• Investigation •

Refractive surgery: the most cost-saving technique in refractive errors correction

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Abstract

• AIM: To compare the lifetime and annual economic burden of spectacles, contact lenses, and refractive surgery in correction of refractive errors.

• METHODS: This is a cross-sectional study with convenience sampling which 120 patients were interviewed in a tertiary referral hospital in the Iranian health care system. The bottom-up based cost of illness approach was estimated using a face-to-face interview to assess the direct and indirect cost of different refractive errors correction of any correction technologies.

• RESULTS: Correction with spectacle imposes a total direct cost of US dollar (US$) 342.5 (±8.41) per year and US$9373.5 (±230.1) per lifetime to each patient. These figures for the contact lenses were obtained US$198.3 (±0.12) and US$5203.1 (±256.3) and for refractive surgery were obtained US$19.1 (±1.2) and US$568.1 (±64.6), respectively. Overall, based on age-adjusted prevalence rates, astigmatism had the highest share of refractive errors economic burden with a lifetime direct cost of slightly less than US$5.49 billion, while hyperopia and myopia imposed less than US$5.24 and 4.2 billion on patients, respectively. The annually imposed cost on each individual Iranian patient with refractive errors is US$308.5.

• CONCLUSION: Based on 18mo post refractive surgery course observation, which is generalized to whole life, refractive surgery significantly imposed much less cost compared with spectacles and contact lenses. Refractive errors among Iranians result in considerable economic burden. Using the refractive surgery instead of other two correction methods has the ability to reduce this economic loss in the future.

• **KEYWORDS:** refractive error; economic burden; refractive surgery; spectacle; contact lenses

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INTRODUCTION

Uncorrected refractive errors (REs) are the leading cause of low vision and the second cause of blindness worldwide[1] and one of the most important causes of correctable visual impairment[2]. REs affect people of all ages and have been reported in more than 60% of subjects over 40 years of age and in more than 20% of students[3]. About 153 million individuals are visually impaired due to REs, of which 8 million are blind[1]. Blurred vision can be relieved, in most cases, by neutralizing it with spectacles, contact lenses, or refractive surgery. Nevertheless, the high prevalence of REs and the costs of their correction make these conditions a substantial public health and economic problem in many parts of the world[4]. Providing eye care services to the many persons who use or need refractive correction involves substantial expenses[2] and imposes a huge financial burden on societies[5]. Studies measuring the economic burden on the society are limited in developed countries[6-11]; thus we aimed to estimate the economic burden of common corrective methods in order to introduce more cost-saving scenarios from patients' perspective.

SUBJECTS AND METHODS

This investigation is a study of 120 RE patients of at least 23 years of age and free of any comorbidity was collected by consecutive sampling from those referring to Farabi Eye Hospital, a third level center in Iranian referral system. The sample comprised who underwent refractive surgery 18mo before enrollment. This time was chosen to ensure follow-up was complete, there were no more related costs, and clinical outcomes were stable. Mean of both pre- and postoperative

Table 1 Expected value, uncertainty range and distribution types of models parameters among Iranian people with REs

Items	Expected value	Range for sensitivity analysis	Distribution
Average age at first SC use	15.5 years old	13.5-17.5	Gamma
Average replacement time			
Between 15.5-29y	1.75 time	1.5-2	Beta
Between 29-73y	8 time	7-9	Beta
CL use	25%	21-29.5	Beta
Average age at first CL use	21.8 years old	20.1-23.5	Gamma
CL follow-up visit due to complication	18.8%	17.4-20.2	Beta
Lost days (d)			
SC maintenance	1.27	1.22-1.32	Gamma
SC Repair	3.13	2.85-3.41	Gamma
Receiving first CL	2	1.6-2.4	Gamma
CL complication	4.4	3.9-4.9	Gamma
CL loss and maintenance	0.7	0.55-0.85	Gamma
Surgery process	3.96	3.58-4.34	Gamma
Rest after surgery	7.11	6.4-7.8	Gamma
Retreatment	5.5	5-6	Gamma
Surgery complication	1.64	1.52-1.76	Gamma
Average complication period (mo)	6	4.9-7.1	Gamma
Complication lasting longer than 1y	17.6%	17.1-18.5	Beta
Hyperopic patients (MSE)			
Preop. RE	+3.81 D	+1.64	Lognormal
Postop. RE	+0.56 D	+0.39	Lognormal
Myopic patients (MSE)			
Preop. RE	-5.63 D	-2.54	Lognormal
Postop. RE	-0.83 D	-0.28	Lognormal
Astigmatic patients (MSE)			
Preop. RE	-3.75 D	-2.25	Lognormal
Postop. RE	-0.75 D	-0.50	Lognormal

REs: Refrcutive errors; SC: Spectacle; CL: Contact lenses; RS: Refractive surgery; MSE: Mean spherical equivalence.

decimal best spectacle corrected visual acuity of the patients were 1.0 and mean pre- and postoperative decimal uncorrected visual acuity were 0.32 and 0.8, respectively. Also, none of these patients had used spectacle or contact lens after surgery. This study was adherence to the guidelines of the Declaration of Helsinki and the Ethical Board of Tehran University of Medical Sciences and Iranian Ministry of Health approved the study proposal and we obtained a written free and informed consent from the participants.

Studied Conditions and Modalities We studied the imposed costs related to three common corrective methods for REs including spectacles, contact lenses, and refractive surgery, and also their combinations compared with actual spectacles, contact lenses and refractive surgery combined in the society. Contact lenses included soft and hard lenses. RE in the current study was defined as myopia [spherical equivalent refraction less than -0.5 diopter (D)], hyperopia (spherical equivalent more than 0.5 D) and astigmatism (cylinder power of ≥-0.5 D). Based on expert panel opinions, we assumed that refractive surgery is performed between 23 and 35 years old.

In order to obtain a country prevalence rate for myopia, hyperopia, and astigmatism for calculating the economic burden of correction for Iranian RE patients, we performed a systematic review based on 13 published population-based studies by age groups (49 488 cases) in different Iranian provinces that adhered to above cut-offs between 1995 to 2015. We searched Medline, Web of Science, and Cochrane databases as well as the reference lists of retrieved articles to identify studies that met the inclusion criteria.

Costs The cost-of-illness (COI) approach was used to assess the individual and social impact of REs[12]. Indirect costs, which is estimated using the human capital approach, determines lost productivity due to the complication, maintenance, repair and travel costs as a measure of patients' and caregivers' lost earnings[13]. In this method, we multiplied the number of lost working days attributed to correction scenarios in the average wage of Iranians. The required parameters are shown in Table 1. Future earnings were discounted at 3% level.

We used the below formula to discount the cost values in which, the 'n' equal number of intended years and 'R' is discounted rate. Present value=Future value/$(1+R)^n$. The bottom-up method was used for assessing direct costs in both one-year and lifetime horizons[14-15]. In this approach, cost estimation is based on the medical resource consumption of the individual patient. Among the three major studied correction methods, the just spectacle is covered by basic insurance. Supplementary insurance policies partly cover refractive surgery costs only for functionally blind patients.

Elements of direct costs include costs incurred for receiving correction, ophthalmologist and optometrist visit fees, drugs, educational courses, and usual follow-ups. For the first three items, we used the 2013 official tariffs for different correction methods fixed by the government, and for latter items, a questionnaire was used.

Study Process After determining and defining cost elements, detailing them, and designing a suitable closed questionnaire, face-to-face interviews were conducted to gather the required data including costs, lost days, complications and insurance coverage related to any studied vision correction method. Required micro and macroeconomic data including health care discount rate as 3%, exchange rate of US dollar (US$) to Iranian Rial (IRR) as 31 000, monthly per capita income as US$648, ophthalmologist and optometrist visit tariffs in public and private sectors, average refractive surgery fee and drug prices were derived from the National Central Bank, the Statistical Center of Iran, and the Ministry of Health. We used expert opinion to estimate the percentage of RE patients receiving refractive surgery. Collected data was entered in EXCEL software (Microsoft Corporation, Redmond, WA, USA) spreadsheets for analysis and computations. In 2014, life expectancy in Iran was 73y[16]. Monte Carlo simulation was used to extrapolate lifetime survival to derive the lifetime REs economic burden after receiving REs cares based on 18mo follow-up results. The basic considered assumptions for this projection, that are applied in our economic base model, are; the studied economic and epidemiological factors including inflation rate, RE prevalence rate and also effectiveness and complication rate of studied modalities will continue in the future as they have behaved in the past[17], clinically recommended age ranges for people with RE disorders is between 21 to 35 years old and also on average, Iranian people for the first time are wearing the spectacle, contact lenses, and undergoing the refractive surgery at 15, 21, and 28 years old, respectively. The detailed data and probabilities about receive, use, follow-up and opportunity costs of spectacles, contact lenses and refractive surgery in Iran are shown in Table 1 that are extracted from the primary analysis of current investigation.

Statistical and Sensitivity Analysis To comparison the means of two and more than two groups, we used Student *t*-test and one-way ANOVA test statistics, respectively. Also, we applied the Pearson's Chi-squared test for comparing the differences between frequencies. All *P*-values quoted were two-tailed and was presumed statistically significant when the values are below 0.05.

To deal with uncertainty about data, deterministic and probabilistic sensitivity analyses were performed. In a deterministic analysis including one and two-way, each sensible parameter of the model was subject to a variation of ±15% and the model, results were compared to the value of the base case. In a deterministic sensitivity analysis type named the optimistic or pessimistic sensitivity analysis, we compared three major studied scenarios in different ages against status quo and also we added the indirect costs to direct costs in a separate analysis and compared these two scenarios. For probabilistic sensitivity analysis and to scaling-up the samples, we used the Monte Carlo simulation with 5000 iterations at each model parameter with 95% confidence interval (CI).

RESULTS

Results showed no significant gender, education and income differences in refractive surgery use, but there were significant differences in favor of younger, urban residents, married and also employed participants (Table 2).

Refractive Error Types, Corrections, and Complications Of the 120 RE patients corrected with refractive surgery, 60.83% and 24.17% had myopia and hyperopia, respectively, and the rest of them had astigmatism. About 69.17%, 19.17% and 5.83% of cases had used spectacle, spectacle along with contact lenses, or only contact lenses, respectively, before receiving refractive surgery.

Contact lenses use had the highest complication rate (46.66%) and infection was responsible for half of these cases; rates were 30.83% and 11.32% for refractive surgery and spectacles, respectively. Since the mean age at first use of spectacles, contact lenses, and refractive surgery was 15.5, 21.8 and 28.6y, respectively, lifetime horizons for using them were about 58, 52 and 45y, respectively.

Refractive Errors Correction Costs Correction with spectacle imposes a total direct cost of US$342.5 (±8.41) per year and US$9373.5 (±230.1) per lifetime to each patient. These figures for the contact lenses were obtained US$198.3 (±0.12) and US$5203.1 (±256.3) and for refractive surgery were obtained US$19.1 (±1.2) and US$568.1 (±64.6), respectively (Table 3). Adding the indirect cost to these costs increased incurred yearly total costs by the spectacle, contact lenses, and refractive surgery to US$12454.6, 3243.5 and 132.7 respectively.

Based on systematic review results presented in Table 4, multiplying the expected total cost for any RE type by patient number provides an estimate of the RE-related ophthalmic

Table 2 Demographic characteristic of participants

Variables	Number (%)	*P*
Sex		
M	55 (46)	0.09
F	65 (54)	
Age (y)		
<28	53 (44)	
28-33	35 (29)	0.04
>38	32 (27)	
Marital status		
Single	44 (37)	
Married	71 (59)	0.04
Divorced	5 (4)	
Place of residence		
Urban	118 (98)	
Rural	2 (2)	0.01
Suburban	0 (0)	
Education status		
Illiterate/low literacy	3 (3)	
High school	60 (50)	0.07
Academic	57 (47)	
Income ($ Per month, 1$=31000 Rials)		
<300	14 (12)	
300-600	69 (57)	0.09
600-900	34 (28)	
>900	3 (3)	
Occupation status		
Employed	74 (62)	
Unemployed	5 (4)	0.03
Housekeeper	28 (23)	
Others	13 (11)	

Table 3 Cost components of REs correction methods

Parameters	Lifetime cost	Annual cost	Total (%)	Standard deviation (US$)
Correction with spectacle (58y time horizon)				
Direct costs				
For first visit and spectacle replacement	889.1	32.4	0.26	4.2
Spectacle	8484.4	310.1	2.49	3.5
Indirect costs				
Visit due to complication	322.8	11.8	0.10	2.7
Complication treatment	1072.5	39.2	0.31	8.4
Spectacle repair	2851.2	104.5	0.84	15.6
Spectacle maintenance	55582.1	2031.5	16.31	41.1
Travel due to spectacle	76.6	2.8	0.02	0.4
Physical access	1559.5	57	0.46	16.5
Patient opportunity cost	180453.7	6595.5	52.95	121.6
Caregiver opportunity cost	83341.7	3046.1	24.46	78.4
Days without spectacle	6120.5	223.7	1.80	10.2
Total	340754.1	12454.6	100.0	302.6
Correction with contact lenses (52y time horizon)				
Direct costs				
Visit for the first time and the following	4280.3	163.4	5.04	3.5
Contact lenses	353.9	13.5	0.41	0.1
Drug	566.3	21.6	0.67	0.1
Indirect costs				
Visit due to complication	3533.7	134.9	4.16	12.6
Complication treatment	1372.6	52.4	1.62	8.7
Contact lenses maintenance	2973.2	113.5	3.50	11.9
Physical access	1199.7	45.8	1.41	11.4
Patient opportunity cost	61608.9	2351.9	72.51	54.8
Caregiver opportunity cost	9076.7	346.5	10.68	52.4
Total	84965.3	3243.5	100	155.5
Correction with refractive surgery (45y time horizon)				
Direct costs				
Visit for first time	18.9	0.8	0.60	0.1
Surgery and drug	549.2	18.3	13.79	1.1
Indirect costs				
Visit due to complication	109.2	4.5	3.39	0.8
Complication treatment	349.3	14.2	10.70	2.8
Spectacle for protection	5.6	0.2	0.15	0.1
Physical access	363.8	14.8	11.15	4.6
Patient opportunity cost	1411.3	57.5	43.34	11.6
Caregiver opportunity cost	549.9	22.4	16.88	3.1
Total	3357.2	132.7	100	24.2

expenditure in 2013. The Iranian population is divided into four groups of elementary and middle school children, high school children, between 20 and 59y, and over 60-year-old patients. Actual annual imposed cost is estimated by a weighted average of correction cost by studied a corrective method which was US$340.3 per patient per year.

Overall, based on age-adjusted prevalence rates, astigmatism had the highest share of REs economic burden with a lifetime direct cost of slightly less than US$5.49 billion, while hyperopia and myopia imposed less than US$5.24 and 4.2 billion on patients, respectively. These shares were not the same for all age groups; the economic burden quota was highest in 15-19-year-old with myopia, under 14 and 20-59-year-old groups with hyperopia, and elderly peoples with astigmatism. There were significant differences in the incurred costs among RE types. Overall, the annually imposed cost on each individual Iranian patient with REs is US$308.5.

DISCUSSION

The present study was designed to seek the imposed economic burden of different correction modalities on the people with REs. The most interesting finding was that refractive surgery with a high certainty selected as the most cost-saving technique compared with spectacles and contact lenses from the patient's

Table 4 Prevalence and population correction direct cost of REs by age groups in Iran

Age (population)	REs	Prevalence (SD)	Population correction cost (US$)	*P*
<14 (17561778)	Myopia	3.61 (0.8)	195582887	
	Hyperopia	20.08 (9.1)	1087895949	0.001
	Astigmatism	9.23 (2.7)	500063726	
15-19 (6607043)	Myopia	16.53 (13.2)	336926488	
	Hyperopia	8.33 (7.3)	169788121	0.001
	Astigmatism	10.63 (4.9)	216668395	
20-59 (44774850)	Myopia	22.03 (0.4)	3043012982	
	Hyperopia	29.39 (5.8)	4059652816	0.001
	Astigmatism	27.99 (2.8)	3866270239	
>60 (6205998)	Myopia	32.83 (6.6)	628546891	
	Hyperopia	32.83 (21.9)	628546891	0.04
	Astigmatism	47.37 (11.5)	906922516	
All ages (75149669)	Myopia	18.11 (1.9)	4204069248	
	Hyperopia	25.59 (8.1)	5945883777	0.001
	Astigmatism	23.68 (3.7)	5489924876	

perspective. This result is completely consistent with those of Javitt and Chiang[18] that showed excimer laser photorefractive keratectomy (PRK) as a refractive surgery method, is a less expensive investment than both daily wear and extended wear soft contact lenses in a 20y' time period in the United States.

Average adjusted annual direct costs of REs corrections by spectacles and contact lenses were respectively about 18 and 10 times of that for refractive surgery. Given to total costs, in all studied scenarios, the main share of total costs was indirect and they comprised 93.89%, 97.25%, and 91.62% of the total costs associated with contact lenses, spectacles, and refractive surgery, respectively. In contrast to spectacles and contact lenses modalities, refractive surgery, a one-time payment is made early on, and then its costs are prorated in all benefited years and finally imposed a lower annual cost on the users. In addition, refractive surgery involves no maintenance, replacement, loss or repair costs which support our results.

Since the vast majority of subjects were urban residents, Iranian rural residents have very little utilization of these services, causes of which should be studied. We also found that refractive surgery utilization significantly correlated with a higher education level and being employed. Also, contrary to our previous assumption, there was no significant relation with income status, so we called it a normal service, not a luxury one. Also, we did not observe a significant difference between two sexes in this regard. The gender and occupation-results are in accord with those obtained by Gupta and Naroo[19].

We observed an inverse relation between utilization rates of different correction methods and their complication rates. The low rate of contact lenses use compared to spectacles could be attributed to the wider range of its complication and severity. Higher education, better financial status and also eye health status can explain using 70% of spectacles in patients with REs.

Overall, based on the 2011 total population in Iran and obtained RE prevalence rates in our systematic review, myopia, hyperopia and astigmatism respectively imposed an average US$4.2, 5.2 and 5.5 billion annually, of which, respectively 15%, 10.6%, and 16.5% is incurred by the elderly, whereas these ratios for elementary and middle school children are 4.6%, 18.3% and 9.1%, and for high school children they are 8%, 2.8% and 3.9%, respectively and rest of the correction cost is imposed on the 20-59-year-old population. Average imposed cost on any Iranian patient with REs was obtained as US$308.5, while this value for Singapore school children was calculated as US$148 in 2009[20].

Deterministic sensitivity analysis showed that discount rate, the percentage of contact lenses use, initial age at receiving refractive surgery, and productivity loss due to refractive surgery were the key variables that had the highest impact on the total cost of different studied scenarios. The annually imposed cost ranges between US$125.3 and 796 with a 2% change in discount rate. One day variation in productivity loss due to refractive surgery increases the total cost range from US$170.9 to 285. In measuring the actually imposed cost by all three correction methods, the percentage of patients receiving refractive surgery had an important effect on the incurred cost by the Iranian society such that a 7% change in refractive surgery rate among patients leads to a US$ 54 difference of US$ 340.3.

Starting with spectacles and switching to contact lenses as early as eligible imposes the highest cost on patients with REs. The total cost of this expensive and pessimistic scenario was US$431.3. The lowest cost, US$43.1 was when patients started with spectacles and received refractive surgery as early as eligible which is our optimistic scenario. Costs are high when the only spectacles are used; this cost increases when contact

Table 5 Epidemiological and economic burden of diseases and its components and definitions

Potential burden types of REs	Outcome dimensions	Example
Epidemiological burden		
Direct	Physical	Disabilities
	Mental	Depression and suicide
	Emotional	Loss of self-esteem/self-confidence
Indirect	YLL and YLD related to any incident attributed to vision impairment and blindness	Fall and accident
Economic burden		
Direct	Medical and non-medical attributed diagnostic, therapeutic and rehabilitation processes costs	Doctor visit and medicine costs
Indirect	Time lost and public expenditure	Productivity and deadweight loss
Intangible	Psychological effects	Pain and suffering costs

YLL: Years of life lost; YLD: Years lost due to disability.

lenses use is added while it can be addressed if replaced through refractive surgery. The patients use a combination of methods, and at present, Iranian patients spend US$340.3 per year and US$9310.65 per lifetime for the treatment of REs.

Probabilistic sensitivity analysis indicated that annual correction expenditure per patient by spectacles, contact lenses, refractive surgery, and actual combination of these corrective methods were US$350.5 (95%CI: 348.16-352.84), 184.9 (95% CI: 184.73-185.01), 18.1 (95%CI: 17.96-18.24), and 343.6 (95%CI: 341.45-345.75), respectively.

Globally, uncorrected RE imposes approximately 268 838 international million dollars[5]. The burden of myopia has been studied in different countries. In the United States, the annual burden was US$2 billion in 1983[21] and US$4.6 billion in 1994[18] for correcting myopia, and it was US$8.1 billion in 1990 for correcting products such as contact lenses, spectacles and eyeglasses frames for all types of REs[22]. Estimates for Singaporean myopic patients were more than US$248 million[20]. Since we included indirect costs and lifetime horizons in the current study, our results are not directly comparable with these studies.

A similar study reported an average cost of US$1707.4 for type 2 diabetes in Iran[23]. In another study, the total annual cost per patient for chronic hepatitis B, cirrhosis, and hepatocellular carcinoma was reported US$3094.5, US$17483 and US$32 958 during 2012, respectively[24]. As shown, REs imposes lower costs in comparison with the mentioned diseases. Rein *et al*[8] have reported that among major ophthalmic diseases, REs have a higher financial burden in under 60-year-old but rank second in over 60-year-old after cataract develops. Other high ranking ophthalmic diseases, in descending order, were glaucoma, age-related macular edema, and diabetic retinopathy.

Disease imposes not only an economic burden but also an epidemiologic burden that its definitions and components are illustrated in Table 5. Next logical step is identifying the more cost-effective type of refractive surgery, *i.e.* PRK, laser *in situ* keratomileusis (LASIK), phakic intraocular lens implants, and refractive lenses. In response to cost questions about using spectacles, contact lenses, and refractive surgery and their observed complications, we were faced with recall bias. In order to minimize its effect, in addition to using the bottom-up approach costing, we developed a comprehensive list of potential complications and asked participants to check mark the one they had experienced.

Other limitations of this study are the relatively small sample size and uncertainties regarding variables, were minimized by scaling-up the sample numbers to 5000 subjects through Bayesian-based probabilistic sensitivity analysis. Although we extrapolated the 18mo followed-up cost data to lifetime period, but the findings must be interpreted with caution and considered the underpinned hypothesis. Refractive surgery outcome is generally stabilized during the 6 to 12mo follow-up (LASIK course is shorter and that of PRK is longer). Long-term studies have shown that the outcome is generally stable in the coming decade[25-27]. So considering an 18mo' time course postoperative seems to have enough strength to be generalized beyond decades. Valuation of different modalities, in addition to the very direct costs, is influenced by long-term course and stability of the outcome, life expectancy, complication rates, *etc*. Related rates of complication for instance "corneal ectasia" is much more in younger age refractive surgery. So considering different lifetime horizons change results. But our assumption of over 25 years age and less than 30 seems to have a very good potential for routines of refractive surgery everywhere.

Nonetheless, the current study is the first investigation to measure the burden of an ophthalmic condition in a developing country and introduces a well defined and detailed burden of disease in economic terms. The inclusion of longevity, indirect correction costs and using sensitivity analysis are some other advantages of this study because the direct cost for a short time period alone is more likely to have misleading results.

In conclusion, our observation on the 18mo postoperative course of refractive surgery (which was generalized to the whole life) revealed a huge economic burden of REs on the Iranian society and strongly recommends the refractive surgery as the most cost-saving method to correction of the disorder. This has a loud public health message which needs to be scrutinized by health purchaser, especially health insurances organization.

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