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SYMPOSIUM

Cost-Effectiveness of Implementing the Chronic Care Model for Diabetes Care in a Military Population

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Abstract

Background:

Applying the chronic care model (CCM) for diabetes management helps improve health outcomes and patient care. The CCM was implemented at U.S. Air Force Wilford Hall Medical Center through the Diabetes Outreach Clinic (DOC) in 2006, but its cost-effectiveness in this setting is unknown.

Methods:

We constructed a Markov decision model to estimate DOC cost-effectiveness compared with usual care (UC) over a 20-year period. Based on empirical, post-intervention demographic and clinical data, we applied United Kingdom Prospective Diabetes Study risk equations to predict long-term probabilities of developing microvascular or macrovascular complications. Health care system and societal perspectives were considered, discounting costs and benefits at 3% annually. Intervention costs and outcomes were obtained from military data, while other costs, disease progression data, and utilities were drawn from published literature.

Results:

From a health care system perspective, the DOC cost $45,495 per quality-adjusted life-year (QALY) compared with UC; from a societal perspective, the DOC compared with UC cost $42,051/QALY (when the model started with the uncomplicated diabetes cohort), $61,243/QALY (when starting with the DOC cohort), or $61,813/QALY (when starting with the UC cohort). In one-way sensitivity analyses, results were most sensitive to yearly costs for specialty care visits. In probabilistic sensitivity analysis, the DOC was favored in 51% of model iterations using an acceptability threshold of $50,000/QALY and in 72% at a threshold of $100,000/QALY.

Conclusions:

The DOC strategy for diabetes care, performed with the CCM methodology in a military population, appears to be economically reasonable compared with UC.

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Abbreviations: (A1C) glycated hemoglobin, (CCM) chronic care model, (DOC) Diabetes Outreach Clinic, (ICER) incremental cost-effectiveness ratio, (MHS) Military Health System, (QALY) quality-adjusted life-year, (UC) usual care, (UKPDS) United Kingdom Prospective Diabetes Study, (WHMC) Wilford Hall Medical Center

Keywords: chronic care model, cost-effectiveness, diabetes care, Markov decision model, military population

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Introduction

Diabetes is a major cause of morbidity and mortality in the United States, resulting in substantial human and economic costs.[1–3] Diabetes management is complicated, requiring continuous patient involvement and the assistance of a team of health care professionals.[4,5] Despite the availability of effective medications and evidence-based practice recommendations,[5,6] most diabetes patients do not achieve therapeutic goals, and significant opportunities remain to improve diabetes management.[7–9] Moreover, broad variations persist in the quality of diabetes care across both health care providers and practice settings.[5]

The chronic care model (CCM),[10] a multifaceted framework to redesign daily medical practices and enhance health care delivery, is used in many health care settings to guide systematic and individual improvements in chronic illness management, including diabetes.[4,11–14] The premise of the CCM is that quality care is not delivered in isolation but that each of the CCM elements works in tandem.[15] Six key elements are identified by the CCM, including four interdependent elements at the practice level (self-management support, decision support, delivery system design, and clinical information systems); a higher-level element (organizations of health care) at the health systems, which plays an overarching role in guiding practice-level development; and a broader-level element (linkages of resources and policies) at the community, which provides necessary resources and establishes policies linked to chronic illness care.[12,15–18] Previous studies show that CCM-based diabetes interventions improve patient outcomes, including better processes of care [e.g., diabetic foot examinations and glycated hemoglobin (A1C) checks] and intermediate outcomes (e.g., A1C, blood pressure, and lipids), reduced risk for cardiovascular events, and higher health status and health-related quality of life.[4,11–16,19–35] However, little is known about the cost-effectiveness of implementing the CCM for diabetes care.

Through its TRICARE program, the U.S. Department of Defense Military Health System (MHS) is one of the largest providers of health care in the United States, providing care to approximately 9.5 million beneficiaries at an annual cost of $48.5 billion (fiscal year 2010).[36] Diabetes is a critical issue for the MHS, with a prevalence of 5% among MHS enrollees and even greater prevalence rates in overweight (8–11%) and obese (16–37%) retirees and their dependents.[37–42] The total annual cost of TRICARE beneficiaries aged 20–65 years with diagnosed diabetes was approximately $300 million in 2006; the average additional medical cost per beneficiary diagnosed with diabetes was $2150 annually.[43,44]

In an effort to improve outcomes and reduce costs associated with diabetes, the U.S. Air Force Wilford Hall Medical Center (WHMC) implemented the CCM in 2006 through the Diabetes Outreach Clinic (DOC), which restructured health care for diabetic beneficiaries by delivering services through a single, centralized location. Our analysis aimed to estimate costs, clinical outcomes, and cost-effectiveness of implementing the CCM for diabetes care in this military setting.

Methods

Diabetes Outreach Clinic at Wilford Hall Medical Center

The DOC operated during calendar years 2006–2008 at the WHMC. It was operating as a "one-stop shop" for diabetes patients, which allowed patients to obtain comprehensive care with one visit. The DOC staff consisted of an endocrinologist, a nurse practitioner, a counselor, an ophthalmologist, a dietitian, a certified diabetes educator, and support staff. Diabetes patients were seen for both diabetes-related treatments and routine primary care in the DOC.

The population for these analyses included individuals with an ICD-9-CM diagnosis of diabetes (250.xx) receiving care in the WHMC in the San Antonio area between January 2005 and December 2008. A total of 9654 diabetes patients, including 1171 DOC patients and 8483 usual care (UC) patients, from the military population health database were identified. Administrative data included demographics, clinical data (e.g., A1C, blood pressure, and lipids), medical utilization (e.g., primary and specialty care visits), and pharmacy records. For DOC patients, we defined the records from 1 year prior to DOC entry as pre-DOC data (or baseline) and all records after DOC entry as post-DOC data (or follow-up); for UC patients, we defined the records from 1 year prior to January 2006 (i.e., DOC starting date) as baseline data and all records after that time as follow-up data. A total of 249 patients less than 18 years of age were excluded, and thus the study cohort in this analysis comprised 9405 diabetes patients (or 97.4% of the original population), including 1171 DOC and 8234 UC patients (**Appendix 1**).

Framework of a Markov Decision Model

Using TreeAge Pro Suite 2009 (TreeAge Software, Williamstown, MA), we modified a prior Markov decision model[45] to estimate the incremental cost-effectiveness of the DOC compared with UC. The model directly incorporated intervention costs and effectiveness from military data to estimate life expectancy, quality-adjusted life-expectancy [expressed as quality-adjusted life-years (QALYs)], clinical outcomes, as well as direct medical and nonmedical costs associated with the DOC and UC. Our base case model examined 50-year-olds with type 2 diabetes who participated in the DOC or UC in yearly cycles over a 20-year time horizon from the health care system perspective. Future costs and benefits were discounted at 3% annually,[46] and the U.S. Consumer Price Index[47] was used to convert all monetary costs to 2010 U.S. dollars.

Basic Model Structure

The model is illustrated in **Figure 1**, which describes the progression of disease through microvascular complications, macrovascular complications, and mortality. In this model, all patients were assumed to have uncomplicated diabetes at the start of the model. Over time, diabetes could progress to microvascular complications (including retinopathy, nephropathy, or neuropathy), macrovascular complications (including coronary heart disease or stroke), or both. Complications were assumed to be irreversible. To be conservative, the DOC and UC were assumed to have identical effects on the progression of disease in patients who already had diabetes complications, thus implying that the model only examined differences between strategies in the development of complications.

In the model, cost-effectiveness was estimated over a 20-year period following the intervention period, assuming that treatments continued for the duration. The United Kingdom Prospective Diabetes Study (UKPDS) risk equations were applied to predict treatment effects, i.e., long-term probabilities of developing microvascular[48–50] and macrovascular[51–53] complications, using empirical, post-intervention demographic and clinical data in those diabetes patients who were alive and without diabetes complications at the date (i.e., December 2008) when the DOC closed operation. Among 9405 diabetes patients, 1417 diabetes patients who fulfilled these criteria were identified (196 DOC and 1221 UC patients;

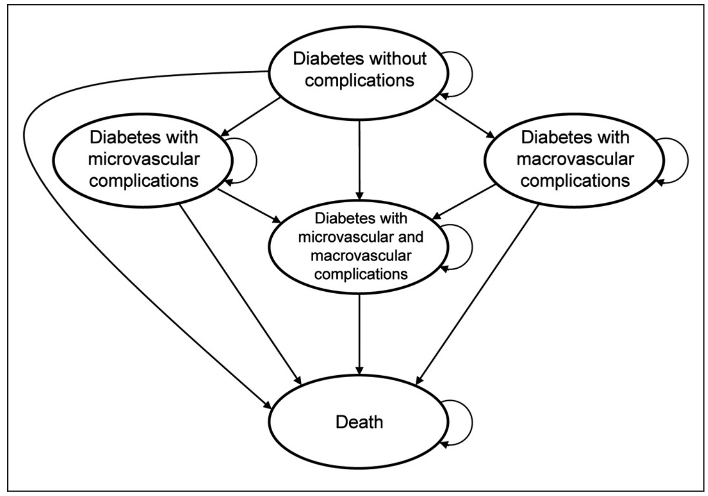

Figure 1. Markov-state diagram for the basic model structure. Ovals indicate health states. Subjects may remain within a health state (short curved arrow) or may move to a different health state (straight arrow or long curved arrow).

Appendix 2). The parameters applied in the UKPDS risk equations and the Markov decision model are summarized in **Table 1**. Given significant differences in parameter values between groups (**Appendix 2**), **Table 1** contains values adjusted for all known demographic and clinical characteristics that differed between groups at baseline. Model assumptions are listed in the footnotes for **Table 1**; in the base case analysis, based on our data characteristics, we assumed a cohort with a mean age of 50 years, white race, nonsmoking status, mean diabetes duration of 5 years, and other patient parameters as listed in **Table 1**.

Model input parameters are shown in **Tables 2** and **3** and **Appendixes 3–7**. Probabilities of death and of micro-vascular or macrovascular complications were predicted using the UKPDS risk equations and/or derived from the Action in Diabetes and Vascular Disease: Preterax and Diamicron Modified Release Controlled Evaluation study[54] (**Appendixes 3–6**).

Annual direct medical costs related to health care providers, laboratory tests, physician office visits, diabetes complications, death, and medications were included in the model (**Table 2** and **Appendix 7**). Indirect costs were not included, assuming their capture in the assessment of QALYs, per the recommendation of the Panel on Cost-Effectiveness in Health and Medicine.[46] Medicare reimbursement data were used to estimate costs of laboratory tests (A1C and lipid panel) and physician office visits.[55] Hourly wage costs for health care providers in both the DOC and UC were based on National

Table 1.
Parameters Used in UKPDS Risk Equations and the Markov Decision Model[a]

Parameter used in UKPDS risk equations (based on 1417 diabetes patients surviving without diabetes complications at the date when the DOC closed operation)	DOC (*n* = 196)	UC (*n* = 1221)
Adjusted mean A1C (%)[b]	6.8	7.1
Adjusted mean SBP (mmHg)[b]	128.4	130.2
Adjusted mean total cholesterol (mg/dl)[b]	173.7	185.0
Adjusted mean HDLc (mg/dl)[b]	49.6	48.2
Adjusted mean LDLc (mg/dl)[b]	94.7	104.0
Gender	M, 100 (51.0%); F, 96 (49.0%)	M, 506 (41.4%); F, 715 (58.6%)
Age at the date when the DOC closed operation (years)[c]	50	50
Race (White/Afro-Caribbean/Asian-Indian)[d]	Assumption	Assumption
Weight (kg)[e]	88.8	88.8
Height (cm)[e]	167.9	167.9
BMI (kg/m^2)[e]	31.4	31.4
Smoking status (nonsmoker/exsmoker/current smoker)[f]	Assumption	Assumption
Creatinine clearance <100 ml/min (Yes/No)[g]	Assumption	Assumption
Atrial fibrillation (Yes/No)[h]	Assumption	Assumption
Macroalbuminuria (Yes/No)[i]	No	No
Microalbuminuria (Yes/No)[j]	No	No
Duration of diabetes[k]	Assumption	Assumption
Parameter used in the Markov decision model (based on all 9405 diabetes patients)	DOC (*n* = 1171)	UC (*n* = 8234)
Diabetes complications at the date when the DOC closed operation, *n* (%)		
No complications	196 (16.93)	1221 (15.11)
Microvascular complications only	678 (58.55)	3165 (39.18)
Macrovascular complications only	27 (2.33)	302 (3.74)
Microvascular and macrovascular complications	257 (22.19)	3391 (41.97)
Adjusted mean yearly number of primary care visits per patient (SE; 95% CI; median)[l]	2.7 (0.2; 2.3–3.1; 2.0)	3.9 (0.1; 3.7–4.1; 3.0)
Adjusted mean yearly number of specialty care visits per patient (SE; 95% CI; median)[l]	15.3 (0.4; 14.4–16.1; 9.0)	16.1 (0.3; 15.6–16.7; 10.3)
Adjusted mean yearly number of A1C tests per patient (SE; 95% CI)	2.6 (0.04; 2.58–2.72)	2.1 (0.02; 2.07–2.17)
Adjusted mean yearly number of lipid panel tests per patient (SE; 95% CI)	2.1 (0.03; 2.03–2.15)	1.6 (0.02; 1.55–1.63)

[a] SBP, systolic blood pressure; HDLc, high-density lipoprotein cholesterol; LDLc, low-density lipoprotein cholesterol; M, male; F, female; BMI, body mass index; SE, standard error; CI, confidence interval.
[b] The mean value of each clinical data was adjusted for age at study entry, A1C at baseline, and gender.
[c] The mean age of 50 years was from all 1417 diabetes patients surviving without any diabetes complications at the date (i.e., December 2008) when the DOC closed operation, and this age was also used as the starting age for both the DOC and the UC cohort in the model.
[d] White population was assumed for base case analysis.
[e] The most current post-study data (mean weight, height, and BMI) from 1417 patients were used in the model.
[f] Patients were assumed to be nonsmokers (since less than 10% of our population was the current smoker) for the base case analysis.
[g] Patients were assumed to have creatinine clearance <100 ml/min for base case analysis.
[h] Patients were assumed to have no atrial fibrillation [because no DOC patients had atrial fibrillation and only 15 (1.2%) UC patients had atrial fibrillation] for base case analysis.
[i] Patients had no macroalbuminuria for base case analysis.
[j] Patients had no microalbuminuria for base case analysis.
[k] The mean duration of diabetes for patients was assumed to be 5 years.
[l] The mean numbers were used for base case analysis.

Table 2.
Cost Parameters for the Markov Decision Model[a]

Parameter	Value: Base case analysis	Value: Probabilistic sensitivity analysis distribution[b]	Reference
Direct medical costs			
Annual health care provider costs per patient for diabetes education class and visit			DOC data; U.S. Bureau of Labor Statistics[47]
Costs for GDC for the DOC and UC strategies, U.S. dollars			
Endocrinologist	23	Uniform (11 to 34)	
Registered nurse/certified diabetes educator	20	Uniform (16 to 24)	
Exercise physiologist	8	Uniform (4 to 11)	
Costs for DIGMA visit for the DOC strategy, U.S. dollars			
Endocrinologist/nurse practitioner	32	Uniform (16 to 48)	
Rotated staff	16	Uniform (14 to 20)	
Medical assistant	8	Uniform (6 to 9)	
Annual costs of laboratory tests and physician office visits per patient			DOC data; CMS[55]
Costs for laboratory tests, U.S. dollars			
A1C			
DOC	47	Uniform (24 to 71)	
UC	38	Uniform (19 to 57)	
Lipid panel			
DOC	53	Uniform (27 to 80)	
UC	41	Uniform (20 to 61)	
Costs for physician office visits, U.S. dollars			
Primary care			
DOC	205	Triangular (118 to 371)	
UC	301	Triangular (170 to 536)	
Specialty care			
DOC	1,035	Triangular (666 to 2,101)	
UC	1,149	Triangular (700 to 2,211)	
One-time and annual costs of complications per patient			CDC Diabetes Cost-Effectiveness Group[56]
One-time costs, U.S. dollars			
No complications	0	Not varied	
Microvascular complications	2,165	Triangular (333 to 3,999)	
Macrovascular complications	3,713	Log normal (0 to 37,924)	
Microvascular and macrovascular complications	5,878	Log normal (333 to 41,923)	
Annual costs, U.S. dollars			
No complications	0	Not varied	
Microvascular complications	6,264	Triangular (3,133 to 9,397)	
Macrovascular complications	1,518	Log normal (0 to 12,914)	
Microvascular and macrovascular complications	7,783	Log normal (3,133 to 22,311)	

continued →

Table 2. Continued

Parameter	Value		Reference
	Base case analysis	Probabilistic sensitivity analysis distribution[b]	
Direct medical costs			
One-time costs of death per patient			CDC Diabetes Cost-Effectiveness Group[56]
Age < 65 years, U.S. dollars	14,199	Not varied	
Age = 65–74 years, U.S. dollars	14,356	Not varied	
Direct nonmedical costs			
Annual time costs per patient			DOC data; U.S. Bureau of Labor Statistics;[47] Smith and associates[57]
Costs for physician office visits, U.S. dollars			
Primary care			
DOC	191	Not varied	
UC	276	Not varied	
Specialty care			
DOC	1,085	Not varied	
UC	1,142	Not varied	
Costs for GDC for the DOC and UC strategies, U.S. dollars	71	Not varied	
Costs for DIGMA visit for the DOC strategy, U.S. dollars	89	Not varied	
Annual monetary costs per patient			DOC data; U.S. Bureau of Labor Statistics;[47] Smith and associates[57]
Costs for physician office visits, U.S. dollars			
Primary care			
DOC	10	Not varied	
UC	15	Not varied	
Specialty care			
DOC	58	Not varied	
UC	61	Not varied	
Costs for GDC for the DOC and UC strategies, U.S. dollars	15	Not varied	
Costs for DIGMA visit for the DOC strategy, U.S. dollars	11	Not varied	

[a] GDC, Group Diabetes Class; DIGMA, Drop-In Group Medical Appointments; CMS, Centers for Medicare and Medicaid Services; CDC, Centers for Disease Control and Prevention.
[b] Uniform (*a* to *b*) = uniform distribution (minimum to maximum); triangular (*a* to *b*) = triangular distribution (minimum to maximum); log normal (*a* to *b*) = log normal distribution (95% confidence interval).

Occupational Employment and Wage Estimates.[47] One-time and annual costs of diabetes complications, one-time costs of death, as well as medication costs for diabetes, hypertension, and cholesterol control were based on data from the models developed by the Centers for Disease Control and Prevention and Research Triangle Institute International.[56]

In analyses from the societal perspective, both direct medical and nonmedical costs were included. Direct nonmedical costs included patient time and monetary costs for physician office visits and diabetes education classes/visits (**Table 2**). Patient time costs for time missed from work or school to receive care and for time donated by others (e.g., for rides or babysitting) to allow care to occur were quantified based on DOC data or published literature[57] and then valued according to the average hourly wage of a U.S. nonfarm production worker[47] and the average annual frequency of visits and classes as measured in DOC data. In addition, monetary costs to the patient for expenses such as transportation, parking, and babysitting or childcare were estimated from published literature[57] and then valued based on the average annual frequency of visits and classes as derived from DOC data.

Health utilities are a measure of health-related quality of life, with perfect health = 1 and death = 0. In a cost-effectiveness analysis, this utility weight for each health state is multiplied by time in that state. As an individual's health changes over time, these products are summed to represent the total number of QALYs.[46] To estimate health utilities associated with type 2 diabetes with or without complications, an additive prediction model was applied to estimate health utilities according to demographic, treatment, and complication variables.[58] The baseline health utility of 0.689 depicts a nonobese man with type 2 diabetes who is treated with diet and exercise and has no cardiovascular risk factors nor any microvascular, neuropathic, or cardiovascular complications (**Table 3**).

Sensitivity Analyses

One-way sensitivity analyses were conducted for model parameters (**Appendix 5** and **Tables 2** and **3**) to assess the effect of varying parameter estimates within clinically plausible ranges and identify parameters whose variation changed the base case incremental cost-effectiveness ratio (ICER) >20%. Next, the ICER was recalculated using the societal perspective instead of the health care system perspective. Finally, the original assumption that all DOC and UC patients had uncomplicated diabetes at the start of the model was tested by changing initial proportions of patients in health states to mirror the DOC cohort and then the UC cohort, recalculating cost-effectiveness for each starting cohort from the societal perspective.

A probabilistic sensitivity analysis was performed from the health care system perspective, where model parameters were simultaneously varied over distributions.[59] Distributions for parameters were chosen to reflect the level of certainty and the characteristics of the parameter range: beta distribution was assigned for probabilities; uniform, triangular, or log normal distributions for costs; and normal or uniform distributions for utilities. A value from each parameter's probability distribution was randomly selected during each of 10,000 Monte Carlo iterations, and then these values were used to compute the cost-effectiveness among strategies of being studied for each iteration. The cost-effectiveness acceptability curve[60] was used to summarize results, showing the likelihood that a given strategy would be favored for a given acceptability threshold, which is defined as the maximum amount that society is willing to pay for an incremental gain in health.[61]

Results

Over the study period, DOC patients had better glycemic control (from 7.8% to 7.2% vs from 6.8% to 7.0%) and dyslipidemic control (total cholesterol, 173 vs 184 mg/dl; low-density lipoprotein cholesterol, 93 vs 102 mg/dl), fewer annual primary care visits (2.0 vs 3.0), and more annual A1C (2.2 vs 1.7) and lipids (1.7 vs 1.4) checks compared with UC patients. **Appendices 1** and **2** summarize the observed demographic, clinical, and medical utilization characteristics at baseline and follow-up.

Table 3.
Parameters of Health Utilities and Discount Rates for the Markov Decision Model

Parameter	Value		Reference
	Base case analysis	Probabilistic sensitivity analysis distribution[a]	
Health utilities			
Diabetes without complications	0.689	Normal (0.662 to 0.716)	Coffey and coworkers[58]
Diabetes with microvascular complications	0.599	Uniform (0.519 to 0.678)	
Diabetes with macrovascular complications	0.631	Uniform (0.617 to 0.645)	
Diabetes with microvascular and macrovascular complications	0.599	Uniform (0.519 to 0.678)	
Discount rates			
Discount rate applied to costs, %	3.00	(2.00 to 5.00)[b]	Assumption
Discount rate applied to quality-adjusted life-expectancy, %	3.00	(2.00 to 5.00)[b]	Assumption

[a] Normal (*a* to *b*) = normal distribution (95% confidence interval); uniform (*a* to *b*) = uniform distribution (minimum to maximum).
[b] (*a* to *b*) = (minimum to maximum). This parameter was not varied in the probabilistic sensitivity analysis.

Base Case Analysis

Table 4 summarizes the cost-effectiveness results. The DOC cost $5311 more than UC and produced 0.117 more QALYs, resulting in an ICER of $45,495 per QALY over 20 years from the health care system perspective.

Sensitivity Analyses

Figure 2 shows the results of one-way sensitivity analyses, where six parameters whose variations changed the base case ICER >20% were identified. Of these, only the yearly cost for specialty care visits in DOC patients could drive

Table 4.
Incremental Cost-Effectiveness of Cost per Quality-Adjusted Life-Year by Strategies from the Base Case Analysis and Three One-Way Sensitivity Analyses over a 20-Year Time Horizon of Model

Scenario	Strategy	Cost (U.S. dollars)	Incremental cost (U.S. dollars)	Effectiveness (QALYs)	Incremental effectiveness (QALYs)	ICER (cost per QALY)
Base case analysis	UC	$116,242	—	8.351	—	—
	DOC	$121,553	$5,311	8.467	0.117	$45,495
Societal perspective[a]	UC	$137,084	—	8.351	—	—
	DOC	$141,993	$4,909	8.467	0.117	$42,051
Mirror the DOC cohort[b]	UC	$152,647	—	7.236	—	—
	DOC	$157,859	$5,212	7.321	0.085	$61,243
Mirror the UC cohort[c]	UC	$153,333	—	7.214	—	—
	DOC	$158,552	$5,219	7.299	0.084	$61,813

[a] The ICER of cost per QALY was calculated from the societal perspective.
[b] Initial proportions of patients in 5 health states at the start of the model were changed to mirror the DOC cohort, and then the ICER of cost per QALY was calculated from the societal perspective.
[c] Initial proportions of patients in 5 health states at the start of the model were changed to mirror the UC cohort, and then the ICER of cost per QALY was calculated from the societal perspective.

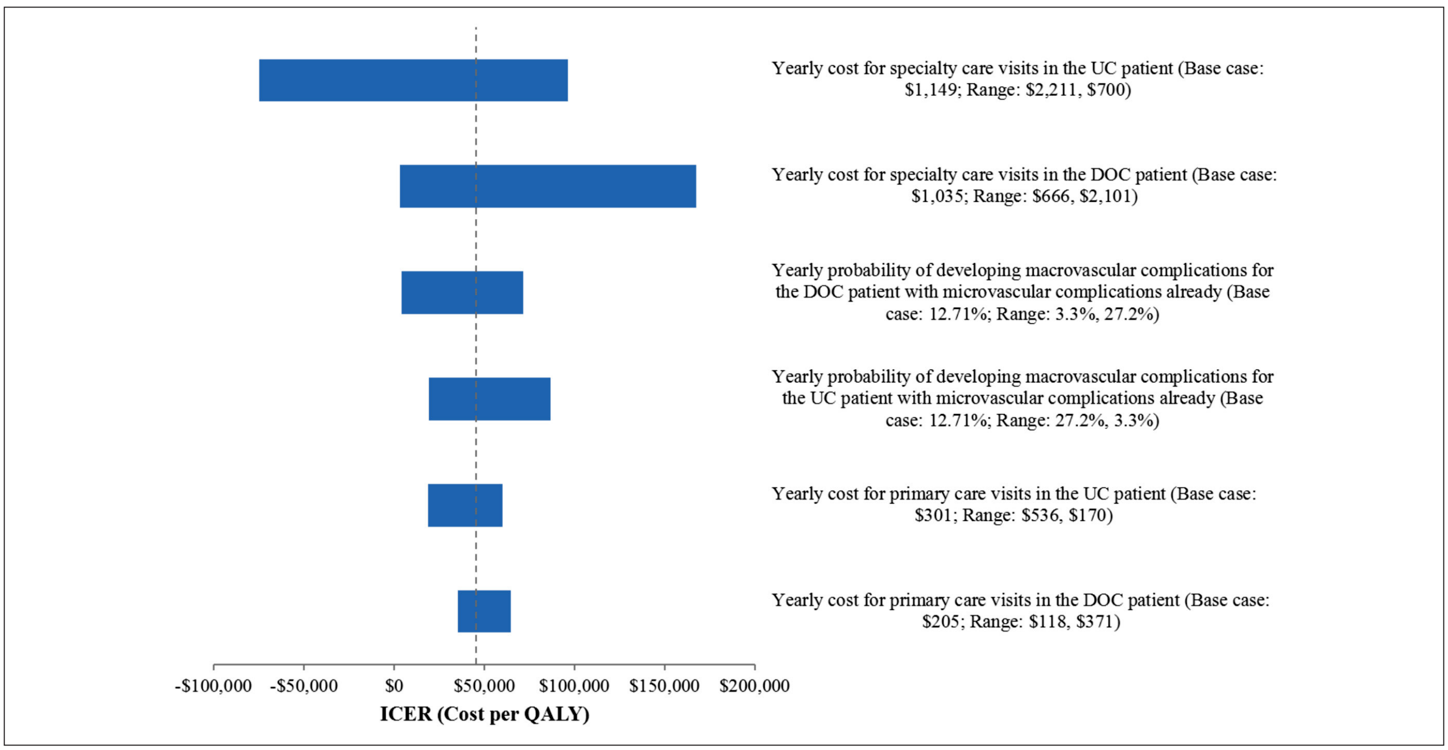

Figure 2. One-way sensitivity analyses for the DOC and UC strategy. One-way sensitivity analyses of parameters whose variations changed the base case ICER (*x* axis) by more than 20%. Horizontal bars depicted the range of ICERs corresponding to the values shown in each parameter. The vertical dotted line depicted the base case ICER. Variation of all other parameters not shown in the figure did not increase the ICER above $50,000 per QALY.

the ICER >$100,000/QALY. Variation of parameters not shown in **Figure 2** did not increase the ICER above $50,000/QALY. Analysis from the societal perspective showed that the DOC cost $4909 more than UC and gained 0.117 QALYs, resulting in an ICER of $42,051/QALY over 20 years (**Table 4**). Changing the initial proportion of cohorts in the five health states at the start of model to mirror the complication rates of DOC patients and then again of UC patients resulted in ICERs of $61,243/QALY and $61,813/QALY, respectively, from the societal perspective (**Table 4**).

When parameters were simultaneously varied over the distributions in the probabilistic sensitivity analysis, the DOC was more likely to be favored with an acceptability threshold >$48,000/QALY (**Figure 3**). In addition, at a threshold of $50,000/QALY, the DOC was favored in 51% of model iterations; at $100,000/QALY, the DOC was favored in 72%.

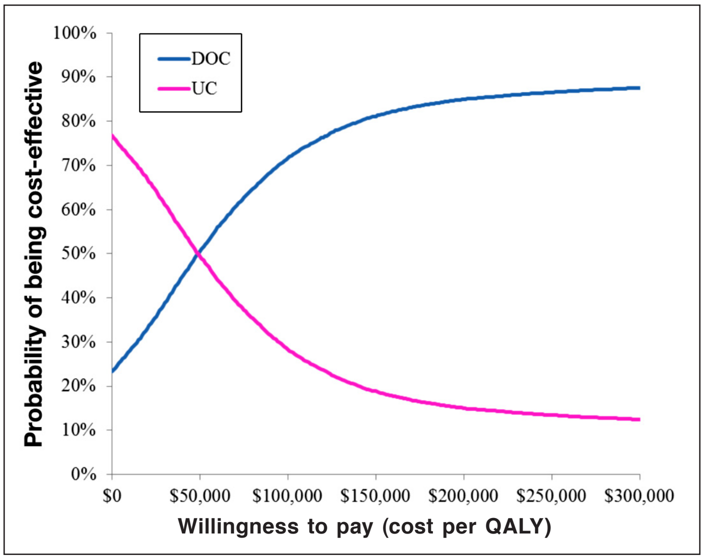

Figure 3. Probabilistic (second-order Monte Carlo) sensitivity analysis for the DOC and UC strategy. The acceptability curve depicted the likelihood of the DOC or UC strategy being favored for a given cost-effectiveness acceptability threshold (willingness to pay).

Discussion

The CCM is a multifaceted intervention intended to provide effective and comprehensive care for diabetes and other chronic conditions. Although transformation of health care organizations using the CCM must expend considerable resources, in theory, their expenditures will be offset downstream with the delay or elimination of diabetes-related complications. In this regard, cost-effectiveness analysis from a health care system perspective may be particularly compelling. Our study showed that, from a health care system perspective over 20 years, the CCM strategy performed through the DOC in a military-based setting was quite cost-effective, costing approximately $45,500/QALY. From a societal perspective, it was even more favorable, with an ICER less than $42,100/QALY.

Diabetes care involves complex interactions among patients, physicians, health care systems, and society as a whole, with barriers occurring at every level.[11] A major contributor to suboptimal diabetes care is a delivery system that too often is fragmented, lacks clinical information capabilities, duplicates services, and is poorly designed for the delivery of chronic care.[5] The American Diabetes Association suggests that the CCM may be well-suited to the management of diabetes because it addresses these complex issues, redefines the role of providers, and promotes patient self-management.[5,14] Moreover, our analyses showed that patients in the DOC had a lower number of visits for primary or specialty care (**Table 1**) and that total annual cost for primary or specialty care visits, compared with other model parameters, influenced more the cost-effectiveness of the DOC (**Figure 2**), which may suggest that centralizing the patient's care by the DOC combined with the CCM potentially eliminated the need for multiple visits.

Knowledge on CCM cost-effectiveness in diabetes care is nascent;[14] more research is needed to understand the costs and benefits to practices, payers, and patients. Studies are available to document cost-consequence or cost-effectiveness results related to various potential components of the CCM,[14,32] but the cost-effectiveness analysis of the CCM as a whole may not be well-known. We found only one full economic evaluation[62] published by Huang and colleagues,[63] comparing CCM implementation costs with the benefits of improved health outcomes in diabetes patients in U.S. federally qualified community health centers. In that study, CCM reduced lifetime risks of blindness, end-stage renal disease, and coronary artery disease, resulting in an increase in benefits at a cost of $33,386/QALY. Compared with that study, our estimate of CCM cost-effectiveness over 20 years from the societal perspective, $42,051/QALY, is higher. This discrepancy is likely due to a number of differences in models; for instance, our patient cohort was a military population, younger (50 vs 55 years), less racially diverse, and transitioned through a model where some assumptions were made to bias against the CCM effect (discussed later). Furthermore, we used costs in 2010 U.S. dollars rather than 2004 U.S. dollars and included data from a two-group effectiveness study rather than pre- and postcomparisons. Despite these differences, both studies found that implementation of the CCM was economically reasonable and consistent with accepted societal cost-effectiveness thresholds.[64]

Cost-saving medical interventions are rare. Most new diabetes treatment strategies are more effective but also more costly, requiring incremental resources per QALY gained.[65] There is no absolute cost-effectiveness threshold, and the long-cited benchmark from the literature of $50,000/QALY is unsupported.[64,66] One analysis[66] argues that a more plausible threshold of society's willingness to pay for modern health care ranges between $100,000 and $300,000 per QALY, which is substantially higher than the traditional threshold.

Health care costs in the United States are increasing unsustainably, and efforts to control expenditures should focus on the value of health care interventions, reflecting health benefits that justify their costs.[67] High-cost interventions may provide good value when they are highly beneficial. The ICER estimates the additional cost required to obtain additional health benefits and provides a key measure of the value of a health care intervention.[67] Based on our analysis, the CCM strategy through the DOC in a military-based setting appears to be a good-value care for diabetes, but unfortunately, further data on the DOC do not exist since it was closed in 2009 because of military priority considerations. We recognize that the cost-effectiveness of an intervention should not solely determine its application; at the same time, however, cost-effectiveness should be one of several factors when considering the delivery of high-value, cost-conscious health care.[67] Furthermore, the goal of policy should be to preserve the delivery of interventions that do have good value.[68]

As with all modeling efforts,[69] the computational model developed here has several limitations. First, interpretations of study results are contingent on data quality and model assumptions. Second, subjects in this analysis were representative of the diabetes population in a military community, although they may not be fully generalizable to other populations or health care settings. Third, our effectiveness data were not from a randomized controlled trial, resulting in differences in baseline characteristics between the DOC and UC. For instance, we cannot directly apply the unadjusted follow-up A1C in the UKPDS risk equations to predict probabilities of developing microvascular and macrovascular complications. Instead, we used the adjusted follow-up A1C, which was adjusted for all known demographic (i.e., age at baseline and gender) and clinical characteristics (baseline A1C) that differed significantly between two groups at baseline (**Appendix 2**). Fourth, the A1C *per se* or the change in mean A1C *per se* was not directly considered a model parameter. However, the baseline A1C and the change in mean A1C were considered when the adjusted mean post-intervention A1C was estimated for predicting probabilities of developing microvascular and macrovascular complications using UKPDS risk equations. As such, our current model cannot address how much reduction in A1C needs to be realized by the DOC in order to achieve a given cost-effectiveness threshold. Fifth, assuming an identical risk of disease progression for DOC and UC patients with diabetes complications was a conservative strategy. This is because if, instead, the DOC combined with the CCM strategy has intervention effects on disease progression in the patients who already had diabetes complications, then this assumption potentially biases the model against the DOC effect. Sixth, because there is no empirical utility data, we applied the same literature-based utility weights to both strategies, which again may underestimate the CCM's potential to improve quality of life.[13,34,35] Lastly, our base case analysis was assumed to model the cost-effectiveness over a 20-year time frame; however, the base case ICERs over shorter time horizons, e.g., at 5 years ($189,138/QALY) and 10 years ($87,092/QALY), are still below the currently suggested cost-effectiveness thresholds for modern health care.[66]

Conclusions

Status quo is not an option; reforms at the delivery system level are imperative to address significant lapses in quality of care as well as the high and rapidly increasing cost of care.[70,71] One potentially important tool for slowing the growth of health care expenditures is reliable information regarding the cost-effectiveness of alternative interventions.

Information on the cost-effectiveness of implementing the CCM strategy for diabetes care is just beginning to emerge, and our study adds evidence to document that, compared with UC, the CCM strategy provides greater health benefits at an attractive cost. From the perspective of a health care system or society, the CCM strategy provides good value. When the CCM strategy is used for diabetes care in the military-based setting, not only is it effective in improving patient outcomes, but it is also an economically reasonable, promising investment.

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