19). The percentages of exotropes with a PDD of >2.5 at 16, 14, 12, and 10 feet compared to 18 feet were 13.6% ($n = 3$), 13.6% ($n = 3$), 18.2% ($n = 4$), and 27.3% ($n = 6$), respectively. In the esotrope group, 11.8% ($n = 2$), 35.3% ($n = 6$), 47.1% ($n = 8$), and 47.1% ($n = 8$) had a PDD of >2.5 at the same distances, respectively.

Conclusion: This pilot study is the first to investigate the change in measured angle of strabismus at various non-mirrored distances from the patient to the fixation target. Our methodology defines a framework that could be used in a higher-powered study to further our understanding of the effect of room length on strabismus evaluation.

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Strabismus; measurement; exam room; length

Introduction

The ability to precisely measure the angle of strabismus is a critical step in the evaluation and management of a strabismic patient. The standard examination length for measuring the distance angle of strabismus has traditionally been 20 feet. At this distance, there are only 1/8th diopters of accommodation, which is considered negligible.[1] Research conducted by Burian HM over 50 years ago also helped support the practice of measuring the distance angle of strabismus at 20 feet by finding an insignificant difference in the degree of exodeviation between 20 and 100 feet.[2] In order to meet this standard, ophthalmology practices make efforts to allow for a long exam lane for the evaluation of strabismic patients.

A room of this size, however, can be a substantial burden on a practice because this room may take the place of two standard examination lanes, thereby reducing capacity and patient flow. Pediatric eye care practices bear the brunt of this burden as they perform most strabismus evaluations in children and adults. The U.S. Census bureau estimated a 10% increase in the pediatric population from 2000 to 2020.[3] Continued growth of the pediatric patient population and the increasing cost of medical care highlight the need to evaluate space utilization in eye clinics. The exam room length necessary for the evaluation of strabismic patients is one such element to consider.

Kushner and Morton previously investigated this idea by comparing strabismus measurements of eso- and exotropic patients with known distance-near disparity (greater than 10 PD) taken at the standard 20 feet to measurements taken in a 10-foot lane and a 20-foot mirrored system (a 10 foot room with a mirror to simulate a longer viewing distance).[4] They concluded that there was a significant difference in the measurement of strabismus in these patients when comparing the standard length to the shorter lane lengths. Stager and Everett conducted a similar study where they compared the measured angle of strabismus at the standard 20 feet to a 20-foot mirrored system that utilized a larger

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sized mirror.[5] In contrast to Kushner and Morton, they found that there was no significant difference in the measured angle of strabismus between these two types of eye lanes.

To our knowledge, no studies have investigated the effect of various intermediate examination lengths on strabismus measurements. The goal of this study is to assess how different examination lengths would affect the measured distance angle of strabismus in pediatric and adult patients with known distance-near disparity.

Methods

All subjects enrolled were patients who sought care at the Penn State Eye Center and were examined by one pediatric ophthalmologist. An internal review board (IRB) was created and approved for this study by the Penn State College of Medicine. The only inclusion criterion was a horizontal strabismus with a distance (18 feet) to near (16 inches) disparity of 10 or more prism diopters. The age of patients enrolled in this study ranged from 3 to 77 with an average age of 16 and SD of 9.9. Patients were recruited over a year-long period from July 2019 to October 2020. Young children who may not be able to attend to the fixation target for the duration of the testing protocol were excluded from the study. Strabismus measurements were obtained by a single fellowship trained pediatric ophthalmologist at the clinic's standard examination length of 18 feet (measured from the patient's eyes to the fixation target), as well as distances of 16, 14, 12, and 10 feet from the fixation target. Each of the shorter distance measurements was done with the patient sitting in a chair that was moved forward to the designated distance from the fixation target (20/200 age-appropriate optotype targets on the M&S acuity system). The size of the optotype was kept constant at each distance, and the M&S system remained calibrated for the original 18-foot distance. The order in which the angle of strabismus was measured at various intermediate distances was randomized to reduce the impact of fatigue on measurements and analysis. The angle of strabismus was measured in prism diopters using prism and alternate cover testing for all measurements. Measurements and analysis of the level of control of intermittent strabismus were not performed as part of this study.

Patients who were found to have a divergence excess (DE) pattern of exotropia underwent additional measurements after the measurements at shorter distances were taken (30-min patch test followed by near measurements with a +3 lens) to determine if they had pseudo-divergence excess exotropia, high accommodative convergence/accommodation ratio, (AC/A) exotropia, or true divergence excess exotropia. After 30 min of monocular patching, the angle of strabismus was remeasured at near and distance. If the distance-near disparity collapsed to less than 10 PD, the patient was diagnosed with pseudo-divergence excess exotropia (PDE). If the disparity did not collapse, then the near angle was re-measured with +3 lenses held over both eyes (ensuring the patient did not regain fusion following the patch test). If the distance-near disparity now collapsed to less than 10PD, the patient was diagnosed with high AC/A exotropia. If the distance-near disparity persisted, the patient was diagnosed as having true divergence excess exotropia.

All strabismus measurements were done before cycloplegia. Refractive errors were generally addressed in our typical fashion for each strabismus entity. Among exotropes, hyperopia was undercorrected. Myopia was fully corrected if more than −0.50 except Subject 36, a −1.50 myope, was measured without correction. Only one patient (Subject 20) was over-minused by 2D. Among esotropes, hyperopia was fully corrected if more than +1D (except Subject 13 who was measured on his initial visit before 2.5 D of hyperopia was corrected, and Subject 33 who was measured wearing glasses that were later determined to be over-plussed by 1D). Myopia was fully corrected except for subject 40, a − 2.50 D myope who was measured without correction.

The patient's strabismus type, age, sex, visual acuity, history of eye surgery and other ocular or systemic conditions were recorded. We considered differences greater than 2.5 PD to be significant, as this could result in a change to the surgical plan (as surgical tables are typically published in 5 PD increments).

Results

A total of 39 subjects were included in the study (22 exotropes and 17 esotropes). Table A1 displays the demographics and various strabismus types included. The majority of exotropes had convergence insufficiency (CI) (10, 45.5%) or PDE (7, 31.8%). Nearly all the patients in the esotrope group (16, 94.1%) had high accommodative convergence/accommodation ratios (AC/A).

Table A1 provides data for both XT and ET patients with respect to the average magnitude of strabismus at 18 feet. The average absolute magnitude of strabismus was calculated by using the largest degree of strabismus at either 18 feet or near.

Table A2 shows the mean PDD and range for measurements at different distances. We calculated the PDD by comparing the measured angle of strabismus at 18 feet to the measured angle of strabismus at 16, 14, 12, and 10 feet for each patient. When calculating mean PDD, we used absolute values for the PDD. For example, if a hypothetical subject had a PDD of 5, and another subject had a PDD of −5, the average of these two values would be calculated as

5, and not zero. As can be seen in Table A2, for both XT and ET patients, there was a substantial percentage of patients in whom the PDD was greater than 2.5 at all of the shorter test distances, increasing significantly from 16 feet to 10 feet. We did not see any correlation between the magnitude of the distance-near disparity and the degree of PDD.

Also shown in this table is the percentage of patients measured at each shorter distance with a PD difference of >2.5 compared to our standard distance measurement. Among the exotropes 13.6% demonstrated such a clinically meaningful difference at 16 and 14 feet, which consisted of 2 CIs (20% of total CIs) and 1 PDE (17% of total PDEs). At 12 feet, 18.2% of patients had a PDD > 2.5, consisting of 3 CIs (30% of total CIs) and 1 PDE (17% of total PDEs). At 10 feet, 27.3% had a PDD > 2.5, consisting of 2 CIs (20% of total CIs) and 3 PDE (50% of total PDEs).

The percentage of all esotropes with a PD difference measuring >2.5 at 16 feet was 11.8%, consisting of 1 high AC/A (7% of total high AC/As) and 1 DI (100% of total DIs). At 14 feet, 35.3% had a PDD > 2.5, consisting of 5 high AC/A (31% of total high AC/As) and 1 DI (100% of total DIs). At 12 and 10 feet, 47.1% had a PDD > 2.5, consisting of 7 high AC/A (44% of total high AC/As) and 1 DI (100% of total DIs).

We assessed the correlation between the magnitude of distance near disparity and the PDD at each shorter distance. The Pearson's correlation coefficient was used to assess this correlation, and we considered values from .10 to .39 to be a weak correlation and values from .40 to .69 to be a moderate correlation.[6] The correlation coefficient for the exotropia group at 16, 14, 12, and 10 feet was .18, .15, .12, and .22, respectively, indicating a weak correlation for each of the shorter distances. For the esotropia group, the calculated correlation coefficient was .19, .60, .45, and .52 which indicated a weak correlation at the 16-foot distance and a moderate correlation at 14, 12, and 10 feet.

Tables A3 and A4 display the percentage of patients with a PDD > 2.5 among the different subgroups of exotropia and esotropia patients. In Table A3, we describe a category of "non-CI XT" which includes two patients on whom definitive patch testing was not performed.

Figures A1 and A2 graphically plot the prism diopter measurements obtained at various lengths compared to the measurement taken at 18 feet.

Discussion

The previously mentioned studies on this topic defined a significant difference in strabismus to be equal to or greater than 5 PD. Kushner and Morton compared measurements at the standard 20 feet to those taken at a reduced 10 foot examination distance and a 20 foot mirrored system. In their study, the subgroups of DE XT and high AC/A ET demonstrated a significant change in the alignment measured at 10-foot distance and 20-foot mirrored system compared to the 20-foot distance. CI XTs in contrast demonstrated an insignificant change in alignment. Furthermore, they reported that within the subgroups of DE XT and high AC/A ET, a higher percentage of patients had altered measurements at the 10-foot distance compared to the 20-foot mirrored system.

Stager and Everett followed this study by comparing measurements at 20 feet to a 20-foot mirrored system. They used a larger mirror than the one used in Kushner's study (42 inches vs 30 inches). The series consisted of either high AC/A esotropes or divergence excess exotropes. In contrast to the previous study, no patients with either strabismus types had a significantly different (≥5 PD) angle of measured strabismus. However, it is possible that they may have found a clinically significant difference had they used a change of ≥2.5 PD as their cutoff, as we did in our study.

Our study differs from previous studies by reporting the number of subjects with a PDD > 2.5. Commonly used strabismus tables display treatment doses in 5 PD increments, but it is important to consider the potential change in surgical plan when rounding up or down measured values in shorter exam lanes. For example, consider the surgical plan for a patient with 30 PD of misalignment in a 20-foot lane and 26 PD in a shorter lane. Most surgeons would round 26 PD down and dose surgery based on 25 PD. In this scenario, a PD difference of 4 would be clinically meaningful. For this reason, we recommend consideration of PD difference of >2.5 to be clinically significant.

Comparing our study results to the previously published studies is further limited by the differences in fixation target size, standard lane measurement length, study protocol, sample size, and strabismus types sampled. Both our study and Kushner's study measured strabismus in a non-mirrored 10 feet lane. Our study found 47.1% of esotropes to have a significant PDD at 10 feet. This was similar to the 56% found in Kushner's study. Amongst exotropes, we found 27.3% to have a significantly different measurement at 10 feet. This was much lower than the 64% reported by Kushner. As we considered an explanation for this discrepancy, we reflected on the unusually high ratio of convergence insufficiency exotropes in our data set compared to the generally more common divergence excess type. However, the percent differences in PDD at 10 feet between the CI group and the non-CI XT group were

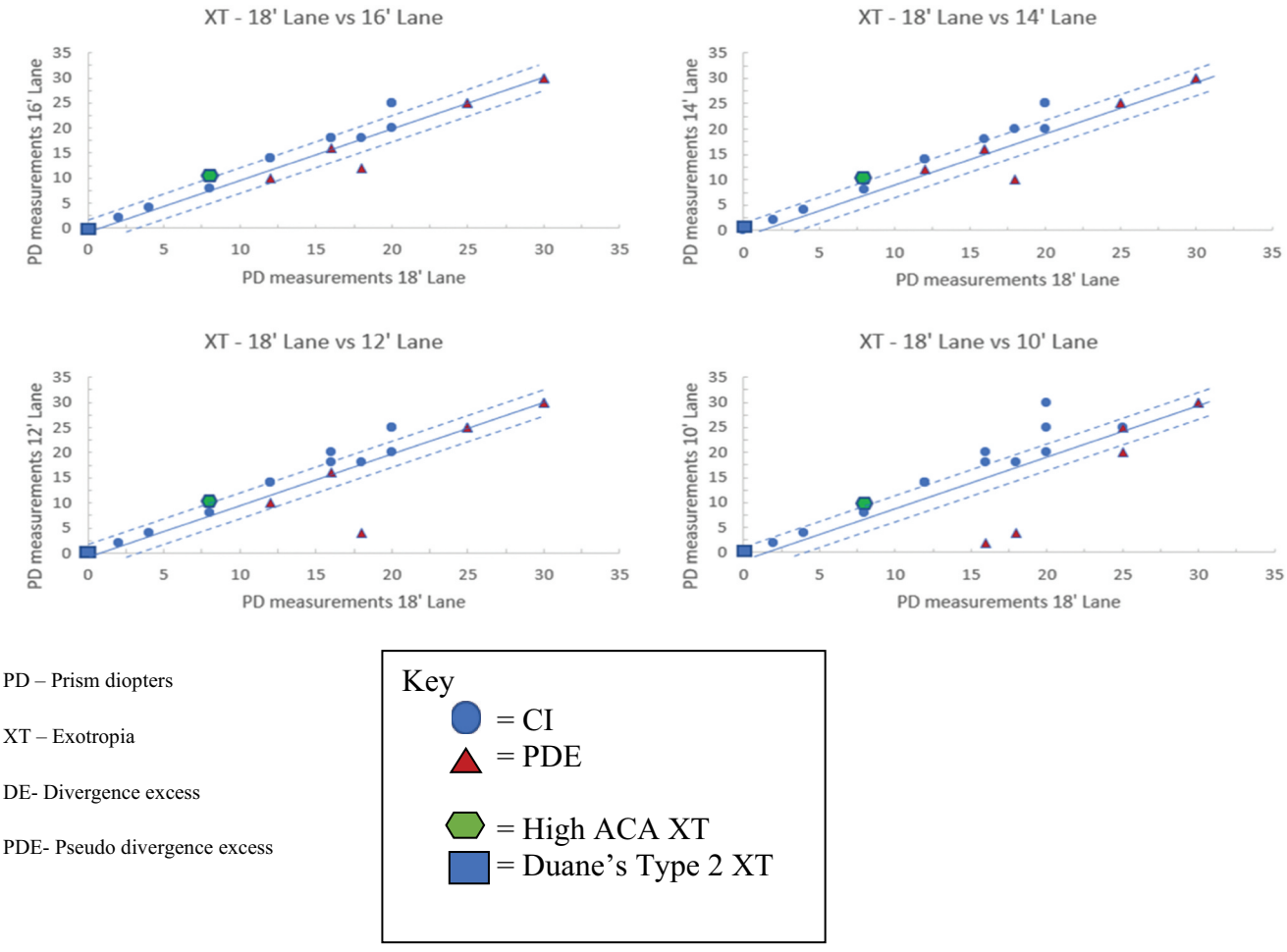


Figure A1. Graphs of alternate prism cover measurements of various lane lengths relative to an 18-foot lane in patients with an exodeviation.

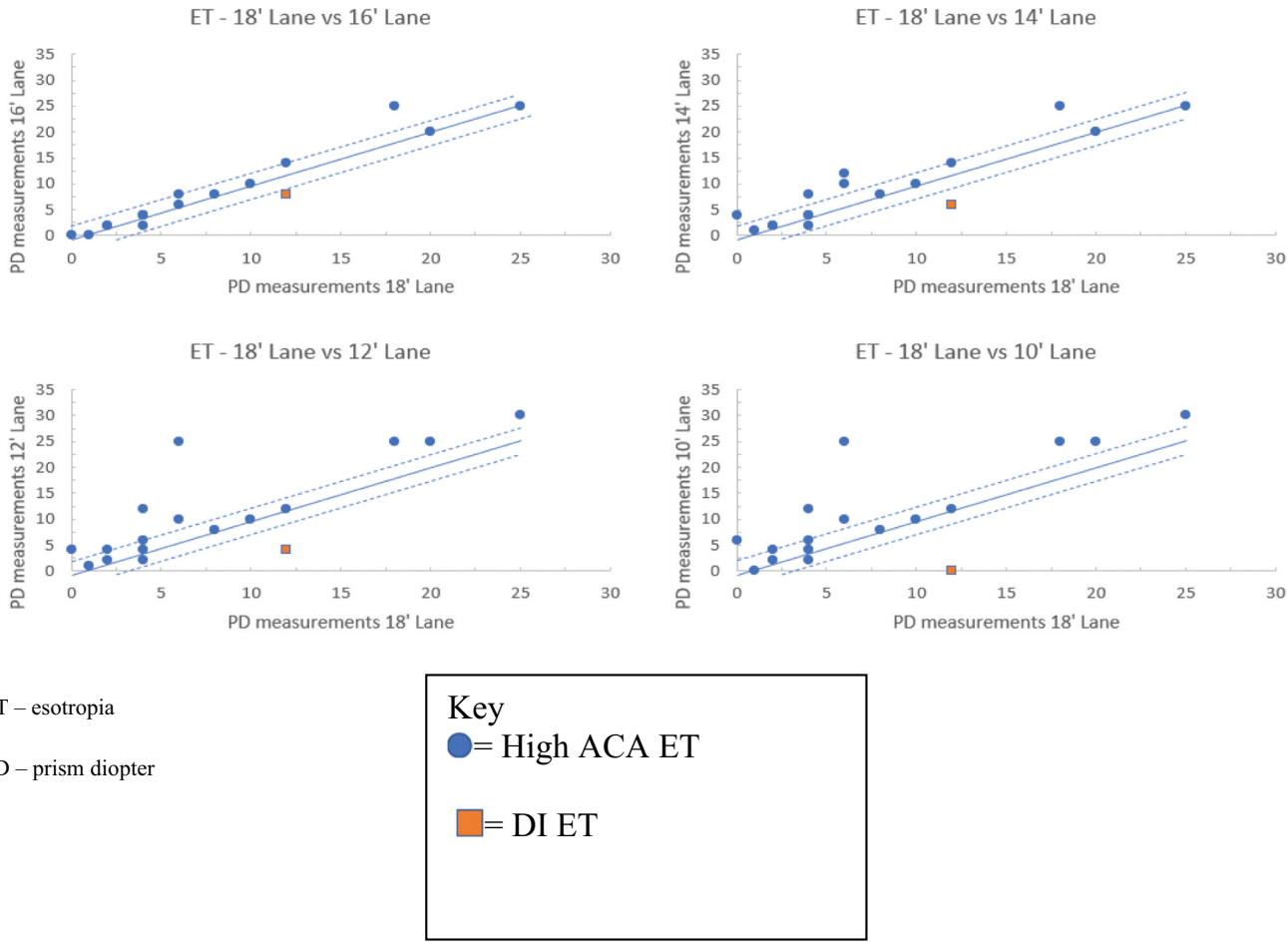
comparable (Table A3). Thirty percent of the CI XT subgroup was found to have a significantly different measurement at 10 feet versus 33.3% in the non-CI-XT group. Therefore, our higher proportion of CI XT would not be expected to skew our results.

Our data set did not include a patient with confirmed true divergence excess exotropia. Although this is an uncommon subgroup of intermittent exotropia, this is a significant limitation of our study.[7] We would expect that this subgroup would be more affected by the change in room length, though this remains unconfirmed. Kushner's study did not utilize patch testing to differentiate among patients in the "divergence excess" subgroup.

We recognize that in our study that we did not appropriately adjust the size of the fixation optotype for the closer examination distances in order to control for accommodation and accommodative convergence, as was done in the preceding studies. Though we regret this omission, we theorize that the reduction of the optotype size at each intermediate distance would further stimulate accommodative convergence and exacerbate the changes that we report at each intermediate distance.

We also acknowledge that our standard distance measurement was 18 feet from patient to fixation target. This is shorter than the standard of 20 feet from patient to fixation target in previous studies and could explain the lower percentage of subjects with a meaningful difference. Patient fatigue could also contribute to any differences found between the studies as more measurements were taken in our study, which could lead to changes in the measured angle of strabismus. Finally, our sample size was smaller than the Kushner study, which may explain the difference in results. Our ability to enroll patients was hampered by reduced clinic volumes during the COVID-19 pandemic during the last 3 months of the enrollment period.

Our study had several additional limitations that we identified during our analysis, and these points may be considered during the design of a larger scale study.



ET – esotropia

PD – prism diopter

Figure A2. Graphs of alternate prism cover measurements of various lane lengths relative to an 18-foot lane in patients with an esodeviation.

First, the changes in the angle of viewing between different distances is a potential confounder that may affect the measured angle of strabismus if a patient had a previously unrecognized pattern strabismus. In other words, if the fixation target is somewhat above the eye level of the subject, as the subject moves closer to the target, the number of degrees they would have to look up would progressively increase. Assuming the largest difference in the viewing angle would be with the smallest child, we calculated this value for our youngest participant in the study at 18 and 10 feet. We used the average sitting height of the youngest child when sitting in the exam chair at 18 feet versus the sitting height in a movable chair at 10 feet and the height of the fixation target to calculate the change in the angle of viewing.[8] We found that the angle of viewing at 18 feet was 2.7 degrees and at 10 feet was 6.7 degrees. Considering the small difference in the angle of viewing and the absence of any known A/V pattern strabismus in any of our subjects, we do not feel that this influenced our results. Future studies should attempt to minimize a change in the viewing angle when measuring at different distances. Second, future studies may consider utilizing two or more examiners for each patient. This may improve the reliability of the measurements and reduce bias, though it may also contribute to additional patient fatigue. Fifth, our study did differentiate between pseudo-divergence excess XT from true divergence excess XT utilizing the 30-min patch test. However, two subjects included in our data did not undergo patch testing. Future studies should include patch testing for all exotropic patients with a larger strabismic angle at a distance as this is considered standard of care for strabismus management.

Lastly there were minor inconsistencies in the management of refractive error involving five subjects, as detailed in the methods section. However, when the measurements of these subjects were compared to their respective subgroups, they followed the pattern of the majority of patients. Therefore, we do not believe these inconsistencies had a significant influence on our results.

When a new clinic is being designed, optimizing strabismus examination lane length could have far-reaching implications with regard to clinical productivity and patient access to care. Our data shows that among exotropes 13.6% of patients would have their treatment altered if measured at shorter distances of 16 and 14 feet, 18.2% at 12 feet, and 27.3% at 10 feet. Among esotropes, 11.8% of patients would have their treatment altered if measured at 16 feet, 35.4% at 14 feet, and 47.1% at 12 and 10 feet.

It is our hope that the data and design used in this study can be utilized by interested investigators to conduct a study with a larger sample size to further elucidate the effect of shorter examination lengths on the various types of strabismus. Perhaps, the greatest benefit of our research into shorter examination distances is for the clinican to be aware that their use will result in an unacceptable amount of error. We suggest that the clinician make every effort to have access to a standard length room for making any pre-surgical measurements. If that is not possible, they should consider setting up a chair and fixation target in a hallway that can allow for a 20 foot measurement.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendices

Table A1. Demographics of participants with strabismus.

	Esotropes n	SD	%	Exotropes n	SD	%
Sex						
Female	10		58.8	12		54.6
Male	7		41.2	10		45.5
Average age	15.95	9.9		12.45	.71	
Age range	3–43			6–77		
History of muscle surgery	4		23.5	7		31.8
Average magnitude of strabismus at 18 feet	8.1 PD	7.2		16.7 PD	8.9	
Average absolute magnitude of strabismus at near and 18 feet	20.9 PD	7.5		23.8 PD	7.7	
Measured degree of strabismus range	0–30			0–30		
Strabismus Type						
Esotropia						
High ACA E(T)	16		94.1			
Divergence insufficiency E(T)	1		6.0			
Exotropia						
Convergence Insufficiency X(T)				10		45.5
Pseudo-divergence Excess				7		31.8
Other*				5		22.7

*-2–unspecified divergence excess (patch testing not performed), 1 – Duane Syndrome type 2, 1 - consecutive XT w/high ACA, 1 - high ACA.

Table A2. Comparison of strabismus measurements to the standard lane length.

Lane Lengths	Exotropes mean PDD (range)	SD	% of XT patients with PDD >2.5	Number of XT patients with PDD >2.5	Esotropes mean PDD (range)	SD	% of ET patients with PDD >2.5	Number of ET patients with PDD >2.5
18 feet vs 16 feet	1.3 (0–6)	1.9	13.6%	2 CI and 1 PDE	1.1 (0–7)	1.9	11.8%	1 high ACA and 1 DI
18 feet vs 14 feet	1.3 (0–8)	2.2	13.6%	2 CI and 1 PDE	2.1 (0–7)	2.6	35.3%	5 high ACA and 1 DI
18 feet vs 12 feet	1.7 (0–14)	3.2	18.2%	3 CI and 1 PDE	3.9 (0–19)	4.9	47.1%	7 high ACA and 1 DI
18 feet vs 10 feet	2.8 (0–14)	4.4	27.3%	2 CI and 3 PDE	4.3 (0–19)	5.1	47.1%	7 high ACA and 1 DI

Exotropes, $n = 22$.
Esotropes, $n = 17$.
PDD = Prism diopter difference.
CI = Convergence insufficiency, PDE = Pseudo-divergence excess.
AC/A = Accommodative convergence/Accommodation, DI = Divergence insufficency.

Table A3. Exotropia subgroups with a prism diopter difference of >2.5.

Lane Lengths	Non-CI-XT ($n = 9$)	PDE ($n = 7$)	CI ($n = 10$)
18 feet vs 16 feet	11.1% (1 PDE)	14.3%	20%
18 feet vs 14 feet	11.1% (1 PDE)	14.3%	20%
18 feet vs 12 feet	11.1% (1 PDE)	14.3%	30%
18 feet vs 10 feet	33.3% (3 PDE)	42.9%	30%

CI = Convergence insufficiency, PDE = Pseudo-divergence excess.
Non-CI_XT – 7 patients with confirmed PDE, and 2 patients where patch testing was not performed.

Table A4. Esotropia subgroups with a prism diopter difference of >2.5.

Lane Lengths	DI ($n = 1$)	High AC/A ($n = 16$)
18 feet vs 16 feet	**100%**	**6.3%**
18 feet vs 14 feet	**100%**	**37.5%**
18 feet vs 12 feet	**100%**	**43.8%**
18 feet vs 10 feet	**100%**	**43.8%**

DI = Divergence insufficiency, AC/A = Accommodative convergence/Accommodation.