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Research Article

Cost-Effectiveness Analysis of Remote Monitoring in Patients with Diabetes Type 2

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Abstract

Background: This study aimed to investigate the economic evaluation of remote monitoring of type 2 diabetic patients for controlling glycosylated hemoglobin, compared to routine care.

Methods: Economic evaluation was carried out to calculate the unit cost of the remote patient monitoring (RPM) technology and routine treatment for type 2 diabetics, incremental cost-effectiveness ratio (ICER), and sensitivity analysis using the key variables, such as population size and cost items (in five categories of equipment and devices, building, staff, overhead costs, and consumables costs).

Results: Considering the ICER in the base-case model and in comparison to the routine treatment of type 2 diabetes, the remote type 2 diabetes monitoring system was placed in the second quarter (i.e., more effective and affordable technology) of the graph as the most dominant alternative (RPM vs. routine care: Total annual cost difference: -38476.477 US$/Unit reduction in hemoglobin A1c [HbA1c] difference: 0.488). The results of the sensitivity analysis revealed that in all scenarios, RPM was dominant, compared to routine treatment (the optimum ICER: -610.128 US$ per "Unit reduction in HbA1c" for the scenario with a 10% increase in the costs of the control and intervention group).

Conclusions: The RPM is a dominant alternative in comparison to routine treatment. The results indicated that the RPM interventions of 2 diabetes play an effective role in the reduction of HbA1c, which might be considered the rationale for policymakers to use this technology.
Keywords: Remote Monitoring, Telemedicine, Type 2 Diabetes, Glycosylated Hemoglobin, HbA1c, Economic Evaluation

1. Background

Diabetes is a chronic disease that imposes huge expenditure on healthcare systems (1). Diabetes is currently the fourth leading cause of visits to physicians in Western countries and the seventh leading cause of mortality across the United States (2, 3). Regarding the remarkable incidence over the past 2 decades, the number of diabetics is expected to reach 438 million by 2030 (4). In Iran, the prevalence of diabetes in individuals within the age range of 35-64 years was higher than 8% in 2004 (5). The treatment of diabetes is time-consuming and costly with relatively low success. In terms of age and gender, the costs for diabetics are estimated to be 20.3-fold higher than those for other patients (3, 6).

It is difficult to have access to proper specialist assistance in service offering units in villages and remote areas. The factors, such as physical disability, geographical, financial, and time limitations prevent individuals in these areas from visiting specialized centers in the city at the right time. It creates injustice and imposes expenditures on the health system (7). Remote patient monitoring (RPM) lessens such limitations by gathering data on patient health from places,

such as homes, using digital technologies, and then transmitting data to healthcare providers in various locations via telecommunication lines for more consideration and receiving feedback. The RPM involves the analysis of physiological parameters (e.g., blood sugar, blood pressure, and weight), counseling, education, and early diagnosis (8, 9).

According to the evidence, the RPM technology reduces the number of hospitalizations, visits to emergency departments, and the length of hospitalizations. Therefore, RPM is an efficient solution for disease prevention, proper access to services, a decrease in healthcare costs, and the minimization of complications. With RPM, resources are used more efficiently (10-13), and the patient's quality of life is remarkably increased (13). As a result, RPM can be more affordable than other approaches (14).

2. Objectives

This study deals with the economic evaluation of the RPM system in patients with type 2 diabetes in Iran's primary care system to provide physicians with reliable evidence to encourage them to use this effective technology. This study also aims to convince the health system and insurance policymakers to promote and allocate funds and reimburse for services.

3. Methods

This study concerns the economic evaluation of RPM technology for type 2 diabetic patients compared to routine treatment. Routine care refers to the patient's face-to-face visit by a health worker at a healthcare house (the lowest level of the healthcare network in Iran). The economic aspects are addressed through the relationship between costs and outcomes. In the present study, the outcome is the decrease in hemoglobin A1c (HbA1c) levels based on the consequential aggregated outcomes obtained from Salehi et al.'s meta-analysis (15). The costs of RPM technology were prospectively calculated through a standard costing method for the projection (RPM technology is not currently used in Iran). The cost of routine treatment was calculated, focusing on the level of the healthcare house. Finally, the incremental cost-effectiveness ratio (ICER) and one-way and multiple sensitivity analyses were carried out using variables, such as population size and cost items (in five categories of equipment and devices, building, staff, overhead costs, and consumables costs).

3.1. Cost-Effectiveness Analysis Using a Simple Incremental Cost-Effectiveness Plane

3.1.1. Outcomes

The HbA1c is the desired outcome of the present study. The results of a meta-analysis, which was previously published by the current team (15), showed that in evaluating the effectiveness of RPM technology in type 2 diabetic patients, compared to routine treatment, the index of effect size (i.e., weighted mean difference) was -0.41 with a 95% confidence interval (-0.28 to -0.54). That is, the RPM technology reduces HbA1c by 0.41 in patients with type 2 diabetes. The significance level of the Chi-square index was significant (P = 0.000), which indicated heterogeneity, and the value of was equal to 60.6%. This study also used the DPPC2 effect size index to evaluate the strength of the relationship. The results of the meta-analysis showed that in evaluating the effectiveness of RPM technology in type 2 diabetic patients, compared to routine treatment, the DPPC2 effect size index was -0.32 with a 95% confidence interval (-0.19 to -0.45), indicating that the relationship is significant (P = 0.048). In other words, RPM technology leads to more reduction of hemoglobin glucose levels, compared to routine treatment, although this amount is low. Additionally, the mean values of HbA1c in the control and intervention groups were 8.005 ± 0.57 and 7.517 ± 0.47, respectively [19].

3.1.2. Unit Cost Calculations

Since the technology of remote monitoring of type 2 diabetic patients is not available in Iran, the costs of the technology were projected by the diabetes program experts and information technology specialists. The costs were converted into US dollars based on the foreign exchange reference rate of Iran's Central Bank in 2019 (42000 IRRials per 1 US$). The perspective of Iran's Ministry of Health and Medical Education as the service provider was selected for the economic evaluation. Cost-effectiveness analysis was used for data analysis by considering the reduction of HbA1c outcome and sensitivity analysis. The costs were divided into five categories of capital (i.e., the cost of equipment and devices), building, staff, overhead costs (mainly energy-related), and consumables costs to carry out the calculations.

All construction, equipment, and personnel costs were calculated in their unit cost to their working hours throughout the year. The cost of physical space was calculated considering the minimum area required for the health house (100 m) in routine treatment and 6 m for RPM, and the approximate price of the property was determined at 150,000,000 IRRials (3,571 US$) according to the enactment of the Health Network Management Department of the Ministry of Health and Medical Education. The utilization period of the building was 30 years, and the depreciation rate was considered 1.7.

According to the price inquired from the Ministry of Health and Medical Education, the cost of the equipment required for each method was calculated based on the actual amount paid in 2018. The service life of the equipment was considered 5 years, and the depreciation coefficient was determined at 2.5.

In addition, the cost of human force for routine treatment was estimated based on two male and female health workers during office hours and working hours that the physician of the healthcare center, along with in-service training, spends once a week (1 - 3 hours) in the health house. The cost of human force for the RPM technology of type 2 diabetic

patients was estimated by examining two 24-hour shift health workers and the consultation fee of the remote general physician (if needed). Since there is no enactment on the number of staff and RPM equipment, the cost items of this technology were estimated according to the information technology specialists' views of the Ministry of Health and Medical Education. Moreover, as the introduction of the intervention leads to a change in the allocation of time for the service provider by the staff, it affects the costs of the staff. Given that the staff does not work full time in the routine treatment of patients, they should be motivated to provide full-time services by increasing the payment. Consequently, incremental costs for motivating the staff to provide 24-hour services are included in the analysis.

The price announced by the product support companies and the director of the diabetes program of the Ministry of Health and Medical Education was taken into account for the calculation of the unit cost of the consumables, including office supplies and stationery, network and computer systems maintenance, and the like. Furthermore, the number of tests that can be conducted over the course of one year (300 working days) was estimated up to four times a year. The collected data of the costs were entered into Excel worksheets, and the unit cost of technology was calculated.

4. Results

4.1. Total Annual Costs

The costs were divided into five categories of capital (i.e., the cost of equipment and devices), building, staff, overhead costs (mainly energy-related), and consumables costs to carry out the calculations. According to the estimations in this study, the estimated annual cost for routine treatment was 1,785,428,029 IRRials (42510.191 US$) (Table 1). Additionally, the estimated annual cost for the technology of remote monitoring of type 2 diabetic patients was 169,416,008 IRRials (4033.714 US$) (Table 2).

Table 1. Costing Details of Routine Treatment of Type 2 Diabetic Patients (Base Case; 1st Year)

Cost Items	Cost of Purchasing (US$)	Life (y)	Depreciation Rate	Cost/Year (IRRials)	Cost/Year (US$)
Equipment and devices cost	8530.952	5	1.7	60,911,000	1450.262
Building cost	3571.429	30	2.7	13,500,000	321.428
Consumables cost	-	-	-	497,340,000	11841.43
Human force cost	-	-	-	1,213,262,021	28887.19
Overhead cost	-	-	-	415008	9.881
Total				1,785,428,029	42510.191

Table 2. Costing Details of Remote Monitoring of Type 2 Diabetic Patients (Base Case; 1st Implementation Year)

Cost Items	Cost of Purchasing (US$)	Life (y)	Depreciation Rate	Cost/Year (IRRials)	Cost/Year (US$)
Equipment and devices cost	1666.667	5	1.7	11,900,000	283.3333
Building cost	2142.857	30	2.7	15,471,000	368.3571
Consumables cost	-	-	-	117,630,000	2800.714
Human force cost	-	-	-	24,000,000	571.4286
Overhead cost	-	-	-	0	0
Total				169,416,008	4033714

According to the price inquired from the Ministry of Health and Medical Education, the cost of the equipment required for each method was calculated based on the actual amount paid in 2018. The service life of the equipment was considered 5 years, and the depreciation coefficient was determined at 2.5.

According to the conducted calculations, the technology of PRM for type 2 diabetic patients, compared to routine treatment, can be considered the dominant alternative (RPM vs. routine care: Total annual cost difference: -38476.477 US$/"Unit reduction in HbA1c" difference: 0.488) (Table 3).

4.2. Base Cases

Table 3. Sensitivity Analysis of Remote Monitoring of Type 2 Diabetic Patients' Technology Compared to Routine Treatment

Parameter		Unit Cost (IRRials) of Treatment for Each Type 2 Diabetic Patient		ICER (Cost/Out Come) (IRRials/ Unit Reduction in HbA1c)	ICER (Cost/Out Come) (US$/Unit Reduction in HbA1c)	Status
Changes		RPM Technology	Routine Treatment			
Base case	-	169,416,008	1,785,428,029	-3311500043	-78845.2391	Dominant
Cost items	+ 0.5%	6,014,965	17,929,291	-24451028.48	-582.167	Dominant
	+ 10%	6,301,392	18,783,067	-25625363.46	-610.128	Dominant
	+ 15%	6,587,819	19,636,843	-2677969.44	-63.7612	Dominant
	- 0.5%	5,442,111	16,221,740	-22122360.57	-526.723	Dominant
	- 10%	5,155,685	15,367,964	-20958023.53	-499.001	Dominant
	- 15%	4,869,258	14,514,188	-19793688.55	-471.278	Dominant
Population	Minimum population	14,894,200	44,396,341	-605454.73	-14.4156	Dominant
	Average population	5,728,538	17,075,516	-23286695.55	-554.445	Dominant
	Maximum population	4,964,733	14,798,780	-20181801.58	-480.519	Dominant

Abbreviations: RPM, remote patient monitoring; ICER, incremental cost-effectiveness ratio.

4.3. Sensitivity Analysis

For uncertain parameters, a two-way sensitivity analysis with the recalculation of the results after 5%, 10%, and 15% changes in cost parameter values and one-way sensitivity analysis considering minimum (n = 500), maximum (n = 1500), and average (n = 1300) populations under the auspices of the desired health centers were conducted (Figure 1). These changes were made based on an inquiry from the Ministry of Health and Medical Education.

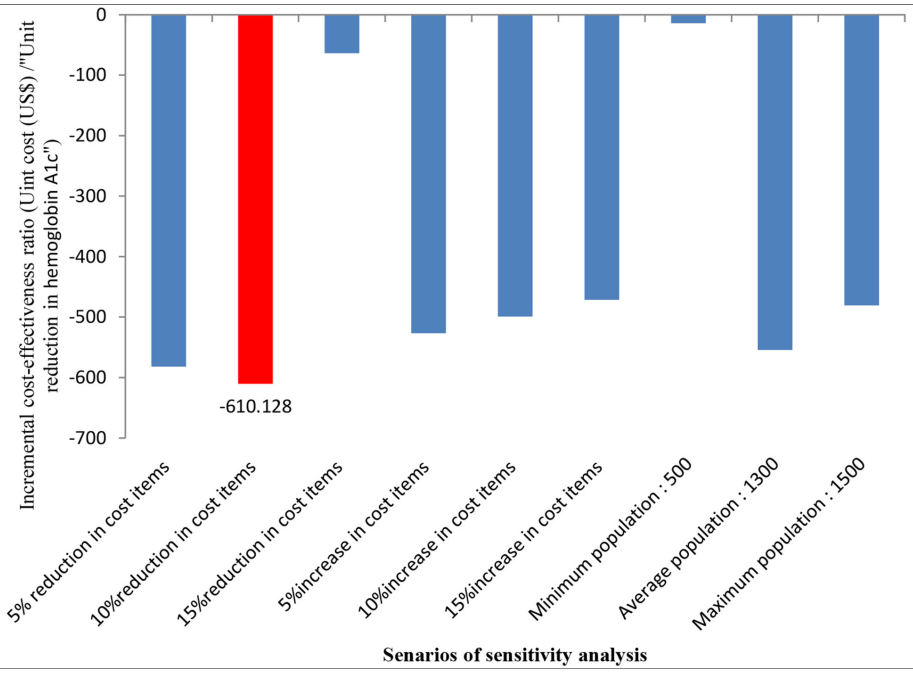

Figure 1. Scenarios of sensitivity analysis

4.3.1. A 5% Increase in Costs of Control and Intervention Groups

A 5% increase in the costs of both groups made the costs of the control and intervention groups equal to 17,929,291 IRRials (426.887 US$) and 6,014,965 IRRials (143.213 US$), respectively. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. According to these values, the calculated ICER value was approximately equal to -24,451,028 IRRials (582.167 US$) per unit of HbA1c reduction. This finding showed that the RPM technology was not sensitive to the 5% price increase parameter and is still a dominant option over routine treatment (charted in the second quarter, i.e., more effective and less expensive technology).

4.3.2. A 10% Increase in Costs of Control and Intervention Groups

As a result of a 10% increase in the costs of both groups, the costs of the control and intervention groups were equal to 18,783,067 IRRials (447.215 US$) and 6301392 IRRials (150.033 US$), respectively. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. The value of ICER was calculated according to the aforementioned values. The ICER value was approximately equal to -25,615,363 IRRials (609.889 US$) per unit of HbA1c reduction (dominant alternative vs. routine treatment).

4.3.3. A 15% Increase in Costs of Control and Intervention Groups

A 15% increase in the costs of both groups made the costs of the control and intervention groups equal to 19,636,843 IRRials (467.543 US$) and 6,587,819 IRRials (156.852 US$), respectively. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. The value of ICER was calculated according to the aforementioned values. The ICER value was approximately equal to -26,779,698 IRRials (637.611 US$) per unit of HbA1c reduction (dominant alternative vs. routine treatment).

4.3.4. A 5% Reduction in Costs of Control and Intervention Groups

By a 5% reduction in the costs of both groups, the costs of the control and intervention groups equaled 16,221,740 IRRials (386.231 US$) and 5,442,111 IRRials (129.574 US$), respectively. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. Again, the value of ICER was calculated according to the aforementioned values. The ICER value was approximately equal to -22,122,360 IRRials (52.672 US$) per unit of HbA1c reduction (dominant alternative vs. routine treatment).

4.3.5. A 10% Reduction in Costs of Control and Intervention Groups

As a result of a 10% reduction in the costs of both groups, the costs of the control and the intervention groups were equal to 15,367,964 and 5,155,685 IRRials (365.903 and 122.754 US$), respectively. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. The ICER value was calculated according to the aforementioned values. The ICER value was approximately equal to -20,958,023 IRRials (499US$) in costs per unit of HbA1c reduction (dominant alternative vs. routine treatment).

4.3.6. A 15% Reduction in Costs of Control and Intervention Groups

By a 15% reduction in the costs of both groups, the costs of the control and intervention groups were 14,514,188 IRRials (345.575 US$) and 4,869,258 IRRials (115.934 US$), respectively. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. The ICER value was calculated according to the aforementioned values. The ICER value was approximately equal to -19,793,688 IRRials (471.278 US$) per unit of HbA1c reduction (dominant alternative vs. routine treatment).

4.3.7. Minimum Frequency of Population under Supervision of Health Houses (N = 500)

In case the frequency of the population covered by health houses is the minimum population (n=500), the cost of routine treatment per individual will be equal to 44,396,341 IRRials (1057.055 US$). However, when using RPM technology for the minimum coverage of the population, the cost per individual equals 14,894,200 IRRials (354.623 US$). The outcome of the intervention and control groups were 7.517 and 8.005, respectively. The ICER value was calculated according to the aforementioned values, approximately equal to -60,545,404 IRRials (14415.572 US$) per unit of HbA1c reduction. This result showed that RPM technology was not sensitive to the minimum population and is still a dominant option, compared to routine treatment (charted in the second quarter, i.e., more effective and less expensive technology).

4.3.8. Average Frequency of Population under Supervision of Health Houses (N = 1300)

In case the frequency of the population covered by health houses is the average population (n = 1300), the cost of routine treatment for each individual is equal to 17,075,516 IRRials (406.559 US$); nevertheless, using RPM technology for the average population makes the cost per individual equal to 5,728,538 IRRials (136.393 US$). The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. The ICER value was calculated according to the aforementioned values, approximately equal to -23,286,695 IRRials (554.445119 US$) in costs per unit of HbA1c reduction (dominant alternative vs. routine treatment).

4.3.9. Maximum Frequency of Population under Supervision of Health Houses (N = 1500)

In case the frequency of the population covered by health houses is the maximum population (n = 1500), the cost of routine treatment for each individual is equal to 14,798,780 IRRials (352.351 US$); nonetheless, employing the RPM technology makes the cost per individual equal to 4,964,733 IRRials (118.207 US$) for the maximum population coverage. The outcomes of the intervention and control groups were 7.517 and 8.005, respectively. The ICER value was calculated according to the aforementioned values, approximately equal to -20,181,801 IRRials (480.519 US$) in costs per unit of HbA1c reduction (dominant alternative vs. routine treatment).

5. Discussion

The results of the economic evaluation (in the base-case model and by calculating the ICER) showed that RPM technology for type 2 diabetic patients was more effective and affordable than routine treatment because they are considered in the second quarter of the ICER graph; therefore, RPM technology is deemed the dominant alternative. Moreover, the results of sensitivity analysis showed that the findings of the study are consistent in terms of both cost items and population size variables, placed in the second quarter in all cases. This finding is consistent with the findings of other studies.

A 2017 randomized clinical trial study performed by Warren et al. revealed that total healthcare costs in the RPM group, including intervention costs, were lower than routine treatment (average 3781 $ vs. 4662 $; $P < 0.001$). Clinically and statistically, the benefits of RPM were achieved at a lower cost. Therefore, using RPM was cost-effective and had more health benefits than routine treatment (16). Fountoulakis et al. indicated that the intervention was more cost-effective for patients who lived more than 100 km away from the health house. The results revealed that RPM technology is more cost-effective than routine treatment (17).

The RPM technology imposes lower costs on the healthcare system and is more effective than routine treatment with no side effects reported to date (15). Moreover, the high accuracy and confidentiality of information are also included. In addition, the results obtained from the patient-measured HbA1c are generally similar to those of the patient's professional tests (18). The RPM technology, which is more cost-effective and affordable, provides better monitoring and higher satisfaction for patients and helps individuals who are unable to refer to clinics due to geographical constraints, infectious diseases (e.g., coronavirus disease 2019), or resource scarcity (19). The implementation of RPM technology is justifiable, compared to the conventional treatment methods, which impose different costs.

5.1. Limitations

It is noteworthy that there was no similar economic evaluation model in the literature review, including the decision tree and Markov model; accordingly, it could be used for domestication. Moreover, a simple ICER had been employed for economic evaluation in most studies, and it was not possible to carry out the economic evaluation based on the quality-adjusted life year in this study.

5.2. Conclusions

The obtained results indicated that RPM technology used for type 2 diabetic patients is more effective and cost-effective in the reduction of HbA1c, compared to routine care, which can be regarded as a justification for policymakers to implement this technology. The evidence on the long-term RPM experience is required for future studies. Considering that there is no such technology for remote monitoring of type 2 diabetic patients in Iran and investment in information technology will be increased in the future, further studies on this field are needed, and the infrastructure for the deployment of this technology should be developed to provide widespread use of this beneficial, effective, and affordable technology in Iran.

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