AN AGE-BASED METHOD FOR PLANNING SCLEROTOMY PLACEMENT DURING PEDIATRIC VITRECTOMY: A 12-YEAR EXPERIENCE

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ABSTRACT

Purpose: Pars plana vitrectomy (PPV) in children requires that sclerotomy placement be adjusted for changing dimensions of the ciliary body during ocular development. Experience with an aged-based method for sclerotomy placement is described.

Methods: Using data from previously reported morphometric studies on ciliary body length by age, an age-based method was used for planning sclerotomy location in children between 1 month and 18 years of age. Sclerotomies were placed 1.5 mm posterior to the limbus in those aged 1 to 6 months, 2.0 mm in those 6 months to 1 year, 2.5 mm in those 1 to 2 years, 3.0 mm in those 2 to 6 years, and 3.5 mm in those 6 to 18 years.

Results: Between 1993 and mid-2005, 82 pediatric PPV procedureswere performed using this scheme. None of the 82 procedures were complicated by inadvertent lens trauma or retinal perforation during sclerotomy placement.

Conclusion: The age-based method for sclerotomy placement may provide a useful guideline for vitrectomy in children with normal ocular growth and development.

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INTRODUCTION

An understanding of ocular growth and development is an important consideration in pediatric vitreoretinal surgery. At pars plana vitrectomy (PPV), changes in ciliary body dimensions with age may affect how sclerotomies are placed so as to avoid iatrogenic damage to the crystalline lens and peripheral retina. These changes are especially dramatic in early childhood. Although developmental descriptions of various ocular features have been published, a graduated, age-based scheme for safe sclerotomy placement is not uniformly applied. We describe a method for planning sclerotomy placement in pediatric patients that has been successful in avoiding intraoperative, sclerotomy-induced injury to the lens and retina.

METHODS

Morphometric data of ciliary body length in cadaver eyes from various pediatric age-groups has been previously reported by Aiello and associates.[1] These data were used to plan anterior-posterior sclerotomy placement to minimize lens or retinal injury in PPV, using the surgical limbus as a reference point. To determine approximate external limbus-to-ora serrata distance, 0.35 mm was added to the minimum ciliary body length for each age-group (Figure 1 and Table 1).

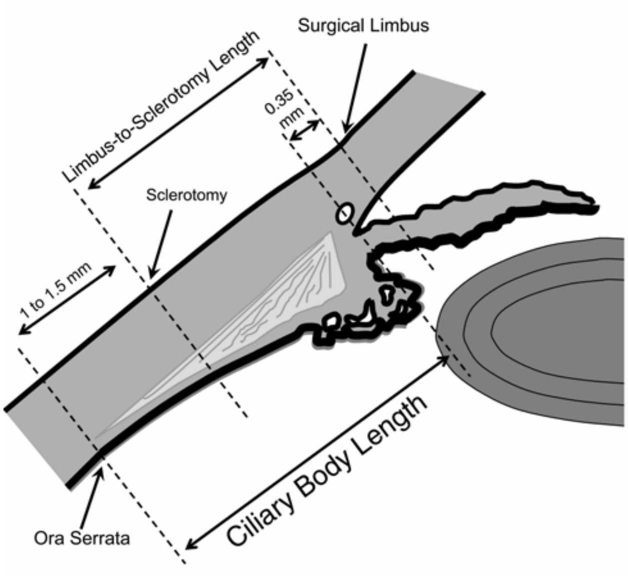

FIGURE 1

Diagram of ciliary body and surrounding structures indicating relationships used to determine safe external (surgical) limbus-to-sclerotomy distance from internal ciliary body length.

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Bold type indicates AOS member.

TABLE 1. DATA USED TO PLAN SCLEROTOMY LOCATION

AGE	MINIMUM CILIARY BODY LENGTH (AIELLO ET AL[1])	MINIMUM LIMBUS-TO-ORA SERRATA DISTANCE	LIMBUS-TO-SCLEROTOMY DISTANCE	
			CALCULATED	APPLIED*
0-6 mo	2.60 mm	2.95 mm	1.45 mm	1.5 mm†
6-12 mo	2.86 mm	3.21 mm	1.71 mm	2.0 mm
1-2 yr	3.28 mm	3.63 mm	2.13 mm	2.5 mm
2-3 yr	3.75 mm	4.10 mm	2.60 mm	3.0 mm‡
Adult	4.60 mm	4.95 mm	3.45 mm	3.5 mm§

*Rounded up to 0.5-mm increment to obtain 1.0 to 1.5-mm clearance from the ora serrata.
†Applied to children aged 1 to 6 months.
|‡Applied to children aged 2 to 6 years.
§Applied to children aged 6 to 18 years.

This amount (0.35 mm) was based on an estimated distance between the anterior aspect of the ciliary body and the external surgical limbus by Aiello and associates.[1] Limbus-to-sclerotomy distance was then calculated to provide approximately 1.0 to 1.5-mm clearance from the ora serrata, assuming the shortest estimate of ciliary body length for each age-group. This estimate was the smallest figure (in millimeters) in the range of measurements observed by Aiello and associates[1]for the nasal ciliary body.

Institutional review board approval was obtained for retrospective review of surgical records at the Medical College of Wisconsin, Milwaukee. Three-port PPV was performed over a 12-year period in children with presumed normal growth and development, from age 1 month to 18 years, by a single surgeon (D.P.H.). Anterior-posterior location of the sclerotomies from the corneal limbus was applied as listed in the right-most column of Table 1. During sclerotomy construction, the microvitrector blade was directed toward the geometric center of the eye. Two ports were placed superior to the horizontal meridians to accommodate microvitrector and endoilluminator, and a third port was placed inferotemporally for an infusion cannula. Surgical techniques in addition to vitrectomy included scleral buckle placement, lensectomy, fluid-air exchange, and removal or placement of silicone oil, depending on clinical indications. During placement of the sclerotomies in all phakic eyes, immediate biomicroscopic inspection of the lenses was performed to assess for lens damage. In all eyes, inspection of the peripheral retina for retinal perforation by the sclerotomy incision was performed with binocular indirect ophthalmoscopy.

RESULTS

Between 1993 and mid-2005, 82 pediatric PPV procedures were performed. Preoperative diagnoses are listed in Table 2. Twelve children were 1 to 6 months of age, 5 were 6 months to 1 year, 2 were 1 to 2 years, 13 were 2 to 6 years, and 50 were 6 to 18 years. Figure 2 demonstrates the relationship between sclerotomy placement and ora serrata position based on data from Aiello and associates.[1] None of the 82 procedures were complicated by inadvertent lens trauma or retinal perforation due to the sclerotomy incision. Twenty-one of the 82 procedures involved pars plana lensectomy or were performed on patients known to be previously aphakic. In the phakic eyes undergoing lensectomy, no sclerotomy-related lens injury was noted during the process of incision.

TABLE 2. PREOPERATIVE DIAGNOSES FOR 82 CHILDREN UNDERGOING VITRECTOMY

PREOPERATIVE DIAGNOSIS	NO. OF PATIENTS*
Retinal detachment	21
Trauma	13
Retinopathy of prematurity	11
Vitreous hemorrhage	9
Cataract	7
Retained, dislocated, or subluxed lens	7
Macular fold, pucker, or epiretinal membrane	6
Giant retinal tear	5
Intraocular foreign body	2
Uveitis	2
Shaken baby syndrome	1
Other	8

*Total exceeds 82 owing to multiple diagnoses in some cases.

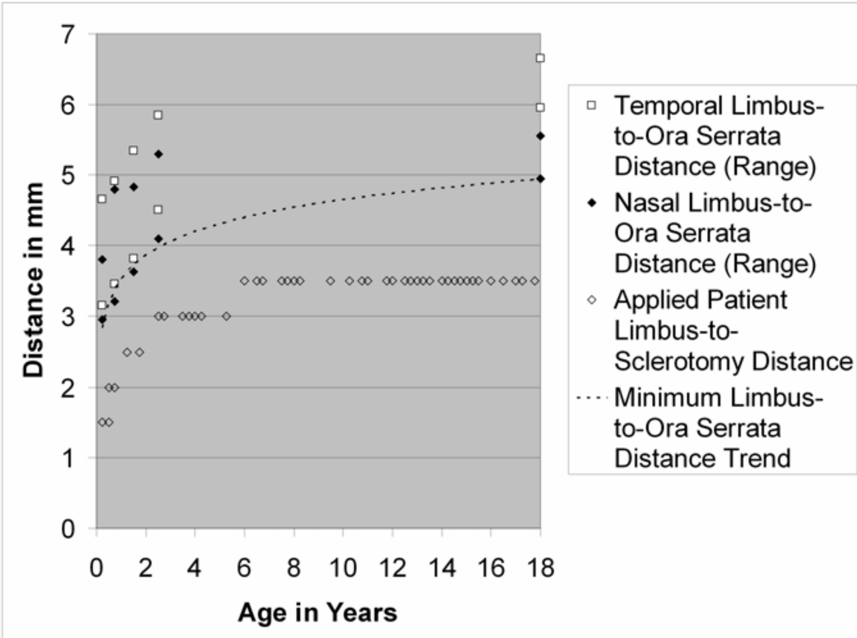

FIGURE 2

Comparison of limbus-to-ora serrata distances approximated from data by Aiello and asssociates[1] to limbus-to-sclerotomy distances used in present study. Values from Aiello and associates[1] (open squares and black diamonds) were empirically assigned to the midpoint of each age-group in their study. Adult values were assigned to age 18 years. The logarithmic trend line (dashed) best fits the minimum limbus-to-ora serrata distance values. For each patient in the present study, the limbus-to-sclerotomy distance applied was plotted against patient age (open diamonds), indicating estimated clearance from the ora serrata.

DISCUSSION

Dimensions of the eye change with postnatal development. The ciliary body, lens, and retina gradually attain adult size by the age of approximately 7 years.[2] A linear relationship exists between axial length and pars plana length during development.[3] At full-term birth, the ciliary body is about 2 mm in length in pathologic specimens.[3,4] Pars plana length at 38 to 42 weeks after conception ranged from 0.9 to 2.8 mm in one study.[3]

During vitrectomy, avoidance of injury to the retina or the crystalline lens is optimal. In the newborn, the small size and anterior placement of the pars plana, as well as the relative greater size of the crystalline lens, make surgical incision site planning different from that in the adult.

Perilimbal incisions can be used in newborn infants, with removal of the crystalline lens and entry to the vitreous cavity through the anterior chamber or iris root.[5,6] Lens-sparing vitrectomy in infants has also been described,[7] in which sclerotomies were made 0.5 mm posterior to the limbus and the microvitreoretinal blade was directed parallel to the visual axis, penetrating the vitreous cavity through the pars plicata. In older children, a pars plana approach is possible. Hairston and colleagues[3] studied morphometric data on ciliary body length and noted that pars plana length reaches 3 mm in a 6-month-old full-term infant. They felt that this pars plana length provided a safe margin for performing pars plana vitrectomy, although no guidelines were given for planning anterior-posterior sclerotomy placement.

In deriving a clinically applicable, age-based method for sclerotomy positioning, a number of assumptions were made:

1. Normal growth of the eyes undergoing vitrectomy was assumed.
2. A minimum of 1.0 to 1.5-mm clearance between sclerotomy and anterior retina was desired. This was specified a priori.
3. It was assumed that surgeons would prefer to apply a single dimension to both nasal and temporal sclerotomy sites for the sake of simplicity. Thus, the smallest of the nasal ciliary body measurements of Aiello and associates were used to calculate limbus to sclerotomy distance. This avoided the possibility of retinal perforation if an estimate derived from the larger temporal ciliary body were applied to placement of a nasal sclerotomy.
4. Precision to less than a 0.5-mm increment was considered impractical given the variable appearance of the surgical limbus and other operative factors. Thus, the calculated limbus-to-ora serrata figures (initially calculated for 1.5-mm clearance from the ora serrata) were rounded up to the nearest 0.5-mm increment to obtain the final applied figures (eg, 1.71 mm rounded to 2.00 mm).
5. Postmortem changes in ciliary body measurement applicable to previous morphologic data were assumed not to be clinically significant. (The current study suggests that this assumption was correct.)
6. A limbus-to-scleral spur distance of 0.35 mm was assumed for all age-groups.

Whether the above assumptions are valid or not, they must be considered when applying the age-based scheme to patients. The surgeon should also realize that the limits of variation of ciliary body anatomy are not known with certainty and that retinal perforation or lens damage may occur in spite of age-based adjustments to sclerotomy positioning.

The patients in the current study were all 1 month of age and older. In newborn infants less than 1 month of age, an entry site closer to the limbus (0.5 mm) may be more appropriate to avoid damage to the retina than the 1.5 mm used in our study for infants 1 to 6 months of age. This may be particularly true for premature infants, in whom gestational age may be less than 40 weeks at the time of surgery. These smallest patients were not represented in our study, since all of the children with retinopathy of prematurity were 3 months of age or older at the time of their first surgery. Nonetheless, others have described using an entry site of 1.0 to 1.5 mm posterior to the limbus in premature infants, in whom the threat to the lens may be a more significant issue than damage to the previously photocoagulated peripheral retina.[8]

Brown and associates[9] have previously reported a limited age-based approach to planning sclerotomy placement in children. Their report emphasized overall results of the vitrectomy technique in children rather than validation of sclerotomy location specifically. They placed sclerotomies 4.0 mm posterior to the limbus in phakic children aged 3 to 9 years and 4.5 mm posterior to the limbus in those older than 9 years of age. Sclerotomies were placed 0.5 mm closer to the limbus in aphakic children. (According to the data of Aiello and associates,[1] such placement might place the nasal retina at risk in the youngest of these children.) In children less than 3 years, they used transillumination to estimate the extent of the pars plana for sclerotomy placement. Although transillumination of the ciliary body can be a powerful technique, it is often difficult owing to individual variation in pediatric ciliary body pigmentation or coexisting ocular conditions. Thus, we found our age-based method for sclerotomy placement very useful, especially for children younger than 3 years of age, in whom ciliary body growth is most rapidly changing.

In summary, Aiello and associates[1] described the postnatal development of the ciliary body from pathologic specimens. Using these data, we developed a method for planning sclerotomy placement for various age categories (between 1 month and 18 years of age) to minimize iatrogenic injury to the retina and crystalline lens during pars plana vitrectomy. No iatrogenic retinal or lens injuries were identified in 82 cases over 12 years using this method. In our experience, this technique has been successful in minimizing both inadvertent lens and retinal trauma and may provide a guideline for future use.

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PEER DISCUSSION

DR J. TIMOTHY STOUT: This retrospective case series represents a nice practical translation of previously reported morphometric studies. The authors based their approach to pediatric pars plana vitrectomy on earlier studies of postmortem eyes from children ranging in age from 1 week to 6 years of age.[1] With this information the authors devised a graded approach to placement based on age and conclude that a safe limbus-to-sclerotomy distance is calculated as follows: 1.5 mm for 0 to 6 months, 2.0 mm for 6 to 12 months, 2.5 mm for 1 to 2 years 3.0 mm for 2 to 3 years, and 3.5 mm thereafter. Ultrasound or transillumination techniques were not employed to guide sclerotomy placement. They claim that with this method, no inadvertent lens trauma or retinal perforation occurred as a result of sclerotomy placement in 82 consecutive vitrectomy cases over a 12-year period. The reasoning behind this approach is sound and should be considered by all pediatric vitreoretinal surgeons.

With regard to the numbers of patients discussed, 2 points bear mentioning. First, it is perhaps a bit unfair to report that no inadvertent lens trauma was observed in 82 patients, as nearly one-quarter of these patients were either aphakic, pseudophakic, or were undergoing a planned lensectomy. Second, the data in this report is skewed toward older children, as 50 of the 82 were 6 years or older. The morphometric data upon which this algorithm were based described children up to 6 years of age; I have based my surgeries on the assumption (perhaps unfounded) that morphologically, the pars plana reaches its “adult” size by 6 years. This fact prompts me to want to focus on the 32 cases in this report that were under 6 years of age. Unfortunately, the way the data are presented, I cannot separate those 32 from the less informative 50.

It is also useful to more thoroughly consider the indication for surgery in these patients. In a review of my pediatric vitrectomies, the indication for surgery can be divided roughly into 5 general categories: (1) premature infants with retinopathy of prematurity (ROP); (2) trauma (ruptured globe, birth-associated hemorrhage, intraocular foreign body); (3) congenital malformations (persistent fetal vasculature [PFV], cataract, congenital folds); (4) infectious/inflammatory disease (endophthalmitis, various uveitic diseases); and (5) a highly variable group not described by the first 4 categories.

Sclerotomy placement should perhaps be different between these groups. The morphometric data used in this report were gathered from "normal" eyes, and the authors appropriately restrict their comments to those children with normal ocular growth and development. In children with PFV, it can be difficult to judge where to best place sclerotomies given the propensity toward microphthalmia and centrally displaced ciliary processes. The same is true for anterior segment dysgenic processes in which the determination of the surgical limbus may be problematic. In these situations transillumination, while often uninformative, should be considered. I will often place sclerotomies more anteriorly in cases in which I anticipate lens removal (cataract, some uveitis), despite an otherwise morphologically normal posterior segment.

The authors have excluded a very common group of pediatric vitreoretinal surgeries—the "micro-premature" infants with ROP. As the authors point out, a variety of reports have addressed sclerotomy placement in these infants. I believe that sclerotomy placement in these infants can be adjusted based on a desire to avoid lens injury in a situation where (1) the lens may occupy a larger fraction of the globe than in older children, (2) the anterior retina may have undergone extensive panretinal photocoagulation (and thus a protective retinopexy effect may be in effect), and (3) the size of the eye and operative field may restrict unfettered access to all operative quadrants.

The approach to sclerotomy placement in children with normal ocular growth and development described by Drs Lemley and Han is a very nice translation of anatomic data into a practical algorithm. I plan to tape their Table 1 to the wall of our OR.

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DR. JERRY SEBAG: I have no conflicts of interests. The tissue adjacent to the ciliary body, the vitreous space, enlarges posteriorly during aging. This is to say that the vitreous space becomes larger with age and studies have shown that this is greater nasally than temporally. Your data suggest that this space is larger temporally. Just on first glance your data also suggests that true, as well. If you consider the percentage difference, the enlargement nasally never attains the same absolute proportions as temporally, but the percentage growth nasally seemed to exceed that of the temporal space. I wonder you can confirm that or not.

DR. GEORGE L. SPAETH: No conflict. Another problematic situation is where to enter the eye with a needle for vitrectomy in a nanophthalmic eye. I recently had a patient with nanophthalmos who required pars plana vitrectomy. The retina surgeon entered over the usual location of the pars plana and the vitrectomy instrument perforated the retina and caused an expulsive hemorrhage. You can also extend your observations to nanophthalmos.

DR. M. EDWARD WILSON, JR.: I do not have any financial disclosures for this discussion. I agree with your algorithm and I believe that it matches pretty closely our practice in pediatric cataract surgery. There is a growing trend to perform an anterior vitrectomy and posterior capsulectomy through the pars plana approach after the IOL is in place, rather than using the anterior approach in these small eyes. In the protocol for the infant aphakia treatment study which is from 30 days of age to the end of six months, we recommended placing the entry site 1.5 mm to 2 mm posterior to the limbus. I have been making the entry site 2 mm posterior to the limbus in the first year of life, 2.5 mm posteriorly in patients from age 1 through age 4, and then 3 mm posteriorly for patients aged 4 and older. I believe that is fairly close to what you described and we have also found this approach very safe in pediatric cataract surgery.

DR. DENNIS P. HAN: First, I would like to address the comments of the discussant, Dr. Stout, about the lens issue. I acknowledge this paper provides stronger evidence to validate the avoidance of retinal perforation, rather than avoiding lens damage, based on the patients who were evaluated. Not all patients in this study were phakic or remained phakic at the end of surgery. In a series of this type it is difficult not to have such patients involved, and we believed that by excluding those patients we would lose the power to evaluate the issue of avoiding perforation of the peripheral retina. I also acknowledge that there were fewer eyes in the younger age groups than the older age group and this probably relates to the nature of my surgical practice. We had no specific rationale for separating younger from older patients in presenting this data. We believed that the existing surgical approaches used, even in the age group 6 years and older had not been vigorously validated previously. We believed that including all patients as a single group for analysis was appropriate.

I would like to add some perspective by saying we also agree with Dr. Stout's approach based on extrapolation of the curves. We believe that children six years of age and older have nearly adult ocular dimensions and, for that reason, we applied the equivalent of an adult limbus-to-sclerotomy entry site length of 3.5 mm. We believed that this was worth validating in this study. I would also like to add some perspective and state that we do not know the full range of anatomic variation in the dimensions of the ciliary body or the pars plana. Our current understanding is really based on the study of Aiello that involved about 76 eyes. To date, no published approach can absolutely guarantee that lens injury or retinal perforation can be avoided with 100% certainty. The data that we present today may be used as a guideline for surgeons in planning their approach. They should consider a variety of clinical parameters, including the underlying disease state, and consider employing other techniques, such as transillumination or indirect ophthalmoscopy, to confirm the location of the pars plana.

Regarding the comment of Dr. Sebag about the development of the vitreous base relative to that of the ciliary body, I cannot make any comments based on our data. Visualization of the vitreous base during surgery is not easily accomplished. I can state that the temporal ciliary body grows to a larger size than the nasal ciliary body, based on the data of Aiello. With respect to the kinetics of nasal versus temporal ciliary body growth rates relative to those of the vitreous body and the vitreous base, I cannot make any comments. I am not familiar with any literature that evaluates these relationships.

Regarding Dr. Spaeth's comments on the nanophthalmic eye, none of the eyes our series were nanophthalmic. I do not recall performing any operative procedure, including vitrectomy, on a pediatric nanophthalmic eye, therefore I really cannot extrapolate any of this data to those eyes. We plotted the curves of the ciliary body growth as measured by Aiello against published axial eye length changes with age and they paralleled each other quite markedly, even though the globe is not perfectly spherical. Perhaps one could use that data to identify an appropriate sclerotomy site for a nanophthalmic eye, but the validity of this approach would be fairly speculative. I am unaware of published literature that directly evaluates ciliary body growth as a function of axial eye length growth.