Rapid assessment of avoidable blindness-based healthcare costs of diabetic retinopathy in Hungary and its projection for the year 2045

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ABSTRACT

Background/aims The purpose of this study was to estimate the total healthcare cost associated with diabetic retinopathy (DR) in the population aged 18 years and older in Hungary, and its projection for the year 2045.
Methods A cost model was developed based on the standardised rapid assessment of avoidable blindness with the diabetic retinopathy module (RAAB+DRM) methodology and recently reported prevalent-based cost of illness model. Projection for 2045 was made based on the estimation for increasing diabetes mellitus (DM) prevalence of the International Diabetes Federation. Costs were analysed from the perspective of the healthcare system and the patients. Our DR cost model was constructed according to the Scottish DR grading scale and based on the DR severity stadium.
Results The total DR-associated healthcare cost was US$145.8 million in 2016 and will increase to US$169.0 million by 2045. The two major cost drivers were intravitreal antivascular endothelial growth factor injections and vitrectomies in this study (US$126.4 million in 2016 and US$146.5 million in 2045); they amounted to 86.7% of the total treatment cost of DR. The DR-related cost per patient was US$180.5 in Hungary.
Conclusions The cost per patient for treating DR was lower in Hungary than in other countries. Due to the increasing socioeconomic burden of proliferative DR and diabetes-related blindness, it would be important to invest in DR screening, prevention and early treatment. Our new RAAB-based cost of DR model may facilitate comparisons of DR treatment costs across countries.

Introduction

The number of people with diabetes mellitus (DM) and diabetic retinopathy (DR) is rapidly growing everywhere in the world.[1] About 463 million people worldwide had DM in 2019, and that number is expected increase to 700 million by 2045. It was estimated in 2019 that 59 million persons are living with DM in Europe, an average prevalence of 8.9%.[2] Prevalence of DM is growing continuously worldwide due to the ageing of the population and increasing rate of obesity.[3]

Almost every third person with DM has some form of DR,[4] and DR is responsible for 1.0–4.8% of blindness globally.[5 6] Diabetic macular oedema (DMO) and DR affect 80% of people with DM after 10 years of onset.[7] It is the leading cause of blindness among Europeans of working age.[8] Approximately 833.7 thousand persons were blind due to DR in 2010 in the world.[9]

Epidemiological surveys on DM are important for public health because about one-tenth of global healthcare spending originates from the financing of DM and its complications.[10]

With periodic follow-ups of DM, screening programmes and timely treatment of DR crises, ocular complications and blindness caused by DM can largely be prevented.[4] Preventing progression of DR is likely to reduce the economic burden of DR.[11]

Knowledge of the cost of DR is needed to estimate the economic burden of DR on the healthcare budget and to calculate the expected profit to be gained with the introduction of screening programmes.

Few studies on the cost of DR are available,[12–14] especially since the introduction of antivascular endothelial growth factor (anti-VEGF) drugs in diabetic eye disease treatment.[11 15 16] Due to differences in methodologies, comparisons between study results are not easy. For this reason, we created a rapid assessment of avoidable blindness with a diabetic retinopathy module (RAAB+DRM)-based cost model for DR to make comparisons possible between studies and countries using a well-known RAAB+DRM methodology. The RAAB+DRM is a quick and efficient population-based survey technique used to estimate the prevalence of blindness, DM and DR among people aged 50 years and older in a defined geographic area.[17–19] Our study aimed to estimate the cost of adequate treatment of DR in Hungary today and the expected treatment cost in 2045.

METHODS

Cost model of diabetic retinopathy

We developed a healthcare cost model for DR, combining the RAAB+DRM[17–21] and a recently published methodology by Sasongko et al.[15] A transition model regarding the different stages of DR severity is shown in figure 1. DR was graded according to the Scottish DR grading system.[22] The model of DR treatment (table 1) was properly formed to the transition model based on Sasongko's methodology[15] and the current Hungarian guidelines for DR. The research followed the tenets of the Declaration of Helsinki.

The frequency of eye examinations and the type of the treatment depend on the level of the DR. People with DM but without any DR need annual

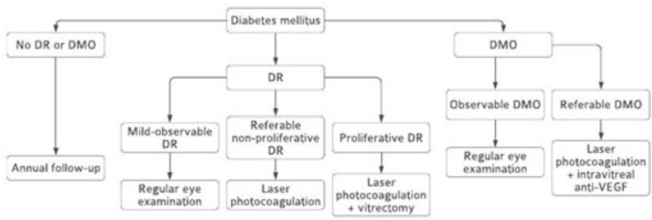

Figure 1 Transition model of diabetic retinopathy across different stages. DMO, diabetic macula oedema; DR, diabetic retinopathy; VEGF, vascular endothelial growth factor. DR, Diabetic retinopathy; DMO, Diabetic macula oedema; VEGF, Vascular endothelial growth factor.

Table 1 Cost of illness model for diabetic retinopathy in Hungary

Cost of illness model	Unit	Cost (US$)	Item(s) included
Model 1a	Per patient	8.6	1. Annual telemedical eye screening cost
Model 1b	Per patient	23.0	1. Annual ophthalmic examination cost 2. Loss of 0.5 workdays
Model 2	Per patient	46.0	1. Biannual ophthalmic examination cost 2. Loss of 2×0.5 workdays
Model 3	Per eye	207.8	1. Ophthalmic examination cost for seven eye exams (one exam for the first examination, three exams for the laser sessions, and three exams for follow-ups) 2. Cost of three pan-retinal photocoagulation sessions 3. Loss of 7×0.5 workdays 4. Cost of one FA examination 5. Cost of two OCT examinations
Model 4	Per eye	2376.2	1. Ophthalmic examination cost for seven eye exams (one exam for the first examination, three exams for the laser sessions, and three exams for follow-ups) 2. Cost of three pan-retinal photocoagulation sessions 3. Loss of 7×0.5 workdays for examinations and laser sessions + 10 workdays for the vitrectomy 4. Cost of one FA examination 5. Cost of two OCT examinations 6. Cost of two ultrasound examinations 7. Cost of one vitrectomy
Model 5	Per eye	3517.3	1. Ophthalmic examination cost for five eye exams (one exam for the first examination one exam for the laser treatment and three exams for follow-ups) 2. Cost of one laser session 3. Cost of three intravitreal anti-VEGF injections 4. Loss of 7×0.5 workdays for examinations and laser sessions + 3 workdays for intravitreal injections 5. Cost of two OCT examinations

FA, fluorescence angiography; OCT, optical coherence tomography; VEGF, vascular endothelial growth factor.

ophthalmological examinations by a specialised ophthalmologist (**Model 1b**) or an annual eye telemedical screening with a non-mydriatic fundus camera as an alternative (**Model 1a**). Persons with mild/observable DR need biannual retinal examinations (**Model 2**). People with referable non-proliferative DR may need pan-retinal photocoagulation in three sessions and regular eye examinations (**Model 3**); proliferative DR may need vitrectomy over the laser photocoagulation and follow-ups (**Model 4**); referable DMO may need one session of laser treatment and intravitreal anti-VEGF treatments (three injections), in addition to retinal examinations (**Model 5**).

Our cost model was built with the assumption that every person with DR receives only the standard DR treatment without any subsequent complications (ie, vitreous haemorrhages after retinal laser treatment or retinal ablation after vitrectomy) (table 1). Costs were divided into medical cost and patient's cost (table 2).

Medical costs addressed only costs related to DR from the perspective of the statutory health insurance system and included inpatient and outpatient charges: general eye exams, optical coherence tomography (OCT), fluorescence angiography (FA), ultrasound, retinal laser treatment, intravitreal anti-VEGF injection and vitrectomy. Patient's costs included loss of workdays, calculated based on the gross daily average income in Hungary in 2016.[23]

Outpatient charges were calculated based on a uniform value scale of the Hungarian health insurance system by multiplying the point values of the preformed ophthalmic services (by US$0.0062). Inpatient costs were estimated according to a case-mix system used in Hungary called Homogeneous Disease Groups. The costs of vitrectomies were calculated assuming a 3-day average stay in the hospital and 7 days of work loss.

Diabetic retinopathy: rates and projection to 2045

Rates of DR were estimated based on the results of recently published epidemiological data on DM and DR in Hungary by Tóth *et al* (table 3).[20 24]

It was reported that there were 0.8 million adult persons with DM in Hungary in 2016 with a prevalence of 9.9%. The number of patients with DR and DMO in the population (age ≥18 years) in Hungary was estimated by extrapolating the DR prevalence data of people aged 50 years and older in Hungary. The prevalence of DM in people aged 18 years and older in Hungary in 2045 was estimated based on prevalence data on DM in 2016[24] in Hungary and the estimation of the International Diabetes Federation for 2045 in Europe (11.5%).[2] We calculated assuming a constant prevalence of DR in Hungary since there is no available data on its longitudinal change of incidence in Hungary.

Table 2 Cost components of diabetic retinopathy treatment in Hungary

Cost item	Unit	Cost (US$)
Medical cost		
Screening cost via mobile camera	Per patient	8.6
General eye examination	Per patient	8.1
OCT examination	Per patient	7.4
FA examination	Per patient	9.2
Ultrasound examination	Per patient	5.9
Retinal laser treatment	Per eye	7.6
Intravitreal anti-VEGF injection	Per eye	1086.9
Vitrectomy	Per eye	1858.6
Patient's cost		
Loss of workdays	Per day	29.8

FA, fluorescence angiography; OCT, optical coherence tomography; VEGF, vascular endothelial growth factor.

Table 3 Prevalence of diabetes mellitus in people aged 18 years and older, and diabetic retinopathy people aged 50 years and older, in Hungary

Parameter	Prevalence (%)	Reference
Diabetes mellitus	9.9	Tóth *et al*[24]
No DR	59.4	
Any DR	20.1	Tóth *et al*[20]
Mild/observable NPDR	16.3	
Referable NPDR	1.4	
Proliferative DR	1.4	
Referable DMO	3.5	

DMO, diabetic macula oedema; DR, diabetic retinopathy; NPDR, non-proliferative diabetic retinopathy.

Cost benefit of screening of patients with DM but without DR

The cost of DR in our study was estimated with the assumption that every person with DM underwent a regular eye examination after pupil dilatation by an ophthalmologist. This additional cost-benefit analysis aimed at determining how much cost could be saved if every patient with DM, but without DR, would undergo the regular eye check-up with a telemedicine screening system using a non-mydriatic fundus camera and qualified reader in a reading centre. We made our estimation both for 2016 and for 2045.

RESULTS

Cost of diabetic retinopathy in 2016

The number of people with any DR was estimated to be 162.4 thousand in 2016 (table 4). Among them, 11.3 thousand had referable non-proliferative DR (NPDR), 11.3 thousand had proliferative DR and 28.3 thousand had referable DMO. The total healthcare cost to regularly examine people with DM and treat persons with DR was estimated to be US$145.8 million for 2016 in Hungary (table 4). This value included the cost of regular eye examinations of patients without DR (US$11.0 million) and patients with mild/observable NPDR (US$6.1 million), referable NPDR requiring pan-retinal photocoagulation (US$2.3 million), proliferative DR needing retinal laser therapy and vitrectomy (US$26.9 million), and referable DMO requiring macular laser and intravitreal anti-VEGF injection therapy (US$99.5 million). The DR-related cost per patient was US$180.5 in Hungary for 2016.

Cost benefit of screening of patients with DM but without DR

We compared the estimated healthcare cost of a telemedicine screening system and regular eye examinations by an ophthalmologist for patients with DM but without DR for 2016 and 2045. In this patient group, the estimated cost of one examination at an ophthalmologist was US$11.0 million in 2016 and will be US$12.8 million in 2045. The cost of the same procedure using a telemedicine screening system would have been US$4.1 million in 2016 and US$4.8 million in 2045.

Projection to 2045

The prevalence of DM in Hungary will increase to 11.5% by 2045, projected to be 938.4 thousand people (table 4). The number of people with DR is estimated to be 188.6 thousand by 2045, among them 13.1 thousand will have proliferative DR and 32.8 thousand referable DMO. The total healthcare cost of DR for 2045 will be US$169.0 million, spent for diabetic people without DR (US$12.8 million), for patients with mild/observable NPDR (US$7.0 million), referable NPDR requiring pan-retinal photocoagulation (US$2.7 million), proliferative DR needing retinal laser therapy and vitrectomy (US$31.1 million), and referable DMO requiring macular laser and intravitreal anti-VEGF injection therapy (US$115.4 million).

DISCUSSION

To the best of our knowledge, this is the first RAAB-based study to examine the cost of DR.

We estimated that the number of people with DM in Hungary was 807.9 thousand in 2016 and that their number may increase up to 938.5 thousand in 2045. Almost 162.4 thousand people with DM in Hungary had some form of DR in 2016; this number is estimated to grow to 188.6 thousand by 2045. Based on our estimation, the DR-associated healthcare cost was US$145.8 million in 2016 and will increase to US$169.0 million in 2045. Total healthcare cost of DR was 2.38% of the total governmental healthcare spending in Hungary in 2016.[25]

The two major cost drivers were anti-VEGF injections and vitrectomies in Hungary; they covered 86.7% of the total healthcare costs of DR both in 2016 and in 2045, suggesting that appropriate prevention and timely treatment of DR could save at least 86% of the total cost.

Vision loss risks due to DR and maculopathy can be reduced through regular ophthalmological examinations (at least annually) along with a timely and effective treatment. In fact, DR is preventable and treatable if detected on time.[20] A properly

Table 4 Healthcare cost of diabetic retinopathy in Hungary in 2016 and its projection for 2025

	Prevalence (%)		Estimated number of patients (×10³)		Cost per patient (US$)	Total cost (US$×10⁶)	
Parameter	2016†	2045	2016	2045		2016	2045
Diabetes mellitus	9.9	11.5	807.9	938.5			
No DR	59.4	59.4	479.9	557.4	23.0	11.0	12.8
Any DR	20.1	20.1	162.4	188.6			
Mild/observable DR	16.3	16.3	131.7	153.0	46.0	6.1	7.0
Referable non-proliferative DR	1.4	1.4	11.3	13.1	207.8	2.3	2.7
Proliferative DR	1.4	1.4	11.3	13.1	2376.2	26.9	31.1
Referable DMO	3.5	3.5	28.3	32.8	3517.3	99.5	115.4
Totally						145.8	169.0

†Tóth *et al*.[20 24]
DMO, diabetic macula oedema; DR, diabetic retinopathy.

organised DR screening programme and early treatment can reduce the risk of visual impairment by 90% and blindness prevalence due to DR by 75%. Furthermore, an organised screening programme can also be very effective in reducing the number of vitrectomies and anti-VEGF injections in patients with severe DR. Moreover, the cost of loss of production of people with visual impairment can be five times higher than direct medical costs.[26 27] With effective prevention causing a dramatic decrease in the incidence of DR-related blindness, a further US$30 million could be saved in Hungary every year, because supporting blind people is a constant cost burden.[28 29]

Studies on the cost of DR are rare, especially for Europe, and they were completed with different methodologies; for this reason, comparisons between results are not trivial.[12 13 16] The total healthcare cost of DR was reported to be US$3.51 billion for 8 million people with DM in Germany in 2002.[13] The cost per patient value related to DR was reported to be much higher in the USA between 1997 and 2004 (US$389)[14], in Switzerland in 1998 (US$2543.9),[12] in Singapore in 2014 (US$2219.4)[11] and in Germany in 2002 (US$438.8)[12] compared to that in Hungary in 2016 (US$180.5). Comparisons between these European studies are difficult, since the anti-VEGF injections for therapy of DMO have been replacing macular laser photocoagulation since 2011, and the cost of DMO treatment increased significantly after anti-VEGF injections were introduced in diabetic eye therapy.[16] The latter comparison also shows the extreme underfinancing of the healthcare system in Hungary. Financing of cost components is significantly lower in Hungary compared to other developed countries in Europe, for example, to Germany: vitrectomy (US$1858.6 vs US$3110.8), OCT (US$7.4 vs US$48.2), FA (US$9.2 vs US$52.8) and ultrasound examination (US$5.9 vs US$13.1).[30 31] Moreover, the gross monthly basic salary of a resident ophthalmologist immediately after graduation is US$905.8 in Hungary and US$5094.1 in Germany.[32 33]

The cost per patient value in Hungary in 2016 was also lower compared to Indonesia in 2017 (US$450.8); however, this difference is deceptive because prevalence of DR in people with DM in Indonesia (43.15%) is more than twice as high than that in Hungary (20.1%).[15]

About 1000 patients go blind every year in Hungary because of DR.[34] We found, as it was earlier reported, that the presence and severity of DR are associated with increased direct medical costs.[11] Accordingly, treatment of people with proliferative DR (US$2376.2) and patients with DMO (US$3517.3) was the biggest economic burden in our sample, similar to that in Indonesia.[15] Severe visual impairment due to DR and the economic burden caused by vitrectomies and anti-VEGF injections would be avoidable with regular eye examinations and timely retinal laser photocoagulation, because laser photocoagulation is substantially less expensive compared to vitrectomy or intravitreal injections.

It was reported by Tóth *et al*[20] that only approximately half of the people with known DM and 60% of people with sight-threatening DR get an annual eye examination, which is the basic requirement of the Hungarian national guidelines for all patients with DM. Moreover, one-third of the patients with known DM have never had a fundus examination.[20] Regular eye check-ups at an ophthalmologist are more expensive (Model 1b; US$23.0 per patient) in cases without DR compared to a telemedical screening system with a mobile camera with a reading centre (Model 1a; US$8.6 per patient) due to loss of the 0.5 workday caused by waiting time at a hospital and the pupil dilatation procedure.

Based on our calculation, a nationwide DR screening programme would be feasible by forming a central grading centre and approximately 30 screening stations equipped with a combined non-mydriatic fundus camera and OCT instrument. The introduction of this system would mean a single investment of US$1.4 million by the country, an additional US$ 0.1 million annually for operational expenditures, the continuous work of 125–210 people and US$65.8 million saving per year after the first 10 years.[35] With the introduction of a national telemedical screening system using non-mydriatic fundus cameras, Hungary could have saved US$6.9 million in 2016 and could save US$8.0 million in 2045 for the national budget if patients with DM without any DR would merely be rerouted to the screenings from the ophthalmic clinics. People's compliance may improve with the introduction of a screening system since patients could inspect their own photograph directly after the screening. In a Hungarian study, patients with DM stated that digital telemedical fundus screening was reliable and satisfactory, and many patients preferred it to the conventional screening method.[36]

The limitations of this study include the following: reliable data on the prevalence of DR and DMO are available only for people aged 50 years and older in Hungary; for this reason we extrapolated these data to the entire adult population of Hungary. Therefore, this may cause an under- or over-estimation of the prevalence of DR and DMO in people with DM. As we have no data on incidence and changes in the incidence of DR and DMO in Hungary, we made calculations similar to Sasongko et al.[15] with the same DR and DMO prevalence data for both 2016 and 2045. For this reason, our cost projection in 2045 may be under- or over-estimated. We made our estimations with the presumption that only one eye of each patient would be treated one time according to the Hungarian national DR guideline without any additional procedures (ie, repeated vitrectomy, intravitreal steroid injection). Finally, we excluded the potential effects of inflation and any fluctuation of exchange rates between the US$ and Hungarian Forint.

CONCLUSIONS

Our new RAAB-DRM-based cost of DR model may facilitate comparisons between countries regarding the cost of DR treatments. The cost per patient value regarding screening and treatment of DR was lower in Hungary compared to other countries. Due to the increasing socioeconomic burden of proliferative DR and diabetes-related blindness, it would be important to invest in DR screening, prevention and early treatment. There is a major need for the start of a well-organised telemedical diabetic eye-screening programme to reduce the economic burden of DR in Hungary.

Contributors GT planned and designed the survey and wrote the manuscript. DS and GLS designed and conducted the survey. ZZN planned the survey and reviewed the manuscript. HL and JN designed the survey, edited and reviewed the manuscript. All authors agree with the final version of the manuscript and agree to be accountable for all aspects of the work.

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