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REFRACTIVE CATARACT

Toric IOL Calculations: Consider the Posterior Cornea

BY LINDA ROACH, CONTRIBUTING WRITER

INTERVIEWING AMAR AGARWAL, MD, DOUGLAS D. KOCH, MD, AND WILLIAM B. TRATTLER, MD

Evaluating a cataract patient's astigmatic error isn't just about the shape of the front of the eye anymore. Failure to include posterior corneal curvature in the presurgical calculations can bring unwanted refractive surprises for both doctor and patient. "Anybody who's doing relaxing incisions or toric IOLs needs to know about this, period," said Douglas D. Koch, MD, at Baylor College of Medicine in Houston.

Old assumptions. "Cataract surgeons base their astigmatic analysis on the cornea alone, recognizing that the lens will be removed. And, heretofore, everybody—myself included—sort of assumed that when there was some preoperative disparity between the refraction and the anterior corneal curvature, this disparity was due to lenticular astigmatism," Dr. Koch said.

New thinking. "But the literature has shown, and I've learned at first clinically and also through studies,^{1,2} that there's a fair amount of astigmatism on the posterior surface of the cornea," Dr. Koch said. "This has an impact in patients undergoing cataract surgery when astigmatic correction is involved." He said that the magnitude of posterior astigmatism increases with higher amounts of anterior with-the-rule (WTR) astigmatism, but when the amount of anterior against-the-rule (ATR) astigmatism increases, the posterior astigmatism stays relatively constant.

"If you want to fine-tune your re-

WTR and ATR Astigmatism

Alcon SNA6Tx	WTR (D)	ATR (D)
0	≤ 1.69 (PCRI if > 1.00)	≤ 0.39
T3 (1.03)	1.70 — 2.19	0.40* — 0.79
T4 (1.55)	2.20 — 2.69	0.80 — 1.29
T5 (2.06)	2.70 — 3.19	1.30 — 1.79
T6 (2.57)	3.20 — 3.79	1.80 — 2.29
T7 (3.08)	3.80 — 4.39	2.30 — 2.79
T8 (3.60)	4.40 — 4.99	2.80 — 3.29
T9 (4.11)	5.00 —	3.30 — 3.79

0.7 D

0.7 D

*Especially if specs have more ATR.

For WTR astigmatism, the nomogram shifts the threshold for selecting a toric IOL up 0.7 D. A toric IOL is not used until the anterior cornea has 1.7 D of WTR astigmatism. For ATR astigmatism, the nomogram shifts the threshold for selecting a toric IOL down 0.7 D. Thus, in an eye with 0.8 D of ATR astigmatism (after factoring in SIA), a toric IOL 1.5 D of toricity is used.

fractive results, what you have to do is analyze the eye properly, and you must include the posterior cornea," said Amar Agarwal, MD, an anterior segment and refractive surgeon in Chennai, India.

The Research Picture

Most devices to assess corneal curvature, such as keratometers and corneal topographers, measure the anterior surface curvature to calculate the cornea's total refractive power and its total astigmatism. In these calculations, the posterior corneal curvature and

the anterior curvature are assumed to have a constant ratio.¹ Dr. Koch and colleagues at Baylor set out to test that long-standing assumption.

Differences of curvature. When they measured 715 eyes, they found that posterior curvature varied widely. The mean value was -0.30 D, but there was wide individual variability.² This variability might explain why toric IOLs and relaxing incisions sometimes leave residual astigmatism, they concluded.

"Ignoring posterior corneal astigmatism may yield incorrect estimation of total corneal astigmatism,"

the researchers wrote. “Selecting toric intraocular lenses based on anterior corneal measurements could lead to overcorrection in eyes that have with-the-rule astigmatism and undercorrection in eyes that have against-the-rule astigmatism.”

A source of ATR corneal toricity.

Dr. Koch explained that the posterior cornea tends to be steep in everyone. “And if it’s steep vertically, then because the posterior cornea is a minus lens, it actually creates net power along the horizontal meridian—a low-powered lens in the back of the cornea that is creating plus power along the horizontal meridian. In other words, it creates against-the-rule refractive astigmatism,” he said.

“So if a patient is steep vertically on the front—that is, with-the-rule astigmatism on the anterior, then total corneal astigmatism actually ends up being less. And, conversely, if a patient has against-the-rule on the anterior surface—that is, they’re steep horizontally on the front—the total corneal astigmatism actually ends up being more,” he said.

Follow-up: Detection techniques unreliable. Late last year, the Baylor group published details of a follow-up study, which examined 41 eyes implanted with toric lenses. The researchers tested the eyes with five ocular assessment devices and compared the results. They found that four of the devices—including a manual keratometer and the widely used IOLMaster partial coherence interferometer—overestimated total corneal astigmatism in eyes that had WTR toric error by 0.5 to 0.6 D. The devices underestimated corneal astigmatism in ATR eyes by 0.2 to 0.3 D.¹

They reported that the Galilei Placido–dual Scheimpflug analyzer (Ziemer Ophthalmic Systems)—the only device that measured the posterior cornea, rather than inferring its curvature from other measurements—had a lower predictive error in most eyes. However, in eyes that had preop WTR corneal astigmatism, Galilei had a significant prediction error of 0.57 D, the researchers found.

Proposed: The Baylor Nomogram

Because no single high-tech device has yet solved the riddle of accurately measuring posterior corneal curvature, Dr. Koch said his research group developed the Baylor Nomogram to help surgeons improve their refractive outcomes with toric IOLs. It is based on population averages for posterior corneal astigmatism, and it requires the user to integrate data from multiple ocular tests in just the right way, he noted. (See the nomogram at www.eyenet.org.) “It’s sort of complicated for the anterior segment surgeon to put it all together. But there really isn’t any one tool or approach out there that takes all the variables into account in this way,” he said.

The method, step-by-step. The surgeon first factors in a correction for surgically induced astigmatism (SIA) and accounts for the IOL’s spherical power and location in the eye (which determine the effective toric power at the corneal plane); the nomogram then makes an adjustment for posterior corneal curvature by adding or subtracting from that IOL power. “You have to factor in more than just what the anterior cornea tells you. You have all these other things that fit into the calculation,” Dr. Koch said.

The recommended steps in the nomogram are as follows:

- **Determine effective toric power.** As you normally would, measure the anterior corneal curvature and other refractive and intraocular parameters for calculating IOL power. (For best results, however, Dr. Koch recommends the Holladay II Consultant Program because it automatically calculates the effective toric power at the corneal plane, including the impact from the IOL’s spherical correction and anterior chamber depth. Online calculators will soon be doing this, he said.)

If you do not have the Holladay II, you can make one of two estimates: 1) for IOLs with low power and eyes with a deep anterior chamber, edge toward using an IOL with 0.5 D more toricity, and 2) for IOLs with high power and eyes with a shallow anterior chamber, edge toward using an IOL

with 0.5 D less toricity.

- **Determine your personalized SIA.** The nomogram calls for surgeons to factor in their average SIA, which for most surgeons is 0.2 to 0.3 D. An online calculator can help determine your personalized SIA value if you do not already have one.
 - **Use a calculator that allows you to factor in your SIA.** This is straightforward, as most online calculators do this.
 - **Apply the Baylor Nomogram.** In addition to the WTR/ATR adjustments noted below, the nomogram aims to leave patients with slight WTR astigmatism to account for the ATR shift that occurs over time with aging.
 - **In eyes with WTR astigmatism.** The nomogram shifts the threshold for selecting a toric IOL up 0.7 D, so that a toric IOL is not used until the anterior cornea has 1.7 D of WTR astigmatism.
 - **In eyes with ATR astigmatism.** It shifts the threshold for selecting a toric IOL down 0.7 D, so that in an eye with 0.8 D of ATR astigmatism (after factoring in SIA), a toric IOL 1.5 D of toricity is used.
 - **In eyes with oblique astigmatism.** Most—but certainly not all—of these eyes are in the process of shifting from WTR to ATR. Target on or slightly below the measured astigmatism, and, when inserting the toric IOL, be sure not to err in orienting on the WTR side of the steep meridian (since the cornea is likely to drift ATR).
- How well does the nomogram work?** The general nature of the data underlying the Baylor Nomogram is one of its chief weaknesses as a clinical tool, Dr. Koch said. “It unfortunately is based on population averages of posterior astigmatism, not individual patients,” he said. “So the holy grail would be a device that really accurately measures the posterior corneal astigmatism for each patient.” The leading candidates are Scheimpflug imaging technology, a new reflective color LED technology, and optical coherence tomography, but these are still under development and investigation for measuring posterior corneal astigmatism, he said. “Hopefully, the nomogram has

Why Not an Online Calculator?

In contrast to the complexity of the Baylor Nomogram, online calculators for planning and evaluating toric corrections may be easier to use, but they have not been researched as extensively as the Baylor approach.

Two astigmatism calculators, available free of charge, are at the websites of the Asia-Pacific Association of Cataract & Refractive Surgeons (www.apacrs.org) and the American Society for Cataract and Refractive Surgery (www.ascrs.org/online-tools). The latter's astigmatism calculator has been undergoing a revision in recent months, and its web page was under construction at time of press.

planned obsolescence as the devices get better at actually measuring posterior corneal astigmatism on an individual basis, so that we can truly customize the planning for each patient."

Another option. The Barrett Toric Calculator (www.ascrs.org/barrett-toric-calculator) is a one-step formula that shows great promise for calculating IOL toricity and recommended alignment. Preliminary data look excellent, Dr. Koch said.

Weighing the Factors

Miami cornea and refractive surgeon William B. Trattler, MD, said he accepts the studies, and he does consider posterior curvature when evaluating patients for surgery. But he isn't sure how much clinical weight to give the back of the cornea at the moment. "The problem is [that] you can't really measure how much posterior corneal astigmatism a specific patient has, and it can be variable," Dr. Trattler said. "You have to assume everybody has it, but for now we can't effectively measure it." Small amounts of residual astigmatism appear to have minimal impact, if any, on the patient's vision after toric IOL implantation, he added.

Although Dr. Trattler said he, too, looks forward to the availability of better testing devices, he is not greatly concerned about the status quo. "If the postop corneal astigmatism is under 0.4 or 0.5 D, patients are typically very happy with all types of lenses, including toric and presbyopic IOLs. And with the help of the Baylor Nomogram, we have a better understanding of the expected impact of the posterior corneal astigmatism on our final postoperative result, which allows us to end

up closer to our postop target as compared with the past," Dr. Trattler said.

Furthermore, he noted that the surgeon can resolve his or her doubts about the toric accuracy of the chosen IOL by performing an aphakic refraction on the operating table. "Surgeons using an intraoperative aberrometer are able to measure the corneal power, including the front and back surface, prior to lens insertion to best determine the optimal amount of astigmatism that should be corrected," he said.

Impact: Now and in the Future

So far, these findings about posterior corneal astigmatism are an issue primarily for anterior segment surgeons whose patients want a surgical fix for their astigmatism. Only about 15 percent of U.S. ophthalmologists (25 percent of internationals) who were surveyed about astigmatism in 2013 said they were implanting toric IOLs, according to John A. Vukich, MD, at a meeting earlier this year.³

Might the new knowledge about posterior corneal astigmatism eventually affect the clinical and surgical routines of the average cataract surgeon? "Yes, 100 percent," Dr. Agarwal said. Like other innovations that began in refractive surgery, analysis of the posterior curvature and its impact on visual acuity will spread into everyday ophthalmic practice, he predicted. He advises comprehensive ophthalmologists to take advantage of educational opportunities that will prepare them for that day.

"Suppose your patient doesn't have any problem with the anterior cornea. That doesn't mean the same is true of the posterior cornea. They are two

different structures," Dr. Agarwal said. "So you cannot examine just the anterior. And you can't make a blanket rule about how much posterior corneal astigmatism a patient will have. That cannot be based on guesswork."

He added that knowledge of posterior curvature will gain importance as people who had corneal refractive surgery 20 or more years ago develop cataracts and require IOL implants. "If you don't have a machine that calculates properly the posterior corneal astigmatism, you will not be able to treat those post-refractive surgery corneas properly," he said. ■

1 Koch DD et al. *J Cataract Refract Surg*. 2013;39(12):1803-1809.

2 Koch DD et al. *J Cataract Refract Surg*. 2012;38(12):2080-2087.

3 Vukich JA. ASCRS Clinical Survey 2013 Results on Astigmatism. Presented at: annual symposium of the American Society for Cataract and Refractive Surgery; April 26, 2014; Boston.

Amar Agarwal, MD. Chairman and managing director, Dr. Agarwal's Group of Eye Hospitals, in Chennai, India. Past president of ISRS. Financial disclosure: Consults for AMO, Bausch + Lomb, and Staar Surgical.

Douglas D. Koch, MD. Professor of ophthalmology, and the Allen, Mosbacher, and Law Chair of Ophthalmology, Baylor College of Medicine, in Houston. Financial disclosure: Consults for AMO, Alcon, ReVision Optics, and Ziemer; receives research support from i-Optics, and Ziemer; and has an equity interest in OptiMedica.

William B. Trattler, MD. Director of Cornea, Center for Excellence in Eye Care, in Miami. Financial disclosure: Consults for Allergan, AMO, Bausch + Lomb, CXLUSA, and LensAR; is on the speaker's bureau for Allergan, AMO, and Oculus; serves as a practice consultant and receives travel reimbursement from AMO; receives research support from Bausch + Lomb; and has an equity interest in Bausch + Lomb and CXL Ophthalmics.



MORE ONLINE. For a slideshow outlining the Baylor Nomogram, see the Multimedia Extra at www.eyenet.org. Also see the Web Extra about the Baylor group's device research that accompanies this article online.