Cost-effectiveness of a shared computerized decision support system for diabetes linked to electronic medical records

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Received 12 May 2011
Accepted 2 October 2011
Published Online First 3 November 2011

ABSTRACT

Background Computerized decision support systems (CDSSs) are believed to enhance patient care and reduce healthcare costs; however the current evidence is limited and the cost-effectiveness remains unknown.

Objective To estimate the long-term cost-effectiveness of a CDSS linked to evidence-based treatment recommendations for type 2 diabetes.

Methods Using the Ontario Diabetes Economic Model, changes in factors (eg, HbA1c) from a randomized controlled trial were used to estimate cost-effectiveness. The cost of implementation, development, and maintenance of the core dataset, and projected diabetes-related complications were included. The base case assumed a 1-year treatment effect, 5% discount rate, and 40-year time horizon. Univariate, one-way sensitivity analyses were carried out by altering different parameter values. The perspective was the Ontario Ministry of Health and costs were in 2010 Canadian dollars.

Results The cost of implementing the intervention was $483 699. The one-year intervention reduced HbA1c by 0.2 and systolic blood pressure by 3.95 mm Hg, but increased body mass index by 0.02 kg/m^2, resulting in a relative risk reduction of 14% in the occurrence of amputation. The model estimated that the intervention resulted in an additional 0.0117 quality-adjusted life year; the incremental cost-effectiveness ratio was $160 845 per quality-adjusted life-year.

Conclusion The web-based prototype decision support system slightly improved short-term risk factors. The model predicted moderate improvements in long-term health outcomes. This disease management program will need to develop considerable efficiencies in terms of costs and processes or improved effectiveness to be considered a cost-effective intervention for treating patients with type 2 diabetes.

BACKGROUND

Diabetes is the 7th leading cause of death in Canada, and is a significant cause of disability and morbidity.[1] The burden of diabetes is enormous due to the increased risk for complications (eg, stroke, heart disease, peripheral vascular disease, retinopathy, and renal failure) arising from the disease. More than 1.16 million (8.3%) Ontario residents are estimated to have diabetes, and this number is expected to grow to more than 1.9 million (11.9%) by 2020.[2] In Canada, $12.2 billion annually is spent on healthcare, disability, and premature death costs related to diabetes.[3] Estimates suggest that the economic burden of diabetes will increase by another $4.7 billion by 2020 given the current increasing trend in diabetes prevalence.[3]

Studies have demonstrated that diabetes complications can be prevented or delayed through periodic health, eye, and foot examinations, along with control of blood glucose levels, lipids, glycated hemoglobin (HbA1c), and other risk factors such as diet, weight, and cigarette smoking.[4–7] However, the development and distribution of clinical guidelines which outline preventive measures are insufficient to achieve a satisfactory level of guideline adherence since considerable demands are placed on the primary care provider and the healthcare system. There are large numbers of patients with diabetes, and the disease itself is complex and progressive, requiring medical care and monitoring, as well as social, psychological, emotional, and educational support.[7] Adherence to evidence-based guidelines which promote diabetes management is critical to the success of any plan to reduce complications arising from diabetes.

There is widespread enthusiasm for computerized decision support systems (CDSSs) to help to actively implement clinical practice guidelines and provide a patient communication system to facilitate patients' behavioral changes to allow for accessible, efficient, and continued medical advice. While some perceive that CDSSs improve the quality of care and reduce healthcare costs for patients with chronic disease, the current supporting evidence is limited and the cost-effectiveness of these systems remains unknown.[8 9]

The lack of cost-effectiveness studies published in the literature is surprising given that well developed methods exist that have the ability to model the progression of diabetes and the lifetime costs and outcomes associated with different disease management strategies. Diabetes decision-analytic models can simulate the impact of alternative interventions on the probability and costs of experiencing complications.[10–14] In fact, economic evaluations have demonstrated that the substantial costs of treating diabetes-related complications can be reduced through investments in measures to control blood glucose and blood pressure.[15 16] The mean quality-adjusted life years (QALYs) or mean life years (LYs) gained from an intervention can be quantified based on the estimated occurrence of complications. These types of models can assist policy-makers in the identification of probable long-term benefits, costs, and consequences of different resource allocation decisions.

The objective of this paper was to measure the long-term cost-effectiveness of a community-based CDSS for diabetes, shared between patients and physicians, using a decision-analytic model, the Ontario Diabetes Economic Model (ODEM).

METHODS

Model parameterization

Diabetes intervention and study group

Pertinent patient information required to populate the economic model was obtained from data collected from the Computerization of Medical Practices for the Enhancement of Therapeutic Effectiveness (COMPETE) II pragmatic randomized trial conducted in 47 primary care practices in three regions of Ontario. COMPETE II was a web-based, continuously updated, secure, patient-specific diabetes tracker, interfaced with the patient's electronic medical record (EMR) for physician access and via a web portal and paper summary for patients, plus an automated telephone reminder service for patients, on access, quality, satisfaction, and continuity of care. The tracker was designed to be seamlessly interfaced with any EMR system. All patient information, including that collected by physicians from clinical visits, by the COMPETE investigators from labs, and by the patient themselves, was entered into the COMPETE central data repository. Information on the status of each patient over time with respect to key diabetes-related variables relative to optimal targets was collected and displayed in an intuitive color-coded format. Short recommendations and the most current evidence-based information were also provided. The information contained in the patient and physician versions was identical, except that lay language was used in the advice for patients.[17] The objective was to ensure that both the physician and the patient had access to up-to-date values for each variable for patient visits in order to improve the quality of diabetes management in primary care. Patients in the control group were provided with usual care from their physician.[17] The primary outcome measure of the pragmatic randomized trial was a process composite score. This outcome was calculated as the difference between the intervention and control groups in terms of mean change for individual patients in a composite score of process quality for the end of the study relative to baseline. The process composite score represented the sum of the quality of monitoring of each of the relevant variables (glycated hemoglobin, blood pressure, low density lipoprotein cholesterol, body mass index, albuminuria, foot check, smoking, and physical activity) compared with their respective targets. The study found that the mean difference in process composite score improved significantly more in the intervention group than in the control group (difference 1.27; $p<0.001$).[17] This result supports the fact that a behavioral change has taken place following implementation of the CDSS.

The results of this trial have been published previously.[17] Briefly, the study recruited 47 community-based primary care providers who were already using EMR systems in their practice. A total of 511 patients 18 years of age and older, with a diagnosis of type 2 diabetes, were randomized into the study, 253 in the intervention group and 258 in the control group. The mean age of patients was 61 years (SD=13.1) in the intervention group and 60.5 years (SD=11.9) in the control group (table 1). Approximately 50% of the population in each group was female; the average HbA1c was 7.0% (SD=1.4) and 7.1% (SD=1.6) in the intervention and control groups, respectively. Roughly 12% of patients in the intervention group and 16% in the control group were smokers at baseline.[17]

Table 1 Baseline characteristics of patients enrolled in COMPETE II (n=511)[17]

Clinical variable	Intervention (n=253)	Control (n=258)
Mean age at study entry (SD)	61.0 (13.1)	60.5 (11.9)
Duration of diabetes, years (SD)	8.7 (9.0)	10.0 (10.7)
Female, n (%)	130 (51.4)	122 (47.3)
HbA1c, % (SD)	7.0 (1.4)	7.1 (1.6)
Systolic blood pressure	134.8 (15.5)	134.6 (16.5)
Diastolic blood pressure	76.2 (9.8)	75.0 (9.6)
HDL cholesterol	1.40 (0.88)	1.32 (0.44)
LDL cholesterol	2.48 (0.56)	2.62 (0.65)
BMI	32.1 (8.2)	31.6 (6.9)

BMI, body mass index; HDL, high density lipoprotein; LDL, low density lipoprotein.

The ODEM

The ODEM is a patient-level computerized simulation model that uses an integrated system of parametric risk equations to predict the likely occurrence and cost of seven major diabetes-related complications (ie, myocardial infarction, amputation, renal failure, stroke, blindness, ischemic heart disease, congestive heart failure) over a lifetime for patients with specified characteristics (eg, age and sex) and time-varying risk factors (eg, HbA1c, systolic blood pressure). The parametric equations are based on the United Kingdom Prospective Diabetes Study Outcomes Model.[12] The ODEM has been described in detail elsewhere.[7] Simulated patients enter the model with a pre-specified health status and can experience one or more complications or die during any annual cycle over the 40-year time horizon. The ODEM estimates complications, life-expectancy, QALYs, and the costs of complications in people with type 2 diabetes. The primary outcome measure for this economic evaluation is the QALY. Consequently, the economic evaluation takes the form of a cost-utility analysis and calculates the incremental cost per QALY gained.

Costs

Ontario-specific diabetes-related healthcare costs in the ODEM

The costs assigned to the seven diabetes-related complications in the ODEM were obtained from a large prospective cohort of individuals with diabetes (n=734 113) over a 10-year time period representing over 4.4 million patient-years in Ontario. The actual annual resource utilization profiles of each diabetes patient and their experience of complications were obtained. Unit costs were collected from various Canadian sources (eg, Ontario Drug Benefit Formulary, Statistics Canada) and assigned to all healthcare resource utilization (eg, inpatient hospital, emergency room visits). The values represent the direct medical costs of each of the seven diabetes-related complications in the year in which an event occurs (eg, immediate costs), as well as the costs in subsequent years associated with the ongoing management of the complication (eg, long-term costs). For example, the cost of suffering a myocardial infarction in the year of the event is $19 015 and the cost associated with treating this patient in subsequent years is $4246.

Program implementation costs

Program development and implementation costs were tabulated. Included in the total were the costs associated with hiring personnel to develop and test the diabetes tracker, provide input into data standards and technical specifications, ongoing project management, and all computer-relevant infrastructure required for the intervention. These expenses were assigned to the treatment group only. All costs are presented in 2010 Canadian dollars.

Parameterization of ODEM

Data from the COMPETE II randomized trial were used as inputs into the ODEM. The differences between the intervention and control groups in the key risk factors (ie, HbA1c,

systolic blood pressure, cholesterol, and smoking status) over the course of the study were calculated and run through the model to provide estimates of life expectancy, QALYs, and costs. Statistically significant improvements were observed in the treatment group for HbA1c (−0.20%, p=0.029) and systolic blood pressure (−3.95 mm Hg, p=0.036) relative to the control group. There was also a reduction in the number of smokers in the treatment group (−0.02) but this was not statistically significant. Body mass index actually increased in the patients receiving the intervention compared to those who were not randomized to the treatment group.[17]

Incremental cost-effectiveness ratios were calculated using the net cost of implementing the diabetes tracker and the cost of treating complications as well as the effectiveness (ie, QALYs) predicted over a patient's lifetime. In the base case, we assumed that there were no continuing benefits of the program in terms of its impact on risk factors beyond the one-year intervention period. Given that we could not be certain that the behavioral change, and thus the effect on clinical outcomes, would be sustained past the study period, the treatment effect was assumed to last for only 1 year. The model had a 40-year time horizon, and a discount rate of 5% for both costs and effects. The perspective for the economic evaluation was the Ontario Ministry of Health and Long-term Care.

Sensitivity analyses

Simple sensitivity analyses were conducted based on different assumptions regarding the duration of the program and treatment effect (ie, 5 and 10 years). This will look at the potential impact of sustaining the behavior change over a longer time period. In addition, both the costs and effects were discounted at rates of 3% and 0%.

RESULTS

Diabetes tracker implementation costs

When the costs associated with the direct labor, consultant and sub-contracts, and direct material necessary to develop and implement the COMPETE II Tracker were taken into account, the total upfront investment was $483 699 or $1912 per patient.

Model predictions of long-term complications and death

Over the one-year treatment period, the ODEM estimated that the one-year intervention resulted in a relative risk reduction of 14% in the occurrence of amputation in the group with access to the diabetes tracker compared to the patients in the control group (table 2). However, if the intervention is removed at the end of the 1-year time period, these short-term benefits are dramatically reduced over the longer term and patient outcomes from the intervention group begin to resemble those of the control. For example, once the follow-up is extended to 40 years, the relative risk reduction for amputations is reduced to 1.5% from 14%.

Cost-effectiveness results

As shown in table 3, the incremental mean lifetime cost per patient in the intervention arm was estimated to be $1912. The ODEM estimated that the avoidance of complications realized through the intervention would result in an additional 0.0117 QALYs. The incremental cost-effectiveness ratio was estimated to be $156 970 per life year gained and $160 845 per QALY gained.

Sensitivity analyses

If the patients in the model were treated for 5 years, there was an increase in the number of incremental QALYs from 0.0117 in the base case to 0.0421, an increase of about 260% (table 4). This is a result of the reductions in downstream complications due to the intervention. These reductions in complications and thus increase in quality of life and life years gained translated into an incremental cost-effectiveness ratio of $186 728. The increase in the incremental cost-effectiveness ratio is due to the increase in program costs being extended by $1912 per patient per year for the 5-year treatment period. Similarly, if the treatment period was extended to 10 years, there was more than a sixfold increase in the number of QALYs gained compared to the base case and the incremental cost-effectiveness ratio was $173 654.

For the 40-year projection, the discount rate was changed to 0% and 3% to explore its impact on the incremental cost-effectiveness ratios. Results presented in table 4 showed that these changes did not change the fact that the diabetes tracker still had a high cost per QALY.

Table 2 Predicted one-year cumulative first event rates as a result of the program and treatment effect duration of 1 year

Complication	Control (per 1000)	1-year program (per 1000)	ARR	RRR
IHD	5.9	5.5	0.4	8%
MI	28.5	26.4	2.1	7%
Heart failure	6.3	5.9	0.3	5%
Stroke	9.7	8.5	1.2	12%
Amputation	2.1	1.8	0.3	14%
Blindness	4.2	4.0	0.3	7%
Renal failure	0.8	0.7	0.1	9%

ARR, absolute risk reduction; IHD, ischemic heart disease; MI, myocardial infarction; RRR, relative risk reduction.

DISCUSSION

This study used a diabetes decision-analytic economic model to assess the cost-effectiveness of an integrated provider–patient web-based decision support prototype system for type 2 diabetes. The CDSS studied here was shown to slightly improve the clinical outcomes in key diabetes-related variables following its implementation. The economic evaluation showed that these modest changes generated a small amount of savings due to the reduction in the costs associated with treating fewer complications, however these were not offset by the high intervention implementation costs.

This study contributes significantly to the literature since it included a full enumeration of the total costs required to develop (eg, capital outlay) and implement (eg, labor, clinical team involvement) the CDSS in addition to healthcare costs. This has been identified as a shortcoming of the limited number of studies in the literature that have provided some information on the effect of disease management on healthcare resource utilization or costs.[9] The authors acknowledge that our investigation of the costs of the CDSS did not include the costs of future maintenance. In any event, the costs were synthesized with the

Table 3 Incremental cost-effectiveness analysis results from the Ontario Diabetes Economic Model (ODEM) (base case analysis)

	Disease management costs	Intervention costs	Mean lifetime cost/patient	QALYs	LYs
Intervention	$61 340	$1912	$63 252	7.6507	9.9688
Control	$61 367	0	$61 367	7.6390	9.9567
Incremental	($26)	$1912	$1886	0.0117	0.0120
ICER				$160 845	$156 970

ICER, incremental cost-effectiveness ratio; LYs, life years; QALYs, quality adjusted life years. Note, numbers do not add up exactly owing to rounding.

Table 4 Univariate sensitivity analyses

Treatment duration	Incremental costs	Incremental QALYs	Incremental LYs	Incremental cost per QALY
Treatment 5 years	$7858	0.0421	0.0414	$186 728
Treatment 10 years	$12 850	0.0740	0.0789	$173 654
Discount rate 0%	$2016	0.0259	0.0292	$77 758
Discount rate 3%	$2048	0.0201	0.0245	$102 053

LYs, life years; QALYs, quality adjusted life years.

consequences or outcomes of the intervention (ie, cost-utility analysis) to produce a full economic evaluation (ie, costs and effects).

There are a number of other strengths of this evaluation. First, the effectiveness of the CDSS that was input into the economic model came from a randomized controlled trial, so there can be little debate over the quality of the evidence. Second, the economic model uses validated risk equations from the United Kingdom Prospective Diabetes Study[12] that followed patients for up to 20 years with a median follow-up greater than 10 years. Second, the costs of treating diabetes and diabetes-related complications in the model are based on actual health-care resource utilization of people with diabetes in the province of Ontario. On the request of the Ontario Health Technology Advisory Committee, Ministry of Health and Long-term Care, the model has been used to evaluate a number of different treatment strategies. For example, the model estimated that a primary care multidisciplinary diabetes management program introduced in Sault Ste. Marie, Ontario,[7] as well as bariatric surgery,[18] would be considered cost-effective treatments for adults with type 2 diabetes while insulin pumps were not cost-effective for adults with insulin-dependent type 2 diabetes.[19]

Although the ODEM has proven useful, the model has a few limitations. One of the limitations of the model is its inability to assess uncertainty, both Monte Carlo error (chance variability between individuals) and parameter uncertainty (uncertainty in estimates). The focus of economic evaluation is on expected costs and effects, and the uncertainty surrounding those expected values. The overall purpose of probabilistic modeling is to reflect the uncertainty in the input parameters (eg, demographics, costs) of the decision model and describe what this means for uncertainty over the outputs of interest: measures of cost, effect, and cost-effectiveness, and how this impacts decision making (ie, decision uncertainty) and the confidence that can be placed in the analysis results. Uncertainty over the results of an analysis implies the possibility of incorrect decision making that would impose a cost in terms of benefits foregone.[20] A new model interface is being planned which aims to address this limitation.

Similarly, while this first version of the COMPETE II diabetes CDSS is not cost-effective, future iterations should benefit from the efficiency of experience and improved implementation for better effectiveness.

CONCLUSIONS

While the COMPETE II intervention resulted in clinical gains, the cost-effectiveness analysis indicated that the tracker was a costly intervention in the treatment of diabetes.

In conclusion, providing computer decision support for diabetes management in primary care modestly improved short-term risk factors and as a result, the ODEM predicted moderate improvements in long-term health outcomes. These improvements were not offset by the high intervention costs. However, it must be acknowledged that the CDSS was implemented in a small group of practices and broader implementation would enable considerable economies of scale in initiating and maintaining the system. In addition, the intervention period was short and over the longer term the intervention may be more economically attractive given that the upfront investment in infrastructure has been made (eg, roll-out costs).

The acceptance and diffusion of new information technologies used to manage chronic diseases is limited without evidence of both clinical and cost effectiveness. This study is one of the only true economic evaluations (ie, includes both costs and effects) of a CDSS for diabetes management. Although CDSSs for chronic disease management may improve the quality of care for patients with chronic disease, long-term studies are required to show the economic benefit and financial return on investment.[9]

Acknowledgments We thank Dr Gary Foster for his help in analyzing the clinical trial data and responding to requests for clarification and extra analyses.

Competing interests The authors had full autonomy over the conduct of this study. This economic evaluation was not supported by any funding source. DO'R holds an Ontario Ministry of Health and Long-term Care Career Scientist Award.

Contributors DO'R was responsible for conducting the economic evaluation, the interpretation of the data, and the writing of the manuscript. AH was responsible for the conception and design of the randomized controlled trial, provided costing data, and also took part in editing the manuscript. GB is a health economist who helped with populating the Ontario Diabetes Economic Model. As the trial project research coordinator, ST helped with the collection of the data and also helped edit the manuscript. RG acted as a resource person for the economic evaluation, assisted with interpretation of the data, and helped in editing the manuscript. All of the authors contributed to and approved the final version of the paper being submitted for publication.

Provenance and peer review Not commissioned; externally peer reviewed.

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