

# Comparing the long-term impact on health care resources utilization and costs due to various single-piece acrylic monofocal intraocular lens implantation during cataract surgery: a cost-consequence analysis for the United Kingdom, Italy, and Denmark

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Mukesh Dhariwal<sup>1</sup>  
Christine Bouchet<sup>2</sup>  
Shantanu Jawa<sup>3</sup>

<sup>1</sup>Global Health Economics & Outcomes Research, Alcon Laboratories, Inc., Fort Worth, TX, USA; <sup>2</sup>Global Patient Access, Novartis Pharma AG, Basel, Switzerland; <sup>3</sup>Patient Access Services, Novartis Healthcare Private Limited, Hyderabad, India

**Purpose:** The objective of this study was to estimate the cost impact of neodymium-doped yttrium aluminum garnet (Nd:YAG) laser capsulotomy and its complications due to single-piece acrylic monofocal intraocular lenses (IOLs) in the healthcare setting of United Kingdom, Italy, and Denmark.

**Materials and methods:** A hypothetical cost-consequence model was developed to estimate economic burden of Nd:YAG laser capsulotomy due to different single-piece acrylic monofocal IOLs. Cumulative incidence of Nd:YAG laser capsulotomy at 3 years after cataract surgery with five single-piece monofocal acrylic IOLs was sourced from retrospective data analysis of electronic medical records of cataract patients in the United Kingdom. Risk probability of post-Nd:YAG laser complications, ie, retinal detachment, glaucoma, and cystoid macular edema at 3 years was derived using published literature. Unit costs were taken from publicly available sources with all costs converted to euro (€). Number of cataract procedures per year for each country was sourced from Eurostat statistics.

**Results:** For the estimated cataract procedures carried out nationally every year, single-piece monofocal hydrophobic AcrySof IOL was associated with substantially lower cases of Nd:YAG laser capsulotomy procedures and subsequent complications in 3 years after cataract surgery when compared to other single-piece monofocal acrylic IOLs. The total cost savings with the use of AcrySof over other IOLs in countries assessed ranged from €0.5 to €4.7 million (vs AMO Tecnis) and €2.1 to €17.9 million (vs Rayner C-/Super-flex).

**Conclusion:** Incidence of Nd:YAG capsulotomy due to the choice of IOL could significantly affect healthcare budgets in the post-cataract surgery period. Our analysis indicates that single-piece monofocal AcrySof IOLs is the most cost-saving treatment option for health care systems when compared to other acrylic single-piece IOLs.

**Keywords:** AcrySof, cost, Nd:YAG capsulotomy, cataract, PCO, IOL

Correspondence: Mukesh Dhariwal  
Alcon Laboratories, Inc., 6201  
South Freeway, TA3-8, Fort Worth,  
TX 76134-2099, USA  
Tel +1 817 363 1577  
Email mukesh.dhariwal@alcon.com

## Introduction

Cataract surgery is one of the most common surgical procedures performed globally with reported rates of 4,000–10,000 per million in developed countries to 500–2,000 per million in developing countries.<sup>1</sup> Posterior capsule opacification (PCO)

is the most common postsurgical complication of cataract surgery which can present several months to years after surgery.<sup>2</sup> PCO reduces patients' visual acuity, impairs contrast sensitivity, and increases glare disability. PCO is usually treated by neodymium-doped yttrium aluminum garnet laser (Nd:YAG) capsulotomy.<sup>3</sup> This procedure is generally considered safe but could occasionally lead to complications such as retinal detachment (RD), glaucoma, cystoid macular edema (CME), intraocular lens (IOL) pitting, iritis, and uveitis,<sup>4-8</sup> which can further impact patients' visual function and vision-related quality of life.

The incidence rates of PCO have been reported to vary from 11% to 43% within the first year of surgery and from 23% to 38% within 2–4 years after cataract surgery.<sup>9-11</sup> Higher incidence of PCO after cataract surgery increases health care resource utilization and costs.<sup>2</sup> According to the Centre for Medicare Services (CMS) data for year 2010, estimated costs for Nd:YAG laser capsulotomy accounted for \$187 million in the CMS population.<sup>12</sup> Further, costs of PCO are not limited to the cost of performing Nd:YAG capsulotomy but also include the cost of managing its complications. Health care consumption due to these complications include consultations and examinations and may also result in additional surgical procedures for treatment.<sup>2</sup> A retrospective study conducted in France estimated the indirect costs associated with the risk of blindness due to Nd:YAG capsulotomy complications particularly glaucoma and persistent elevation of intraocular pressure to be 21% of the total costs of Nd:YAG laser capsulotomy and management of its complications.<sup>2</sup> These data imply that Nd:YAG capsulotomy not only increases the clinical burden but also poses a significant economic burden on patients, caregivers, and third-party payers.

Risk factor for PCOs include age, surgical technique, ocular comorbid diseases but the most important one is IOL material and design.<sup>13,14</sup> Many published studies have reported significantly lower incidence of Nd:YAG capsulotomy in patients implanted with hydrophobic IOLs during cataract surgery compared to patients implanted with silicone and hydrophilic acrylic IOLs.<sup>15-20</sup> AcrySof IOLs (Alcon Laboratories, Inc.) are made from a hydrophobic acrylic material with higher fibronectin bioadhesion properties and a sharp optic edge.<sup>21</sup> Recently, a real-world evidence study evaluated the long-term incidence of Nd:YAG laser capsulotomy and PCO following age-related cataract surgery, comparing 3-year outcomes for hydrophobic acrylic AcrySof IOLs vs cohorts of other hydrophilic and hydrophobic acrylic monofocal IOLs.<sup>22</sup> Published results from this study

suggested that AcrySof IOLs are associated with significantly lower incidence of Nd:YAG laser capsulotomy compared to other hydrophilic and hydrophobic acrylic IOLs. The aim of the present study was therefore to estimate the cost impact of Nd:YAG capsulotomy due to the use of different single-piece monofocal acrylic IOLs.

## Materials and methods

A cost-consequence model was developed in Microsoft Excel to estimate the health care resource utilization and cost impact of Nd:YAG capsulotomy due to different single-piece monofocal acrylic IOLs – AcrySof, AMO Tecnis, B&L Akreos, Lenstec Softec, and Rayner C-/Super-flex. The model was developed per guidance from the National Institute for Health and Care Excellence on Medical Technologies Evaluation Programme methods.<sup>23</sup> The economic perspective adopted in the study was that of the national health care system of the United Kingdom, Italy, and Denmark. These selected countries largely have similar single national payer health care systems and the geographical spread provides a broad picture of European Union.

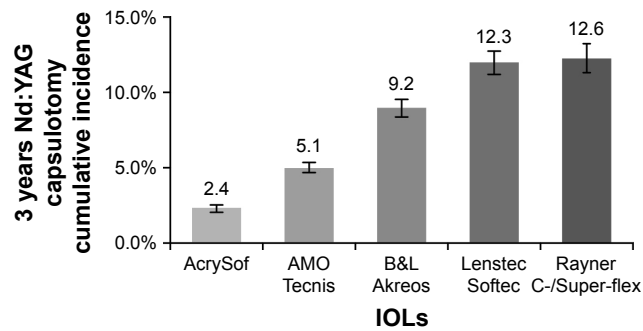
## Patient population

Patients undergoing cataract surgery were assessed for the current economic evaluation. The data for the annualized cataract surgeries for each country were taken from the Eurostat and were available till 2015.<sup>24</sup>

## Model inputs

The 3-year incidence of Nd:YAG laser capsulotomy after cataract surgery with single-piece monofocal acrylic AcrySof IOLs and comparator IOLs was derived from the post hoc analysis of the data available from a real-world evidence study.<sup>25</sup> 3-year risk probability of post-Nd:YAG capsulotomy complications of RD, glaucoma, and CME were derived from the published rates in studies (retrieved through a systematic literature search) using weighted average and probability equation methodology.<sup>26</sup> Various input parameters used for the analysis along with their sources have been illustrated in Figures 1 and 2. These input parameters were considered common for all the countries assessed.

The national average of published Nd:YAG laser capsulotomy and vitrectomy diagnosis-related groups (DRGs) tariffs was used whereas average medical treatment costs for glaucoma and CME were sourced from the literature (Table 1). For performing analysis, Nd:YAG laser capsulotomy rates post 3 years of cataract surgery and rates of



**Figure 1** Three years cumulative Nd:YAG capsulotomy incidence.

**Note:** Error bars represent 95% CIs. 95% CIs for the estimated Nd:YAG laser capsulotomy rates are as follow: AcrySof: 2.1%–2.6%, AMO Tecnis: 4.8%–5.5%, B&L Akreos: 8.6%–9.8%, Lenstec Softec: 11.5%–13.1%, and Rayner C-/Super-flex: 11.6%–13.6%. Three-year incidence of Nd:YAG capsulotomy after cataract surgery with AcrySof IOLs and non-AcrySof IOLs was derived from a real-world evidence study.<sup>25</sup>

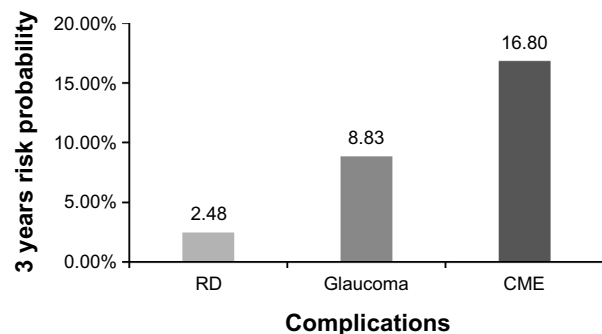
**Abbreviations:** IOLs, intraocular lenses; Nd:YAG, neodymium-doped yttrium aluminum garnet laser.

complications post 3 years of Nd:YAG laser capsulotomy were considered.

Considering the budget owner's perspective, direct treatment costs were considered for the analysis. The components included under direct costs were Nd:YAG laser capsulotomy costs and costs of treating complications due to Nd:YAG laser capsulotomy, ie, RD, glaucoma, and CME. Costs were expressed as 2018 euros. Costs available in pounds and Danish krone were converted to euros using currency exchange rates dated May 30, 2018.<sup>37</sup>

## Assumptions

Prices for AcrySof and competitor brands were considered equivalent in the present analysis because IOL costs are covered under cataract DRGs so overall costs to national payers per cataract procedure remain same regardless of



**Figure 2** Estimated rates of complications at 3 years after Nd:YAG capsulotomy.

**Note:** Three-year post-Nd:YAG capsulotomy risk probability of RD, glaucoma, and CME was estimated using weighted average of published rates from studies retrieved through a systematic literature search.<sup>26</sup>

**Abbreviations:** CME, cystoid macular edema; Nd:YAG, neodymium-doped yttrium aluminum garnet laser; RD, retinal detachment.

the IOL model used during surgery. This is aligned with the approach used in earlier published studies.<sup>38,39</sup> CME treatment costs data for Denmark and the United Kingdom were considered equivalent to Italian CME treatment costs given the lack of reliable published data in these countries.<sup>36</sup>

## Model outputs

The model outputs analyzed in terms of health system benefits were reduction in the incidence of Nd:YAG laser capsulotomy and its subsequent complications with the use of single-piece monofocal acrylic AcrySof IOL vs comparator IOLs for all three countries. As weighted average of published rates was used to estimate probabilities of complications, 95% CIs available for the estimated probabilities of Nd:YAG capsulotomy procedure rates were used to calculate the lower and upper values of different complications. Total cost savings were assessed with respect to reduction in Nd:YAG laser capsulotomy and its complications between single-piece monofocal acrylic AcrySof and comparator IOLs.

## Sensitivity analysis

Sensitivity analysis was conducted to obtain a range of minimum and maximum savings for the comparisons in order to test the robustness of the results. The lower and upper values for Nd:YAG capsulotomy rates were derived from the available CI values, and for complications (RD, glaucoma, and CME), the lower and upper values were derived using the Nd:YAG capsulotomy rates. Further, the  $\pm 10\%$  variation in costs was applied to the lower and upper values for all the events to derive the minimum and maximum cost differences between comparators.

## Results

### Health system benefits

In hypothetical scenarios considered in the model, if the national cohort of cataract surgery eligible patients in a given year were to be implanted with any of the five single-piece monofocal acrylic IOLs, in 3 years after cataract surgery, the highest cases of Nd:YAG laser capsulotomy would be observed in patients implanted with Rayner C-/Super-flex (the United Kingdom: 60,598; Italy: 66,327; and Denmark: 7,150) followed by Lenstec Softec (the United Kingdom: 59,155; Italy: 64,748; and Denmark: 6,980), B&L Akreos (the United Kingdom: 44,246; Italy: 48,429; and Denmark: 5,521), AMO Tecnis (the United Kingdom: 24,528; Italy: 26,847; and Denmark: 2,894), and the lowest with AcrySof (the United Kingdom: 11,542; Italy: 12,634;

**Table 1** Model inputs (country-segregated data, costs in euro 2018)

Parameters	The United Kingdom		Italy		Denmark	
	Estimate	Source	Estimate	Source	Estimate	Source
Number of cataract procedures	480,934	24	526,407	24	56,746	24
<b>Costs</b>						
Nd:YAG laser capsulotomy	267.04	27	95.40	28	275.99	29
Retinal detachment	1,468.15	30	1,549.00	31	2,018.13	32
Glaucoma	544.40	33	788.70	34	305.00	35
CME	79.81 <sup>a</sup>	–	79.81	36	79.81 <sup>a</sup>	–

**Notes:** Exchange rates used for the United Kingdom: costs in pounds  $\times$  1.1461 and for Denmark: costs in Danish krone  $\times$  0.1343. <sup>a</sup>CME treatment costs data for Denmark and the United Kingdom were considered equivalent to Italian CME treatment costs, given the lack of published data in these countries.

**Abbreviations:** CME, cystoid macular edema; Nd:YAG, neodymium-doped yttrium aluminum garnet.

and Denmark: 1,362). Subsequently, Rayner C-/Super-flex IOLs would be associated with the highest frequency of complications due to Nd:YAG capsulotomy followed by LensteC Softec, B&L Akreos, AMO Tecnis, and the least by AcrySof. Differences in number of Nd:YAG capsulotomy procedures and its complications between single-piece monofocal acrylic AcrySof IOL and each comparator IOL are presented in Table 2.

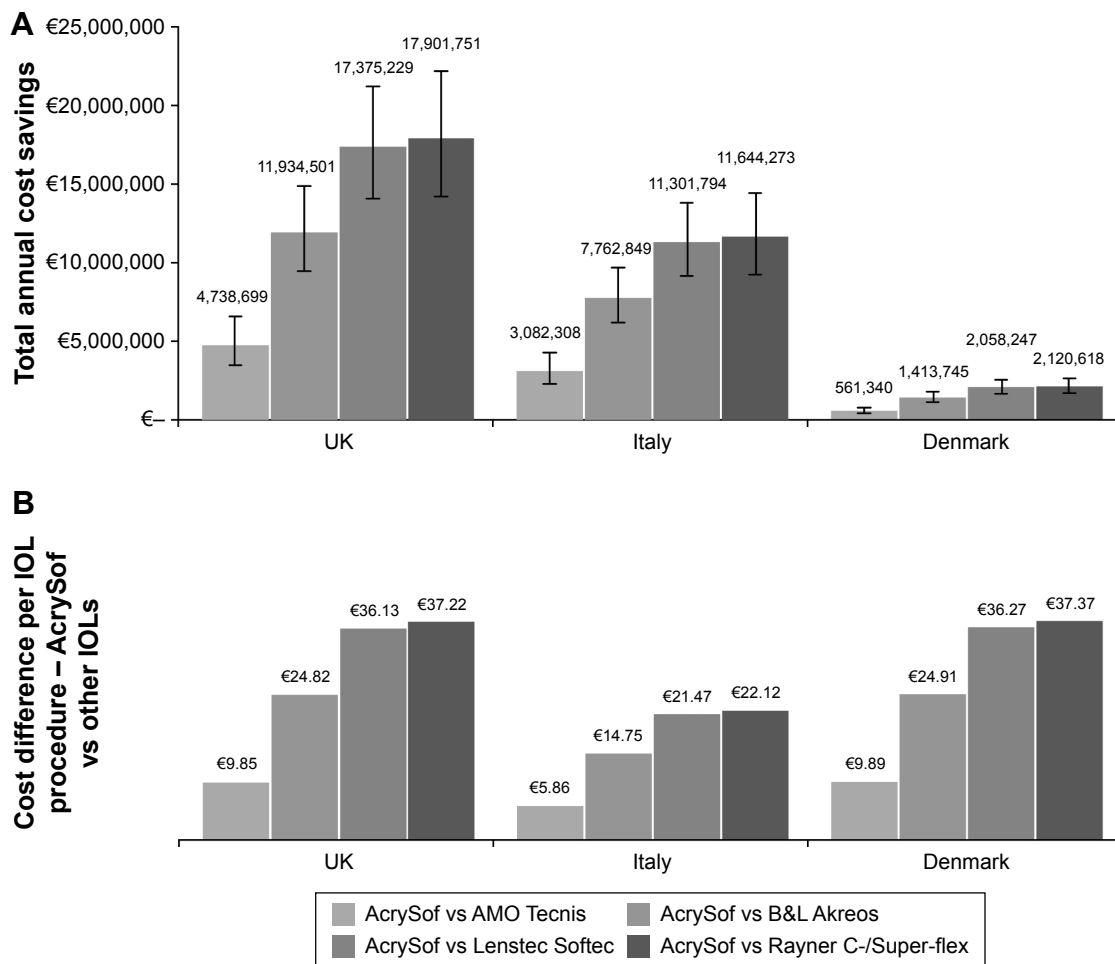
## Cost results

The total national health care costs of Nd:YAG capsulotomy procedure and its complications associated with each IOL considered in the analysis were as follow: AcrySof (the United Kingdom: €4.2 million; Italy: €2.7 million; and Denmark: €0.4 million); AMO Tecnis (the United Kingdom: €8.9 million; Italy: €5.8 million; and Denmark: €1.0 million), B&L Akreos (the United Kingdom: €16.1 million;

**Table 2** Reduction in the number of events of Nd:YAG capsulotomy and its complications with the use of AcrySof over the comparator IOLs in the United Kingdom, Italy, and Denmark

Comparisons	The United Kingdom			Italy			Denmark		
	Baseline	Lower value	Upper value	Baseline	Lower value	Upper value	Baseline	Lower value	Upper value
<b>Reduction in the number of Nd:YAG capsulotomy</b>									
AcrySof vs AMO Tecnis	-12,985	-10,581	-16,352	-14,213	-11,581	-17,898	-1,532	-1,248	-1,929
AcrySof vs B&L Akreos	-32,704	-28,856	-37,032	-35,796	-31,584	-40,533	-3,859	-3,405	-4,369
AcrySof vs LensteC Softec	-47,613	-42,803	-52,903	-52,114	-46,850	-57,905	-5,618	-5,050	-6,242
AcrySof vs Rayner C-/Super-flex	-49,055	-43,284	-55,307	-53,694	-47,377	-60,537	-5,788	-5,107	-6,526
<b>Reduction in the number of RD events</b>									
AcrySof vs AMO Tecnis	-322	-262	-406	-352	-287	-444	-38	-31	-48
AcrySof vs B&L Akreos	-811	-716	-918	-888	-783	-1,005	-96	-84	-108
AcrySof vs LensteC Softec	-1,181	-1,062	-1,312	-1,292	-1,162	-1,436	-139	-125	-155
AcrySof vs Rayner C-/Super-flex	-1,217	-1,073	-1,372	-1,332	-1,175	-1,501	-144	-127	-162
<b>Reduction in the number of glaucoma events</b>									
AcrySof vs AMO Tecnis	-1,147	-934	-1,444	-1,255	-1,023	-1,580	-135	-110	-170
AcrySof vs B&L Akreos	-2,888	-2,548	-3,270	-3,161	-2,789	-3,579	-341	-301	-386
AcrySof vs LensteC Softec	-4,204	-3,780	-4,671	-4,602	-4,137	-5,113	-496	-446	-551
AcrySof vs Rayner C-/Super-flex	-4,332	-3,822	-4,884	-4,741	-4,183	-5,345	-511	-451	-576
<b>Reduction in the number of CME events</b>									
AcrySof vs AMO Tecnis	-2,182	-1,778	-2,747	-2,388	-1,946	-3,007	-257	-210	-324
AcrySof vs B&L Akreos	-5,494	-4,848	-6,221	-6,014	-5,306	-6,810	-648	-572	-734
AcrySof vs LensteC Softec	-7,999	-7,191	-8,888	-8,755	-7,871	-9,728	-944	-848	-1,049
AcrySof vs Rayner C-/Super-flex	-8,241	-7,272	-9,292	-9,021	-7,959	-10,170	-972	-858	-1,096

**Abbreviations:** CME, cystoid macular edema; IOLs, intraocular lenses; Nd:YAG, neodymium-doped yttrium aluminum garnet; RD, retinal detachment.



**Figure 3** Total annual cost savings and cost difference per procedure with AcrySof vs other IOLs. **Notes:** (A) Total annual cost savings with the use of AcrySof over other IOLs in the three countries. Error bars represent CIs. (B) Cost difference per IOL procedure – AcrySof vs other IOLs. **Abbreviation:** IOLs, intraocular lenses.

Italy: €10.5 million; and Denmark: €1.9 million), Lenstec Softec (the United Kingdom: €21.5 million; Italy: €14.0 million; and Denmark: €2.5 million), Rayner C-/Super-flex (the United Kingdom: €22.1 million; Italy: €14.3 million; and Denmark: €2.6 million).

These results indicate that the use of single-piece monofocal acrylic AcrySof IOL would be a cost-saving approach for budget owners in all three countries. For the United Kingdom, Italy, and Denmark, the total cost savings with the use of

single-piece monofocal acrylic AcrySof IOL over other IOLs ranged from €4.7, €3.0, and €0.5 million (vs AMO Tecnis) to €17.9, €11.6, and €2.1 million (vs Rayner C-/Super-flex), respectively (Figure 3A).

### Sensitivity analysis

The results of sensitivity analysis are presented in Table 3. The biggest driver affecting cost savings is the Nd:YAG laser capsulotomy rates.

**Table 3** Sensitivity analysis results for total costs savings with ±10% variation in the costs of Nd:YAG laser capsulotomy, RD, glaucoma, and CME

Comparison	The United Kingdom	Italy	Denmark
AcrySof vs AMO Tecnis	€3,475,046–€6,563,976	€2,260,359–€4,269,567	€411,649–€777,560
AcrySof vs B&L Akreos	€9,477,398–€14,865,474	€6,164,615–€9,669,313	€1,122,680–€1,760,944
AcrySof vs Lenstec Softec	€14,058,140–€21,236,391	€9,144,179–€13,813,304	€1,665,309–€2,515,635
AcrySof vs Rayner C-/Super-flex	€14,216,097–€22,201,682	€9,246,923–€14,441,182	€1,684,020–€2,629,982

**Abbreviations:** CME, cystoid macular edema; Nd:YAG, neodymium-doped yttrium aluminum garnet; RD, retinal detachment.

## Discussion

This analysis aimed at assessing the cost impact of Nd:YAG laser capsulotomy and its complications due to the use of different single-piece monofocal acrylic IOLs.

Results indicate that using single-piece monofocal acrylic AcrySof IOL during cataract surgery could substantially offset the treatment burden of Nd:YAG capsulotomy procedures and subsequent complications when compared with other single-piece monofocal acrylic IOLs resulting in cost savings of €4.7–17.9 million in the United Kingdom, €3.0–11.6 million in Italy, and €0.5–2.1 million in Denmark. The findings indicate that Nd:YAG laser capsulotomy rates after cataract surgery should be considered an important clinical and economic criterion in selecting IOLs.

The 3-year Nd:YAG laser capsulotomy rates used in this study are in accordance with the previously published evidence that showed AcrySof IOLs and hydrophobic IOLs in general had lower incidence of Nd:YAG rates as compared to hydrophilic acrylic IOLs.<sup>15–20</sup>

Results from our study are in agreement with the earlier published economic evaluations. AcrySof IOLs were found to be the most cost-effective IOLs compared to other hydrophobic, polymethylmethacrylate, hydrophilic acrylic, and silicone IOLs in an analysis conducted from French, Italian, and Spanish health care systems' perspective.<sup>36</sup> Similarly, a study conducted in Sweden reported that risk of PCO and Nd:YAG laser capsulotomy and resulting costs were higher with hydrophilic IOLs than hydrophobic IOLs.<sup>40</sup>

The present analysis considered equivalent prices for all IOL brands since IOL costs are covered under cataract DRGs. We computed the cost difference per cataract procedure comparing AcrySof IOL with other IOLs realized due to downward cost savings by reduction in Nd:YAG capsulotomy procedures and treatment for YAG complications. As shown in Figure 3B, cost difference per IOL between AcrySof and AMO Tecnis were €9.85, €5.86, and €9.89, vs B&L Akreos were €24.82, €14.75, and €24.91, vs Lenstec Softec were €36.13, €21.47, and €36.27, and vs Rayner C-/Super-flex were €37.22, €22.12, and €37.37 in the United Kingdom, Italy, and Denmark, respectively. Important to note, IOLs are procured under tendering system in hospitals in which IOL procurement price is an important selection criterion. Therefore, if the price difference between AcrySof and other IOLs matches with the numbers described above, estimated cost savings for budget owners would be neutralized.

The main strength of this study is data sources considered for the analysis. Data for Nd:YAG laser capsulotomy rates were taken from a longitudinal, real-world evidence study

with a large sample size and representative patient population,<sup>22</sup> while risk probabilities of complications secondary to Nd:YAG laser capsulotomy were calculated from published studies retrieved through a recently conducted comprehensive systematic literature review. The current study employed a cost-consequence approach presenting disaggregated data for costs and outcomes thereby allowing decision makers to form their own opinion in a relevant context. Nevertheless, the study also has certain limitations. First, the Nd:YAG laser capsulotomy rates were derived from the UK-based study. Second, CME treatment costs data for Denmark and the United Kingdom were considered equivalent to Italian CME treatment costs, as we were unable to retrieve reliable cost estimates from published sources. Third, the usual demerits of data usage from a retrospective study such as susceptibility to confounding and issues such as missing data and lack of validation cannot be overlooked. Lastly, most recent data for the annualized cataract surgeries for each country were available only until the year 2015.

## Conclusion

Use of single-piece monofocal acrylic AcrySof IOLs over other hydrophobic and hydrophilic acrylic IOLs is associated with substantially lower incidence of Nd:YAG laser capsulotomy procedures and its complications in 3 years after cataract surgery resulting in lower health care resource utilization and cost savings to health care system.

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## Disclosure

MD (Alcon Laboratories, Inc.), CB (Novartis Pharma AG), and SJ (Novartis Healthcare Pvt. Ltd.) are Novartis employees. The authors report no other conflicts of interest in this work.

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