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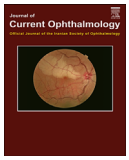

Cost-effectiveness analysis of confocal scan laser ophthalmoscope (HRT II) versus GDX for diagnosing glaucoma

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Abstract

Purpose: The aim of this study was to assess the cost-effectiveness of confocal scan laser ophthalmoscopy (HRT II) and compare it with scanning laser polarimetry (GDx) for diagnosing glaucoma.
Methods: A cost-effectiveness analysis was performed at two eye hospitals in Iran. The outcome was measured as the proportion of correctly diagnosed patients based on systematic review and Meta analysis. Costs were estimated at two hospitals that used the HRT II (Noor Hospital) and current diagnostic testing technology GDx (Farabi Hospital) from the perspective of the healthcare provider. The incremental cost-effectiveness ratio (ICER) was estimated on the base scenario.
Results: Annual average costs were estimated as 12.70 USD and 13.59 USD per HRT II and GDx test in 2012, respectively. It was assumed that 80% of the maximum feasible annual tests in a work shift would be performed using HRT II and GDx and that the glaucoma-positive (Gl+) proportion would be 56% in the referred eyes; the estimated diagnostic accuracies were 0.753 and 0.737 for GDx and HRT II, respectively. The incremental cost-effectiveness ratio (ICER) was estimated at USD44.18 per additional test accuracy. In a base sensitivity sampling analysis, we considered different proportions of Gl+ patients (30%–85%), one or two work shifts, and efficiency rate (60%–100%), and found that the ICER ranged from USD29.45to USD480.26, the lower and upper values in all scenarios.
Conclusion: Based on ICER, HRT II as newer diagnostic technology is cost-effective according to the World Health Organization threshold of <1 Gross Domestic Product (GDP) per capita in Iran in 2012 (USD7228). Although GDx is more accurate and costly, the average cost-effectiveness ratio shows that HRT II provided diagnostic accuracy at a lower cost than GDx.
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Keywords: Cost-effectiveness; Confocal laser scanning; Heidelberg retina tomograph; Scanning laser polarimeter; Glaucoma

Introduction

Glaucoma is considered the second-leading cause of blindness worldwide.[1] Although increased intraocular pressure (IOP) was traditionally used as a defining feature of glaucoma, the contemporary opinion reflects the fact that increased IOP is by no means pathognomonic of this condition.[2] There is no universally accepted definition of glaucoma[2]; therefore, it can be considered a group of diseases that result in progressive optic neuropathy with characteristic morphological changes at the optic nerve head (ONH) and associated visual field defects (the visual field has been defined as `that portion of space in which objects are simultaneously visible to the steadily fixating eye').[2] In developed countries, glaucoma prevalence fluctuates between 0.3 and 0.4 in people in the fifth decade of life.[3] Some population-based surveys in Iran showed that the prevalence of glaucoma varies between 1.44% in the adult population in Tehran to 4.4% in Yazd.[4,5] It is estimated that more than 11

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million people will become blind from glaucoma in the next 10 years.[6] Improved methods for diagnosing glaucoma that can provide rapid and repeatable examinations are urgently required.[7] Objective tests for diagnosing glaucoma are usually based on the detection of structural and functional changes that affect the ONH, peripapillary retinal nerve fibre layer (RNFL), and visual field (VF) exam, respectively.[8] Structural evaluations of the ONH and peripapillary RNFL, using imaging modalities such as optical coherence tomography, scanning laser polarimetry(GDx), nerve fibre analysis, confocal scanning laser ophthalmoscopy (CLSO), and Heidelberg retina tomography (HRT), have become increasingly popular for the early detection of glaucoma.[8] Due to the importance of structural changes when diagnosing glaucoma, this study focused on HRT and GDx, in which HRT measured the topography of the ONH and did not differentiate between different layers of the retina, and GDx measured retardation, which is a surrogate for RNFL thickness.[9,10]

Diagnostic technologies are more important than therapeutic medical technologies because the results of diagnostic testing can influence patient care and affect long-term outcomes due to early disease detection.[11] As a result, analyses of the diagnostic test performance characteristics and the costs are essential to decisions regarding the implementation of HRT or GDx in Iran in light of budget limitations. In our previous study, we assessed the diagnostic accuracies and clinical effectiveness of confocal laser scanning ophthalmoscopy (CSLO) and GDx via systematic review and meta-analysis.[12] The current analysis will assess the cost-effectiveness of CSLO-, also known as HRT, and GDx-based glaucoma diagnoses at a public hospital in Iran from the perspective of a healthcare provider.

Methods

Study setting

A cost-effectiveness analysis was performed in order to estimate and compare the costs per test accuracy of CLSO (Heidelberg Engineering, HRT II) and GDx (Carl Zeiss Meditec, GDxVCC) from the perspective of a healthcare provider. Cost data were extracted from the central financial databases of two hospitals specializing in eyes, using the top-down allocation method. We calculated the direct medical cost per test over a one-year time period. Because of the different tariff per diagnostic test in private and public hospital, we performed a cost accounting method in order to calculate real cost per test in each hospital to reduce the impact of the tariff difference on analysis.

Effectiveness data were collected from the results of a systematic literature review and a meta-analysis based on test accuracy.[12] Clinical assessments by expert ophthalmologist(s), based on visual field tests and assessments of the optic disc or nerve fibre layer, were considered the reference standard test. We calculated the incremental cost-effectiveness ratio as the final outcome of this analysis.

Collection of cost data

All cost data from a 12-month period were collected in May 2012. We considered the financial databases of two eye hospitals in Tehran that used HRT II and GDx (Noor Eye Hospital and Farabi Eye Hospital, respectively) as resources for measurements. Direct medical cost categories included the capital costs (device deployment) and recurrent costs (rent for physical spaces, labour costs, consumable costs and maintenance, and overhead costs). Direct costs outside healthcare and indirect costs such as opportunity costs were not considered. All costs were collected in Iranian Rials and converted to US Dollars (exchange rate: USD1 = 12,226 Rials), using the governmental exchange rates in 2012.

Unit cost valuation

The unit cost of diagnosis for each test was estimated according to the top-down allocation method of all hospital financial resources. In the top-down cost calculation method, financial administration data from the healthcare provider is the primary source for determining the unit costs per product. Departmental costs of a department are derived from the cost-accounting data and then assigned to the products or services produced by the department. Top-down calculations can be applied to cases of departments with relatively homogeneous production. All costs can be obtained directly from the central financial and production administration databases to calculate the direct costs for any output.[13]

An ingredients technique was also implemented to provide data that directly measured the maximum number of diagnostic tests that could be done in one year at full performance and the time required for each test, assuming a working hour shift. Annualized equipment values were estimated with standard procedures. HRT II and GDx purchase costs were determined on the basis of inquiries to suppliers, assuming 10 years of working life and a 5% depreciation rate, to annualize the capital costs. The physical space cost was estimated from the monthly rental price. Labour costs were allocated to each personnel for each device per shift while considering the annual salary and allowance. The maintenance cost of each device was assumed to be 8% of the price index. Overhead costs include costs of utility such as gas, electricity, and water that was dedicated to the glaucoma department in each hospital in this analysis. The amounts of utility items allocated to each hospital were obtained from the financial record. The allocation of the quantities used by the clinic is based on the square meter surface area. The time duration per examination was estimated by inquiring about the time spent by the health professionals performing the test, soliciting expert opinions, and observing a limited number of examinations. The maximum possible numbers of examinations during each shift (as a baseline) and during two shifts (for a sensitivity analysis) were calculated while considering the specified times. However, the efficiency percentage factor was used to modify the numbers of tests performed during one year of practice. The total costs of running the HRT II and GDx were divided by the number of

tests per year, while considering the test efficiency to arrive at the unit cost per test.

Cost-effectiveness analysis model

In order to determine the cost-effectiveness ratio, the effectiveness of each device was measured as the accuracy test (True positive + True negative)/(Number of tested) [Table 3]. In addition, the cost per test was calculated [Table 2]. The actual baseline glaucoma prevalence was considered to be 56%.[12] Next, the incremental cost-effectiveness ratio (ICER) was calculated by the following formula:

ICER = (Average Cost HRT II
− Average Cost GDx)/(Accuracy Test HRT II
− Accuracy Test GDx)

Sensitivity analysis

A sensitivity analysis was conducted on variables that were uncertain and prone to change over time. The ICER was estimated from the change in the number of tests per year, the actual frequency of glaucoma, and the hospital tariffs for each test, rather than the cost per test that was calculated [Table 4].

Result

Cost analysis

The unit cost of each diagnostic test was determined from the number of possible tests per year and by calculating all health-care provider costs. The cost analysis for each device is illustrated in Table 2. The costs of the physical spaces for each device, calculated on the basis of the monthly rental costs in the first year, were estimated as 43 USD, 115 for HRT II and 49 USD, 087 for GDx. Labour costs were estimated on the basis of the number of technicians who worked with each device (per work shift) and from the gross salaries and other intensive payments that were extracted from their pay-slips. We obtained values of 28 USD, 448 for HRT II and 26 USD, 595 for GDx. The difference in labour cost is due to differences in the number of personnel and their qualifications. Annual maintenance costs were estimated from the index purchase price percentages that healthcare providers must pay to corporate services and were found to be 3000 USD and 5572 USD for HRT II and GDx, respectively. The monthly overhead costs for HRT II and GDx, based on the financial reports from 2 hospitals, were 2866 USD and 5490 USD, respectively. The consumable costs per test were 4.3 USD and 3.8 USD for HRT II and GDx, respectively. We estimated the annual consumable cost according to the maximum feasible number of tests per year, while assuming the efficiency rate. The total consumable costs during the first year were 42 USD, 509 for HRT II and 38 USD, 258 for GDx. Technicians and heath care workers should receive training regarding the administration of new diagnostic devices. The amounts of these costs were estimated from the financial records of each hospital, training materials, and workshop costs. The costs for this item were 3774 USD for HRT II and 4854 USD for GDx.

Table 2
Total cost of diagnostic test of glaucoma with HRT II and GDx (USD).

Item	HRT II	GDx
Rent, Lab	43,115	49,087
Labour (1 Shift)	28,448	26,595
Maintenance	3000	5572
Purchase cost (1st year)	3125	5803
Overhead	2866	5490
Training cost	3774	4854
Consumable/Test	42,509	38,258
Max. feasible tests/year	12,480	12,480
Efficiency	0.8	0.8
Number of tests/year	9984	9984
Total Costs for provider	126,838	137,788
Average cost per test	12.70	13.59

Number of test per year = max feasible test * Efficiency
Average cost per test = (Total cost)/Number of test per year.

The prices of HRT II and GDx, based on surveys of medical equipment companies and departments in each hospital, were 28 USD, 627 and 53 USD, 165, respectively. We calculated the price index of each device based on the price index per year of acquisition (2007) and price index of base year (=100) to obtain the adjusted inflation rate. Next, we assumed a useful working life of 10 years for each device, with a depreciation rate of 5%, to estimate the annualized cost [Table 1]. Thus, the portion of capital for each HRT II and GDx that should be considered for the first year was estimated respectively at 3125 USD and 5803 USD.

The duration of each test with each device (including patient preparation, examination, analysis, and printing of the results) was 12 min, and therefore, the maximum possible numbers of tests per device per year, assuming 8-h work shifts, 6 working days per week, and 52 weeks per year, are 12,480 for one shift (as a basis) and 23,712 for two shifts (including the time

Table 1
Estimate annualize cost of HRT II and GDX and cost per test (USD).

Device	Price	Year of acquisition	Index	Index price	Annual cost of purchase	Maintenance	Cost/Year	Test/Year	Cost/Test
HRT II	28,627	2007	1.31	37,501	3125	3000	6125	9984	0.6
GDx	53,165	2007	1.31	69,646	5803	5571	11,375	9984	1.1

Index price = Price * index
Annual cost of purchase = index price adjusted with 10 year with 5% depreciation rate.
Cost/Year = Annual cost of purchase + Maintenance cost.
Cost/Test = (Cost/Year)/(Test/Year).

Table 3
Comparison of effectiveness of the two diagnostic strategies.

Test	Sn*	Sp**	No. Test	Prevalence	Gl+	Gl-	True results	False results	Accuracy	Cost per accuracy
HRT II	0.71	0.85	9984	0.56	5591	4393	7360	2624	0.737	17.40
GDx	0.80	0.89	9984	0.56	5591	4393	7527	2457	0.753	18.11

*Sensitivity**Specificity.
Accuracy = True results/No. Test.
Cost per accuracy = Average cost per test/Accuracy.

Table 4
Summery of sensitivity analysis.

Item	Base	1	2	5	6	7	8	Tariffs
Efficiency	0.8	0.6	1	0.8	0.8	0.8	1	0.8
Glaucoma percent	56	56	56	30	85	56	85	56
Work shifts	1	1	1	1	1	2	2	1
Average cost per HRT II	12.70	16.94	10.16	12.70	12.70	15.55	12.44	19.21
Average cost per GDx	13.59	18.12	10.87	13.59	13.59	16.25	15.13	28.82
Test accuracy for HRT II	0.73	0.73	0.73	0.78	0.68	0.73	0.68	0.73
Test accuracy for GDx	0.75	0.75	0.75	0.79	0.71	0.75	0.71	0.75
Cost per accuracy HRT II	17.40	23.20	13.91	16.28	18.68	21.30	18.29	26.31
Cost per accuracy GDx	18.11	24.16	14.49	17.19	19.13	21.66	21.30	38.42
Δ cost	0.88	1.18	0.71	0.88	0.88	0.70	2.69	9.61
Δ accuracy	0.02	0.02	0.02	0.01	0.03	0.02	0.03	0.02
ICER[a]	44.18	59.00	35.50	88.35	29.45	35.00	89.67	480.26

Δ cost = Cost per accuracy HRT II – Cost per accuracy GDx.
Δ accuracy = Test Accuracy for HRT II – Test Accuracy for GDx.
ICER = Δ cost/Δ accuracy.
[a]ICER = Incremental cost effectiveness ratio.

required to deliver the shift). Assuming an 80% efficiency rate (80% of possible tests run per year), the number of possible tests per year is 9984. The average total costs per test were calculated as 12.70 USD for HRT II and 13.59 USD for GDx. The summary of the diagnostic evaluation costs for HRT II and GDx while considering the basic assumptions is represented in Table 2.

Effectiveness of two diagnostic strategies

Effectiveness of each diagnostic test was calculated based on our recent paper.[12] A meta-analysis was conducted for pooling data to compare Heidelberg Retina Tomograph (HRT II) with scanning laser polarimetry (GDx) with the criteria of ``visual field defect" and ``changes of nerve fibre layer" as the gold standard.

Indices of accuracy of diagnostic test and its comparator including positive likelihood ratio (PLR), negative likelihood ratio (NLR), diagnostic odds ratio (DOR), true test results (TS), sensitivity (Sn), and specificity (Sp) were extracted from the primary studies. In total, 15 studies on 4776 eyes (including 2408 non-glaucomatous and 2369 glaucomatous) had assessed diagnostic accuracy of HRT II. There was considerable heterogeneity between results of the studies ($Q = 43.29$, $P < 0.001$, I2 = 67%), and pooled estimate of DOR (95% CIs) was 11.84 (9.97–14.06) for HRT II. There were 5 qualified studies on the 648 eyes (254 glaucomatous and 394 non-glaucomatous) for GDx concurrent with at least one of the editions of HRT. There was heterogeneity between results of these studies ($Q = 5.61$, $P = 0.23$, I2 = 28.7%). Diagnostic odds ratios (95% CIs) were 21.33 (13.56–33.55) for GDx by random model. True results were 7360 and 7527 for HRT II and GDx, respectively [Table 3]. The results of egger test also show that there is no significant publication bias on the result of HRT II and GDx.[12]

Determining the incremental cost-effectiveness ratio

The average cost difference between the two methods (Cost HRTII − Cost GDx), assuming among others 9984 tests in the first year, was calculated to be 0.88 USD. The test accuracy difference between the two methods (TA HRTII − TA GDx), given the characteristics of the diagnostic tests, was estimated to be 0.02; therefore, at the baseline, the ICER of HRT II to GDx was calculated as 44.18 USD based on ICER formula.

Sensitivity analysis

In a sampling base sensitivity analysis, ICER was estimated by changing the mean cost and test accuracy. We varied the mean cost by changing the efficiency percentage and the number of working shifts. In addition, in the last scenario, we used hospital tariffs instead of the estimated costs per test; furthermore, the accuracy per test was changed by changing the glaucoma percentage for each scenario [Table 4]. If we used the hospital tariff-based costs, which were 19.21 USD and 28.82 USD for HRT II and GDx, respectively, instead of the estimated costs from this project, the ICER is 480.26 USD (other assumptions remain constant).

Discussion

Because diagnostic tests affect short-term outcomes more than long-term outcomes, related assessments are more complicated than evaluating the therapeutic technologies.[14] Confocal scanning microscopy, as applied in the HRT system, is a safe system

without any important reports of side effects in the users and patients.[15] The glaucoma diagnostic accuracy of the GDx system is acceptable and higher than that of HRT II. HRT II-based glaucoma diagnoses had a lower cost (12.70 USD) but a lower effectiveness (0.7372) than GDx-based diagnoses. In fact, a GDx-based diagnostic strategy is both more effective and more costly. In this circumstance, the World Health Organization (WHO) guidelines recommend that when a strategy is both more effective and more costly, the dominance principle provides no guidance. The decision-maker must decide if the greater effectiveness justifies the greater achievement cost.[12] In addition, the average cost-effectiveness ratio of HRT II (17.40 USD) is lower than that of GDx (18.11 USD) in the baseline case analyses and in all scenarios in the sensitivity analyses. Given the difference in diagnostic test accuracy between GDx and HRT II (0.02) and the Average Cost Effectiveness Ratio (ACER) result, health-care providers could implement a new intervention (HRT II) that would detect acceptable numbers of glaucoma cases at a lower cost than that of GDx.

The ICER of HRT II to GDx was estimated at approximately 44.18 USD with basic assumptions. If we concentrate solely on the ICER, the results imply that this intervention is cost-effective according to the WHO threshold, which is < 1 GDP per capita in Iran in 2012 (7228 USD). The interpretation is that the ICER value is less than the national threshold, and therefore, implementation of the new technology will be recommended because it will be more efficient. The new technology will detect more cases, and thus, it will help to treat more episodes.

However, in an older study that was designed to evaluate the cost-effectiveness of open-angle glaucoma screening in the general population of Quebec, scanning confocal microscopy was not considered an effective tool for this intervention.[11] In addition, Kass et al[16] reported uncertainty regarding the use CLSO for diagnosing glaucoma. Also, Kwartz et al[2] showed poor agreement with regard to glaucoma detection between HRT and GDx. In summary, no single modality has sufficient diagnostic precision to be used in isolation, and neither HRT nor GDx should be viewed as a replacement for visual field examination.

There are some limitations in this study. For example, the number of tests is less than the maximum. It may be possible in the future to show more valuable objective test results in comparison to an examination by an ophthalmologist through cohort study follow-ups. This study has also not accounted for analyses by age, sex, and ethnicity that may affect cost-effectiveness ratios.

Conflicts of interest and source of funding

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