IOL FORMULAS FOR REFRACTIVE CATARACT SURGERY

No single formula has the best prediction error across the varying ranges of axial length.

BY ROBIN RAUL VANN, MD, AND ANTHONY KUO, MD

Over the past decade, great strides have been made to improve the efficiency, safety, and stability of outcomes after cataract surgery. With this progress, refractive cataract surgeons can reduce astigmatism and provide spectacle independence better than ever before. To provide these refractive outcomes, surgeons rely on accurate biometric measurements and modern IOL selection formulas. This article shares our strategy for selecting the lens’ power.

PREOPERATIVE DATA POINTS

The fundamental input values for IOL formulas are ocular biometry measurements. The biometric measurements required for third-generation formulas such as Holladay 1, SRK/T, and Hoffer Q are axial length (AL) and average keratometry reading. Newer-generation formulas require additional historical information and other measurements such as age, preoperative refraction, lens thickness, and anterior chamber depth. To ensure that accurate measurements have been obtained before surgery, we repeat multiple measurements of the eye to gather a valid sample of data. This step is the core of our strategy. Once we have captured multiple measurements, we apply screening validation criteria that have been developed for both ultrasound and optical biometry to detect potential errors in gross measurement. Table 1 summarizes these criteria. Measurements that fall outside these ranges need to be repeated by a different examiner or on a separate day to confirm validity.

It is also important to integrate data from the clinical examination and other diagnostics to ensure the validity of the biometry measurements. For example, keratometry is dependent on reflections from the tear film to produce accurate measurements. Disruptions to the tear film affect keratometry, so we keep in mind the effect that dry eye disease (particularly fast tear breakup time) or anterior basement membrane dystrophy may have on the corneal power measurement.

Topographies are frequently obtained in the context of toric IOL planning. We recommend reviewing the topography to ensure that there is no irregular astigmatism from sources such as anterior basement membrane dystrophy or ectasia. Doing so can help increase the surgeon’s confidence in using the keratometry measurements. When the
automated keratometry value has a large standard deviation, it is important to consider these clinical entities.

**ACCURACY**

Once we are comfortable with the measurements we have captured preoperatively, the accuracy of the numerous formulas available becomes a factor. Most current third-generation formulas (SRK/T, Holladay 1, Hoffer Q) accurately determine the effective lens positions (ELPs) required for a strong refractive outcome using AL and keratometry in normal (72% of eyes are 22-24.5 mm in length) and mildly myopic eyes (15% of all eyes are between 24.5 and 26 mm in length). When we try to apply the same ELP predictions to the 13% of eyes that fall outside this range, postoperative refraction predictions become less accurate. This limitation is evident in some large-scale studies that conclude third-generation formulas are able to achieve a mean ±0.50 D prediction accuracy between 70% and 80%. Modifications to the formulas or adopting newer-generation formulas that use additional measurement values will improve predictions.

**AL Adjustment Method for Myopes**

In cases of moderate to extreme axial myopia (> 26 mm; 7% of eyes), we have found that the accuracy of outcomes can be improved by modifying the AL value entered in third-generation formulas. Wang and colleagues stated that highly myopic eyes have much more vitreous liquefaction, which changes the refractive index compared to normal eyes. Unfortunately, current optical biometers use an average refractive index to measure the entire eye. Eyes longer than 26 mm may deviate from this “normal” average refractive index, and as a result, AL measurements in these long eyes can be inaccurate.

Wang et al developed a nomogram based on their data and those from an independent second center to adjust the AL measurements to account for the hyperopic drift in these extremely myopic eyes:

- Holladay 1 two-center optimized AL = 0.8814 × IOLMaster (Carl Zeiss Meditec) AL + 2.8701

### TABLE 1. VALIDATION CRITERIA FOR ULTRASOUND AND OPTICAL BIOMETRY

<table>
<thead>
<tr>
<th></th>
<th>Ultrasound Biometry&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Optical Biometry&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AL</strong></td>
<td>&lt; 22 or &gt; 25 mm</td>
<td>&lt; 21.3 or &gt; 26.60 mm</td>
</tr>
<tr>
<td><strong>Average corneal power</strong></td>
<td>&lt; 40.00 or &gt; 47.00 D</td>
<td>&lt; 41.00 D or &gt; 47.00 D</td>
</tr>
<tr>
<td><strong>Difference between eyes</strong></td>
<td>Average K reading &gt; 1.00 D</td>
<td>Average K reading &gt; 0.90 D</td>
</tr>
<tr>
<td></td>
<td>AL &gt; 0.3 mm</td>
<td>AL &gt; 0.70 mm</td>
</tr>
</tbody>
</table>

<sup>a</sup> Repeat the measurements by a different examiner or on a separate day to confirm their validity.

Abbreviations: K, keratometry; AL, axial length.

### TABLE 2. THE AUTHORS’ RECOMMENDATIONS FOR IOL SELECTION FORMULAS BASED ON AL

<table>
<thead>
<tr>
<th></th>
<th>Short AL (&lt; 22 mm)</th>
<th>Normal AL (22-25.99 mm)</th>
<th>Long AL (&gt; 26 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Third-generation formulas</strong></td>
<td>Hoffer Q</td>
<td>H1</td>
<td>Anticipated IOL &lt; 6.00 D, recommend AL adjustment</td>
</tr>
<tr>
<td><strong>Newer-generation formulas</strong></td>
<td>Haigis, H2, Olsen</td>
<td>Barrett II</td>
<td>H2, Barrett II</td>
</tr>
<tr>
<td><strong>Additional data points needed for newer-generation formulas</strong></td>
<td>Age, Rx, WTW, ACD, LT</td>
<td>WTW, ACD, LT</td>
<td>Age, Rx, WTW, ACD, LT</td>
</tr>
</tbody>
</table>

Abbreviations: AL, axial length; H1, Holladay 1; H2, Holladay 2; Rx, prescription; WTW, horizontal white to white; ACD, anterior chamber depth; LT, lens thickness.

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**AT A GLANCE**

- Take multiple measurements of all of the data used for the formulas for IOL power calculation.
- Apply a data screening verification method to eliminate outliers and refine measurements.
- Apply the appropriate formulas according to the axial length of the eye measured.
In their efforts to improve predictive accuracy, surgeons should continue to evaluate newer formulas and technologies as they become available. As newer formulas have been introduced, predictive accuracy has steadily increased (able to achieve a mean ±0.50 D accuracy: Holladay 1, 88.3%; Haigis, 88.7%; Holladay II, 89.2%; Olsen, 90.9%; Barrett II, 91.5% [W.E. Hill, personal communication, February 2016]). Early trials of a new formula, the radial basis function formula, have achieved a mean ±0.50 D accuracy of 95% for 3,212 cases across 13 surgeons in eight countries (W.E. Hill, personal communication, February 2016).

Other strategies include using intraoperative aberrometry to help improve on the preoperative planning formula outcomes. In addition, surgeons may look at newer IOLS to correct for errors in prediction. For example, the Light Adjustable Lens (Calhoun Vision; not FDA approved) may change the postoperative refraction of the patient from -2.00 to +2.30 D and correct up to 2.60 D of astigmatism after implanted in the eye.9

With multiple strategies to help ophthalmologists achieve their goals, the future is bright for improving outcomes after cataract surgery.


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