Economic Evaluation of Toric Intraocular Lens

A Short- and Long-term Decision Analytic Model

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Objective: To assess the economic value of improved uncorrected visual acuity among patients with cataract and preexisting astigmatism treated with toric intraocular lenses (IOLs) compared with conventional monofocal IOLs.

Methods: We developed a decision analytic model of hypothetical patients with preexisting astigmatism. We examined costs and outcomes among patients 65 years and older with cataract and preexisting astigmatism (1.5-3.0 diopters) who were receiving either toric or conventional IOLs with and without intraoperative refractive correction (IRC). Data were obtained from the literature and from a survey of 60 US ophthalmologists. Total medical costs of bilateral treatment were calculated for the first posttreatment year and remaining lifetime. Cost-effectiveness and cost-utility outcomes were computed. Future costs and utilities were discounted by 3%.

Results: A larger proportion of patients receiving toric IOLs achieved distance vision spectacle independence (67%) and uncorrected visual acuity of 20/25 or better OU (53%) compared with conventional IOLs with (63% and 48%, respectively) or without IRC (53% and 44%, respectively), resulting in fewer future vision corrections. Toric IOLs provided an additional 10.20 quality-adjusted life years (QALYs) compared with conventional IOLs with (10.14 QALYs) and without IRC (10.10 QALYs). Higher first-year costs of the toric IOL ($5739) compared with the conventional IOL with ($5635) or without ($4687) IRC were offset by lifetime cost savings of $34 per patient, $393 per patient achieving uncorrected visual acuity of 20/25 or better, and $349 per QALY compared with the conventional IOL without IRC.

Conclusions: Toric IOLs reduce lifetime economic costs by reducing the need for glasses or contact lenses following cataract removal. These results can inform physicians and patients regarding the value of toric IOLs in the treatment of cataract and preexisting astigmatism.

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Between 15% and 29% of patients with cataract have concomitant corneal or refractive astigmatism.\(^1\) Correction of preexisting astigmatism using corneal incisional surgery and/or by inserting toric intraocular lenses (IOLs) has become a common practice during cataract surgery.\(^2,3\) More recent generations of toric IOLs exhibit improved rotational stability compared with previous models.\(^3\) Cataract extraction and replacement with an artificial IOL is a costly procedure, however. Direct medical costs of cataract surgery were estimated at $2314 (in 2001 dollars) in the United States and €1265 (2002-2003 euros) in Finland.\(^4,5\)

New toric IOLs effectively improve visual acuity, with 91.3% to 93.3% of patients achieving uncorrected visual acuity (UCVA) of 20/40 or better in the affected eye following the procedure.\(^6,7\) Furthermore, improvement in visual acuity is associated with improvement in health-related quality of life, with greater improvements among patients with good UCVA (20/20 to 20/25) in both eyes compared with one.\(^8,10\) Despite these findings, the Centers for Medicare and Medicaid Services has ruled that astigmatism-correcting IOLs will not be fully reimbursed by Medicare.\(^11\) Instead, Medicare will reimburse astigmatism-correcting lenses at the same level as conventional IOLs, and patients are expected to pay the remaining balance.\(^11\)

To our knowledge, the economic value of the clinical benefits of toric IOLs compared with conventional IOLs has not previously been established. In light of Medicare’s policy, an economic assessment study was conducted to test the hypothesis that short-term costs associated with toric IOLs would be offset by long-term cost savings during patients’ lifetimes.

Methods

Source of Clinical Data

A Web-based survey was conducted of US practicing cataract and refractive surgeons recruited through the e-Rewards Physician Panel. Each eligible survey participant (1) per-
formed 20 or more cataract procedures per month using either conventional or toric IOLs in patients with preexisting astigmatism; (2) performed 10 or more refractive procedures per month for astigmatic correction; (3) had been in clinical practice for 2 or more years; and (4) had spent 50% or more of his or her time in a clinical setting. Sixty ophthalmologists met these criteria and completed the questionnaire in May 2008.

Surgeons reported their experience with 3 cataract treatment options: (1) toric IOL, (2) conventional IOL with intraoperative refractive correction (IRC), and (3) conventional IOL without IRC. The IRC represented limbal relaxing or peripheral corneal relaxing incision. Surgeons provided estimates specific to their practice based on experience among patients 65 years and older with regular astigmatism ranging from 1.5 to 3.0 diopters (D) at baseline.

For each treatment option, ophthalmologists indicated the percentage of patients who would normally not need visual aids for distance vision following cataract treatment. They also indicated the percentage of these patients whose UCVA would be 20/25 or better, worse than 20/25 to 20/40, and worse than 20/40 OU.

Surgeons reported the percentage of patients who would require further intervention to achieve optimal distance vision and the proportion of them with less than 1.0 D and 1.0 D or more of residual refractive cylinder after cataract treatment. They also indicated the percentage of these patients who would receive nonsurgical (glasses or contact lenses) and surgical (laser vision correction, incision corneal surgery, or conductive keratoplasty) interventions for each refractive cylinder group.

The respondents reported rates of re-treatment (second refractive surgery) to optimize vision, use of different retreatment options, and the mean time between cataract and follow-up refractive surgery. In addition, the ophthalmologists indicated the percentage of their patients receiving glasses or contact lenses and undergoing refractive surgery among the 3 UCVA groups mentioned previously.

As part of the general profiling, surgeons reported their practice type, the age distribution of their patients, and their use of different surgical procedures. Although 2 models of toric IOLs were available in the United States during the survey (AcrySof [Alcon Laboratories, Fort Worth, Texas] and STAAR [STAAR Surgical, Monrovia, California]), we did not ask the surgeons to stratify responses by lens type.

Statistical measures including mean and standard deviation were generated using SAS statistical software (version 9.1, SAS Institute, Cary, North Carolina).

**MODEL STRUCTURE**

A decision analytic model was created reflecting cataract treatment pathways for patients with preexisting astigmatism (Figure 1). Probabilities of achieving optimal distance vision or undergoing different interventions were applied to each treatment as reported by the survey participants. For the purpose of the analysis, we assumed that optimized distance vision was the ultimate goal of treatment.

**COLLECTION OF COST DATA AND OTHER INPUTS**

We assumed that patients were undergoing bilateral cataract removal for pricing purposes. Medicare physician and ambulatory surgical fee reimbursement amounts and Market Scope Reports (both from 2008) were used to obtain the total and patient out-of-pocket unit costs of cataract and refractive surgical procedures[12-13] (Table 1). Centers for Medicare and Medicaid Services reimbursement amounts were the same for the 3 cataract treatment procedures. However, patients incurred additional costs for toric IOL and intraoperative limbal relaxing and peripheral corneal relaxing incision procedures ow-
Table 1. Medical Costs of Services, Procedures, and Devicesa

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Patient Cost, $</th>
<th>Total Cost, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cataract treatment options</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toric IOL</td>
<td>1950</td>
<td>5240</td>
</tr>
<tr>
<td>Conventional IOL without IRC</td>
<td>823</td>
<td>4113</td>
</tr>
<tr>
<td>Conventional monofocal IOL</td>
<td>1803</td>
<td>5993</td>
</tr>
<tr>
<td>Follow-up intervention to optimize vision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glasses during the first year after cataract treatmentb</td>
<td>59</td>
<td>297</td>
</tr>
<tr>
<td>Glasses during each of the following years after cataract treatmentb</td>
<td>313</td>
<td>313</td>
</tr>
<tr>
<td>Contact lenses during the first year after cataract treatmentb</td>
<td>198</td>
<td>319</td>
</tr>
<tr>
<td>Contact lenses during each of the following years after cataract treatmentb</td>
<td>335</td>
<td>335</td>
</tr>
<tr>
<td>LVC spectrum procedures</td>
<td>4086</td>
<td>4086</td>
</tr>
<tr>
<td>LRI</td>
<td>980</td>
<td>980</td>
</tr>
<tr>
<td>AK</td>
<td>721</td>
<td>721</td>
</tr>
<tr>
<td>CK</td>
<td>3092</td>
<td>3092</td>
</tr>
</tbody>
</table>

Abbreviations: AK, astigmatic keratotomy; CK, conductive keratoplasty; ICS, incision corneal surgery; IOL, intraocular lens; IRC, intraoperative refractive correction; LRI, limbal relaxing incision; LVC, laser vision correction; PCRI, peripheral corneal relaxing incision.

aData sources: 2008 Market Scope Reports12 Your Medicare Coverage13; Medicare Ambulatory Surgical Center reimbursement fee schedule14; and Physician Medicare reimbursement fee schedule15.
bThe cost of wearing glasses or contact lenses included 1 annual eye examination and the cost of lens maintenance (eg, cleaning solutions).

DERIVATION OF UTILITY VALUES

Patient utilities were based on data from a prospective study using the time trade-off and standard gamble methods among patients with various vitreoretinal diseases. Utility weights were calculated by converting the UCVA levels into Snellen decimal values (a midpoint was obtained for the level of 20/25 to 20/40 OU) and applying an equation derived elsewhere (Utility = 0.37 × UCVA + 0.514). Each additional year after surgery was weighted by these utility values to derive quality-adjusted life years (QALYs), which were summed during 18 years and annually discounted by 3% to compute cumulative lifetime estimates.

MODEL OUTCOMES

The outcomes included (1) direct medical costs of bilateral treatment of cataract and preexisting astigmatism; (2) incremental cost per patient with UCVA of 20/25 or better; and (3) incremental cost per QALY. Microsoft Excel software (Microsoft Corp, Redmond, Washington) was used to derive the incremental cost-effectiveness and cost-utility values among the 3 cataract treatments.

SENSITIVITY ANALYSIS

Sensitivity analyses tested the robustness of the results to changes in clinical measures reported by the ophthalmologists and to the costs for toric IOLs. A lower proportion of patients achieving distance vision spectacle independence with toric IOLs was varied from 50% (worst-case scenario) to 90% (best-case scenario). The patient cost of toric IOLs was varied from $850 (best-case scenario) to $1100 per eye (worst-case scenario). We also tested the effects of reducing the frequency of changing glasses from annually to once every 3 years and of different remaining life expectancies.

RESULTS

CHARACTERISTICS OF THE SURVEY PARTICIPANTS

Sixty ophthalmologists completed all survey questions. Most of them practiced in the West or the South (32% and 30%, respectively) and spent most of their time in private clinics or community-based offices (mean [SD], 34% [40%] and 29% [35%] of the time, respectively) as opposed to hospital outpatient or ambulatory surgical centers. Participants reported performing a mean (SD) of 12 (13) cataract surgical procedures per month with toric IOLs and 13 (16) and 44 (28) procedures with conventional IOLs with and without IRC, respectively. Also, they reported performing more laser vision correction and limbal relaxing incision procedures (mean [SD], 28 [31] and 10 [14], respectively) than other refractive procedures. In their practices, a mean (SD) of 44% (18%) and 25% (17%) of patients with cataract were aged 65 to 74 years and older than 74 years, respectively.
Ophthalmologists reported that, on average, a greater proportion of their patients underwent cataract treatment using conventional IOLs with (mean [SD], 32% [26%]) or without IRC (mean [SD], 45% [26%]) than toric IOLs (mean [SD], 21% [19%]).

**SUMMARY OF SURGEON DATA**

Surgeons reported that a greater percentage of patients would not require further intervention with toric (mean [SD], 67% [25%]) than with conventional IOLs with (mean [SD], 62% [24%]) or without IRC (mean [SD], 53% [29%]). Patients who did not achieve optimal distance vision were more likely to have lower residual refractive cylinder (<1.0 D vs ≥1.0 D) with toric vs conventional IOLs (Table 2). Figure 1 depicts the likelihood of undergoing different interventions to correct residual refractive cylinder among patients who did not achieve optimal distance vision after cataract surgery. Laser vision correction was the most commonly used option among patients who required a subsequent refractive surgical procedure (data not shown).

A greater proportion of patients achieving UCVA of 20/25 or better was also reported with toric compared with conventional IOLs (Table 3). Table 3 presents the proportion of patients, stratified by postcataract residual refractive cylinder, with UCVA of 20/25 or better after interventions to correct residual astigmatism.

When utility weights were estimated based on patients’ UCVA for each treatment arm, the resulting cumulative lifetime QALYs with toric IOLs were 10.20 and with conventional IOLs with and without IRC were 10.14 and 10.10 per patient, respectively.

**TOTAL AND INCREMENTAL COSTS**

Total costs were higher for toric than for conventional IOLs during the first year, but were lower across patients’ lifetimes (Table 4). Table 5 presents incremental cost-effectiveness and cost-utility ratios of toric IOLs and conventional IOLs with IRC compared with conventional IOLs without IRC. Although the toric IOL costs more in the first year than the conventional IOL without IRC, it is more cost-effective than the conventional IOL with IRC. Moreover, the first-year additional costs of the toric IOL are offset by cost savings in future years owing to better clinical vision outcomes as demonstrated by negative cost-effectiveness and cost-utility ratios during the patients’ lifetimes. Toric IOLs also produced a mean incremental savings of $195 per patient during his or her lifetime compared with conventional IOLs with IRC (data not shown). The trend was similar for the patient-incurred costs (Tables 4 and 5). Patient costs represented a low proportion of total costs in the second year after cataract removal extrapolated across an average remaining life expectancy of 18 years discounted at 3%.

**SENSITIVITY ANALYSES**

The incremental cost of treatment with toric IOLs compared with conventional IOLs without IRC was sensi-
Table 5. Cost-effectiveness and Cost-Utility Ratios and Incremental Values of First-Year and Lifetime Cost of Cataract Treatmenta

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>First Year, $</th>
<th>Lifetime, $</th>
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<tr>
<td></td>
<td>Incremental Cost of Treatment</td>
<td>Incremental Cost per Patient With UCVA of 20/40 or Better OU</td>
</tr>
<tr>
<td>Toric IOL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total costs</td>
<td>1052</td>
<td>12,074</td>
</tr>
<tr>
<td>Patient costs</td>
<td>1080</td>
<td>12,406</td>
</tr>
<tr>
<td>CM IOL with intraoperative LRI/PCRI</td>
<td></td>
<td></td>
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<tr>
<td>Total costs</td>
<td>947</td>
<td>22,852</td>
</tr>
<tr>
<td>Patient costs</td>
<td>968</td>
<td>23,346</td>
</tr>
</tbody>
</table>

Abbreviations: CM, conventional monofocal; ICS, incision corneal surgery; IOL, intraocular lens; LRI, limbal relaxing incision; PCRI, peripheral corneal relaxing incision; QALY, quality-adjusted life year; UCVA, uncorrected visual acuity.

aWe used CM IOL without intraoperative refractive correction as a baseline comparator.

With conventional IOLs without IRC, cost savings were realized only after 21 years of the remaining lifetime.

Treatment with the toric IOL was a dominant option given a patient’s mean remaining lifetime. Specifically, the typical patient saved $35 in total costs with toric vs conventional IOLs, whereas the savings increased to $393 among patients who achieved UCVA of 20/25 or better owing to more favorable distance vision outcomes. Because more than 50% of the remaining lifetime costs are paid by patients as a result of current reimbursement policies by the Centers for Medicare and Medicaid Services, a substantial proportion of the total cost savings is accrued to patients.

Improvements in patients’ vision function and health-related quality of life are recognized as the most important outcomes of cataract treatment. This has been supported by a recent survey that found that the cost of wearing glasses includes much more than the direct medical costs. Freedom from glasses eliminated other related costs while providing intangible benefits associated with improved self-perception, physical appearance, and self-esteem. Thus, our study may have underestimated the actual cost of wearing glasses and contact lenses, since we considered only direct medical costs and neglected these intangible factors. Incorporating these additional costs would likely have increased the magnitude of the benefits associated with toric IOLs.

For transparency, we offer some insights into the data used for the analysis. Surgical correction of astigmatism during cataract removal is increasing, and to accurately reflect this real-world practice, we included 3 treatments in our analysis supported by data collected from practicing ophthalmologists.

As with all studies depending on self-reported treatments and outcomes rather than on actual observed treatments and outcomes, we were concerned with the possibilities of reporting bias and recall bias. However, the ophthalmologists in our study reported data consistent with published clinical studies. For example, our respondents reported that 87% of patients achieved UCVA of
20/40 or better with the toric IOL, which was within the range of 68% to 94% reported in other studies using different types of toric IOLs in patients with cataract and astigmatism (preoperative astigmatism, when reported, ranged from 2.5 D to 3.5 D). Similarly, our respondents reported that 67% and 53% of patients who received toric and conventional IOLs, respectively, would indicate no need for glasses, whereas others have reported 60% and 38% of patients, respectively. Other clinical outcomes reported by our respondents, including postcataract residual refractive cylinder with conventional IOLs and proportion of patients achieving good vision (ie, UCVA of 20/25 or better) after laser vision correction, were also similar to outcomes reported in published studies (data on file). However, some patient outcomes with toric IOLs reported by the ophthalmologists in our survey did differ from those reported in the literature. These differences could be attributed to various clinical settings and data collection methods (well-controlled experimental environments compared with real-world practice settings). Also, rotation stability varies across different types of toric IOLs, which may affect the correction of astigmatism, and ophthalmologists' experience with different types of toric IOLs may have resulted in the differences between the physician-perceived efficacy rates in our survey and those obtained in clinical studies. These factors were assessed during the sensitivity analyses.

Treatment-related adverse events or repositioning of toric IOLs owing to rotation were excluded from the model because adverse event rates are very similar between toric and conventional IOLs and because rates of rotation requiring repositioning with newer toric IOLs were negligible (95% of patients had rotation within 5°), resulting in similar costs across treatment arms. Because of a lack of evidence of different rates of age-related vision deterioration, this factor was not included in the model.

Our findings should be cautiously applied to patients who require correction of more than 3.0 D because the corrective power of the currently available toric IOLs is limited and IRC is likely to be implemented to achieve optimal astigmatic correction. In addition, patients with short expected life spans may not benefit economically from the use of toric IOLs.

These findings indicate that the remaining lifetime of a patient is an important factor in our utility analysis. As cataract surgery becomes increasingly safer and more effective at addressing refractive issues, surgery could be performed for younger patients. This, combined with the

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<th>Table 6. Results of Sensitivity Analysis: Effect on the Total Lifetime Costs of Treatment With Toric IOL vs Conventional Monofocal IOL Without IRC</th>
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<tbody>
<tr>
<td><strong>Model Inputs</strong></td>
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<tr>
<td><strong>Model Measure</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Modification of 1 measure</td>
</tr>
<tr>
<td>Cost of toric IOL per eye, $</td>
</tr>
<tr>
<td>Likelihood of distance vision independence, %</td>
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<tr>
<td>Frequency of obtaining new glasses</td>
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<tr>
<td>Simultaneous modification of both measures</td>
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<tr>
<td>Cost of toric IOL per eye, $</td>
</tr>
<tr>
<td>Likelihood of distance vision independence, %</td>
</tr>
</tbody>
</table>

Abbreviations: IOL, intraocular lens; IRC, intraoperative refractive correction; QALY, quality-adjusted life year; UCVA, uncorrected visual acuity.
increasing life expectancy of our population, would trend toward greater lifetime benefits for toric IOLs.

Overall, this study suggests that treating astigmatism with toric IOLs at the time of cataract removal yields several important benefits. Specifically, these include better distance vision outcomes that minimize the need for the second surgical procedure, improvement in patient health-related quality of life, and long-term health care cost savings. These results may be informative to physicians and patients regarding the value and long-term benefits of the toric IOL to treat cataract and preexisting astigmatism.

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REFERENCES


