

BMJ Open Economic evaluation of a novel community-based diabetes care model in rural Mexico: a cost and cost-effectiveness study

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ABSTRACT

Objectives Diabetes is the leading cause of disability-adjusted life years in Mexico, and cost-effective care models are needed to address the epidemic. We sought to evaluate the cost and cost-effectiveness of a novel community-based model of diabetes care in rural Mexico, compared with usual care.

Design We performed time-driven activity-based costing to estimate annualised costs associated with typical diabetes care in Chiapas, Mexico, as well as a novel diabetes care model known as *Compañeros En Salud Programa de Enfermedades Crónicas* (CESPEC). We conducted Markov chain analysis to estimate the cost-effectiveness of CESPEC compared with usual care from a societal perspective. We used patient outcomes from CESPEC in 2016, as well as secondary data from existing literature.

Setting Rural primary care clinics in Chiapas, Mexico.

Participants Adults with diabetes.

Interventions CESPEC is a novel, comprehensive, diabetes care model that integrates community health workers, provider education, supply chain management and active case finding.

Outcome measure The primary outcome was the incremental cost-effectiveness of CESPEC compared with care as usual, per quality-adjusted life year (QALY) gained, expressed in 2016 US dollars.

Results The economic cost of the CESPEC diabetes model was US\$144 per patient per year, compared with US\$125 for diabetes care as usual. However, CESPEC care was associated with 0.13 additional years of health-adjusted life expectancy compared with usual care and 0.02 additional years in the first 5 years of treatment. This translated to an incremental cost-effectiveness ratio (ICER) of US\$2981 per QALY gained over a patient's lifetime and an ICER of US\$10 444 over the first 5 years. Findings were robust to multiple sensitivity analyses.

Conclusions CESPEC is a cost-effective, community-based model of diabetes care for patients in rural Mexico. Given the high prevalence and significant morbidity associated with diabetes in Mexico and other countries in Central America, this model should be considered for broader scale up and evaluation.

Strengths and limitations of this study

- This economic evaluation studied a novel, community-based diabetes care model (*Compañeros En Salud Programa de Enfermedades Crónicas* (CESPEC)) in a rural low-income and middle-income country, a setting in which few economic evaluations exist, despite a high burden of diabetes in rural areas.
- We conducted detailed cost analysis using a rigorous time-driven activity-based costing approach.
- Findings of cost-effectiveness of CESPEC were from a societal perspective and were robust to two different time horizons and multiple sensitivity analyses.
- Limitations include: (1) using simplifying assumptions in the decision analysis model that likely generated conservative estimates of cost-effectiveness and (2) a limited geographic scope that tempers generalisability of our findings and warrants additional evaluation in other settings.

INTRODUCTION

Diabetes continues to rise as a leading cause of disability and mortality in the world and now ranks as the 12th leading cause of disability-adjusted life years (DALYs) worldwide.¹ There are an estimated 422 million patients in the world currently living with diabetes and 3.7 million diabetes-related deaths per year.² The growing medical burden comes with concomitant economic costs. By some estimates, the yearly global cost of diabetes is US\$1.31 trillion.³ In Mexico, where diabetes is the leading cause of DALYs and affects over 11.5 million adults,⁴⁻⁶ associated costs are rapidly increasing, currently representing 15% of total health expenditure.⁶⁻⁸

Innovative, low cost models of diabetes care are needed to address the worsening health and economic challenges driven by diabetes.



Most existing cost-effectiveness studies in diabetes care are focused on narrow therapeutic interventions, as opposed to comprehensive models of care.⁹ This is despite the fact that international society guidelines emphasise multi-component, interdisciplinary care models, with modest evidence available supporting cost-effectiveness.^{10–14} The evaluation of multicomponent diabetes care models in low-income and middle-income countries (LMICs) such as Mexico is limited, particularly evaluations that use economic analysis as a tool to assess the value of a large-scale investment to restructure care.

We assessed the cost and cost-effectiveness of a novel chronic disease management programme for diabetes care in rural Chiapas, Mexico, called the *Compañeros En Salud Programa de Enfermedades Crónicas* (CESPEC). We previously described the programme's implementation and quantified its clinical effectiveness for improving diabetes and hypertension control, using thresholds set by the Secretariat of Health of Chiapas (SSCH in Spanish) as a haemoglobin A1c below 7% and a blood pressure <140/90 mm Hg.¹⁵ In this study, we performed an economic evaluation of CESPEC to: (1) estimate the annualised economic cost per patient with diabetes relative to the cost of care as usual and (2) estimate the incremental cost-effectiveness of CESPEC relative to care as usual, measured as cost per quality-adjusted life years (QALYs) gained. We hypothesised that CESPEC would be cost-effective when compared with a standard threshold of three times the national gross domestic product (GDP) per capita in Mexico¹⁶ and when compared with other cost-effective diabetes interventions catalogued in the literature.^{17 18}

METHODS

Setting

Compañeros En Salud (CES) is the Mexico-based affiliate of Partners In Health, a non-governmental healthcare delivery organisation. Since 2011, CES has focused on health system strengthening and the provision of comprehensive primary care in rural Chiapas. Chiapas is one of the poorest states in Mexico and has the third lowest life expectancy in the country.^{19 20} Similar to the rest of Mexico, diabetes is the greatest cause of combined death and disability in the state.²¹

CES operates primary care clinics in 10 rural communities in the Sierra Madre region of the state, serving as the primary source of healthcare. CES runs in collaboration with the SSCH, and the clinics are integrated into the broader public healthcare system. In other rural regions of Chiapas not supported by CES, the SSCH operates rural clinics directly. Both CES and non-CES communities share similar socioeconomic conditions, and additional details regarding the setting and socioeconomic comparisons are described elsewhere.¹⁵

Diabetes treatment models

We evaluated and compared two treatment models for the management of type 2 diabetes. First, we studied usual care at rural clinics run directly by the SSCH. Usual diabetes care at SSCH clinics consists of monthly, routine medical examinations with a general medical provider and nurse. Any medications prescribed during the visit are dispensed on-site through a pharmacy at no cost to the patient, subsidised by the SSCH. In this model, there are no additional resources or health education sessions outside of regular clinic visits.

The second model evaluated was CESPEC, a community-based non-communicable disease management programme started in 2014 by CES. The programme consists of: (1) household engagement by community health workers (CHWs), (2) provider education and support, including evidenced-based algorithms to support decision making, (3) supplemental supply chain management to procure medicines that previously suffered frequent stockouts and (4) active case finding in the community. For diabetes care, the CESPEC model involves monthly clinic visits with a physician who is completing a government-required social service year (*pasante*) before obtaining a full medical licence. Between clinic visits, additional patient teaching and follow-up is provided by CHWs depending on patient history of diabetes control. CHWs act as a liaison between the clinic and the patient, providing education, psychosocial support and medication adherence reinforcement. They are nominated by the community and compensated with food/consumable items. Communities also undergo regular screening with an active case-finding programme that occurs biannually. The design, implementation and clinical effectiveness of CESPEC has been previously published.¹⁵ Detailed process maps of the two comparative care delivery models are available in figure 1.

Cost analysis

We used time-driven activity-based costing (TDABC) to estimate the costs of both CESPEC and usual care.^{22–24} TDABC involves determining the costs of the healthcare by directly observing patient flow through a health system, and assigning costs to each activity in a cycle of care based on activity duration and resources used, such as personnel, equipment and clinic space. We identified all activities related to diabetes care, as well as duration of each activity, through key informant interviews with medical personnel and direct observation of patients receiving care in August–December 2016. We adopted a societal perspective and included the opportunity cost of all involved individuals (including patients). Staff time was valued at full salary cost, including benefits. The cost of volunteered time at CES was estimated based on the salary of staff in similar, paid roles. We estimated the opportunity cost of patient time using local wages in Chiapas.¹⁹

Direct costs incurred by CESPEC were obtained from the organisational budget and price lists from actual

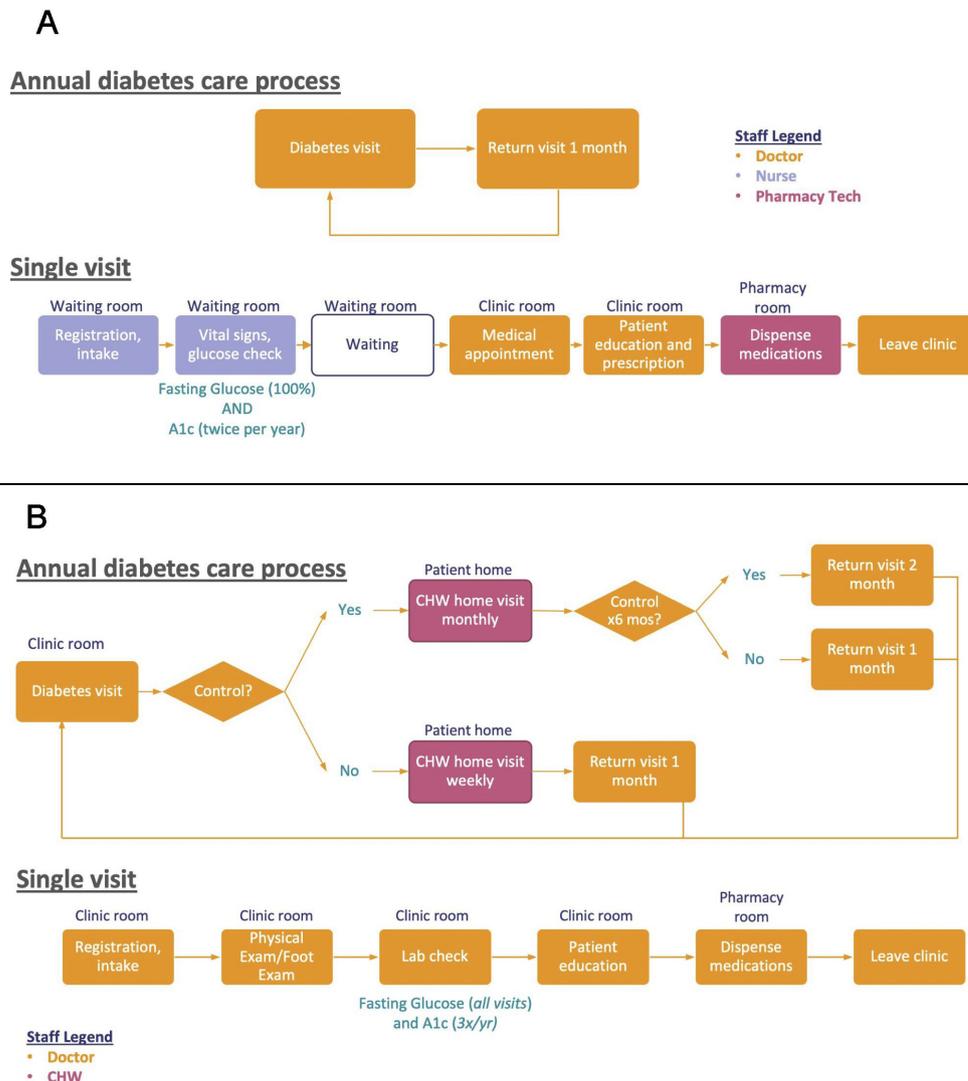


Figure 1 Diabetes care process maps. (A) Diabetes care process maps for usual care. (B) Diabetes care process maps for CESPEC. CESPEC, Compañeros En Salud Programa de Enfermedades Crónicas; CHW, community health worker.

vendors. Costs for medications and labour for the SSCH clinics were obtained from multiple publicly available government pricing lists.^{25 26} We assumed 100% medication adherence with no stockouts. We estimated the cost of physical space based on area construction costs for equivalent square footage and assumed 20-year linear depreciation of physical space. For indirect costs, we calculated CES-related administration and overhead costs associated with operating the NGO. Central, state-level administrative costs were excluded from indirect cost calculations.

Our primary cost analysis outcome was the economic cost of diabetes care per patient per year in 2016 US dollars. We chose 2016 as the year of analysis since that is when direct field observations occurred and the year in which we collected CES budget information. We chose to report results in US dollars for general interpretability and because many cost inputs were obtained in this currency. Costs that were obtained as Mexican pesos were converted to US dollars based on 2016 exchange

rates.²⁷ Any costs obtained from other years were inflation adjusted to 2016 using the Mexican Consumer Price Index.^{28 29}

Cost-effectiveness analysis

We estimated incremental cost-effectiveness ratios using a Markov modelling approach in TreeAge Pro Healthcare 2020 (Williamstown, Massachusetts, USA). The decision analysis model accounted for diabetes control rates for CESPEC and usual care and their relationships to long-term health outcomes and diabetes-related complications (see online supplemental appendix figure 1 for a schematic of the decision tree). The Markov cycle duration was 1 year, and we assumed a treatment effect of CESPEC for only 1 year. That is, the status of diabetes control could change from controlled to uncontrolled or vice versa in any subsequent Markov cycle. The model quantified probabilities and morbidity associated with microvascular complications (nephropathy, retinopathy and neuropathy) and macrovascular complications (stroke and



myocardial infarction), making two simplifying assumptions. First, we conservatively assumed microvascular complications were permanent and mutually exclusive. Second, we also assumed macrovascular complications were transient events that could recur and did not result in long-term sequelae. In our base case scenario, we adopted a lifetime analytical horizon. We also modelled an additional time horizon of 5 years to evaluate short-term incremental cost-effectiveness of CESPEC relative to care as usual. The patient cohort entered the Markov model at age 40 years, given the rapid rise in diabetes incidence that occurs around age 40 years in Chiapas, as reported in Global Burden of Disease data.³⁰ We employed a half-cycle correction in Markov models and incorporated a global discount rate of 3% for both cost and QALYs.^{16 17}

For cost estimates in the models, we used the parameters identified from our cost analysis as inputs for the annual cost of diabetes care under the usual care and CESPEC models. Other model parameters were drawn from existing literature, considering the recency, quality and appropriateness of studies. For the costs of complications, we used national estimates from Mexico as reported by *Fundación Mexicana para la Salud*.³¹ Other studies evaluating costs in Mexico either do not provide separate estimates of individual complications or provide aggregate population costs instead of a per patient annual cost.³² Transition probability inputs were obtained from the existing literature. Where possible, we selected high-quality studies from Mexican populations. Otherwise, we selected the best available studies with detailed assessment of complications based on disease control. We derived health-adjusted quality of life inputs for disease states using the inverse of disability weights from the 2016 Global Burden of Disease study.^{33 34} A detailed discussion of study selection, methods and a table of model parameters is available in the online supplemental appendix.

Our primary outcome for cost-effectiveness analyses was the incremental cost-effectiveness ratio (ICER) per QALY gained for the base case scenario. We chose QALYs instead of DALYs as our primary outcome as an established and accepted measure used by policymakers to assess intervention cost-effectiveness. We considered an ICER less than three times 2016 GDP per capita in Mexico (US\$26 219.28)³⁵ to be cost-effective, based on established guidelines.¹⁶ ICERs less than one time the GDP per capita (US\$8739.76) were considered very cost-effective. We acknowledge that a fixed GDP-based threshold fails to incorporate local context and competing health policy priorities in determining cost-effectiveness,¹⁸ and we therefore also qualitatively evaluated the ICERs compared with ICERS of similar interventions, reflected in the discussion section.

We performed sensitivity analyses to assess the effect of input parameter uncertainty on our cost-effectiveness estimates. First, we performed one-way deterministic sensitivity analyses by varying individual input

parameters. Specifically, we varied programme cost estimates and diabetes control probability from 80% to 120% of point estimate values for both CESPEC and usual care. We also varied the costs of complications from 80% to 120%. Second, we performed a scenario-based deterministic sensitivity analysis, in which we assumed all medical providers in CESPEC were general medical providers instead of *pasantes*, as *pasantes* are paid significantly less. Third, we performed probabilistic sensitivity analysis by varying all model parameters simultaneously by sampling from their respective distributions (online supplemental appendix table 1) following a Monte Carlo approach with 10 000 simulations. We assessed that 10 000 simulations was sufficient to produce stable results by testing for model convergence.³⁶

Patient and public involvement

There was no patient or public involvement in the design, conduct, reporting or dissemination of this study.

RESULTS

Cost analysis

The cost of usual care at SSCH clinics in 2016 was US\$125 per patient per year. This estimate was based on US\$99 in visit costs and \$26 in medication costs. The per visit cost was US\$8.25, of which personnel accounted for 89% of per visit costs, followed by resources at 7% and physical space at 4% of per visit cost (table 1).

CESPEC services cost US\$144 per patient per year. Visits only accounted for 32% of total CESPEC costs, compared with 79% in usual care, because CESPEC relies primarily on *pasantes* for service delivery. CESPEC also incurred an additional US\$53.26 per patient per year of indirect costs, including general administrative costs (US\$12.31), coordinating CHWs (US\$34.24) and active case finding (US\$6.71). The per visit cost was US\$4.02, again primarily driven by personnel that accounted for 90% of the per visit cost, followed by resources at 16% and physical space at 4% of per visit cost. The opportunity cost for a patient to participate in a visit was estimated at US\$0.96 in lost wages.

Cost-effectiveness analysis

Based on the health states and transition probabilities associated with CESPEC and care as usual, estimated gains in health-adjusted life expectancy for CESPEC recipients was 15.40, compared with 15.26 among individuals receiving care as usual. Limited to the first 5 years of treatment, gains in health-adjusted years were 4.15 for CESPEC recipients and 4.13 among recipients of care as usual (table 2).

Under the base case scenario of a lifetime time horizon, we estimated an ICER for CESPEC of US\$2981 per QALY gained, which is considered very cost-effective insofar as this is below Mexico's GDP per capita (US\$8739.76). Under a 5-year time horizon, the ICER for CESPEC remained cost-effective at US\$10 444 per QALY gained.

Table 1 Cost analysis results

Cost element	Usual care (2016 US\$)	CESPEC (2016 US\$)
Per visit per patient	\$8.25	\$4.02
Personnel	\$7.32	\$3.24
Patient	\$2.23	\$0.96
Medical provider	\$3.75	\$1.04
Nurse	\$1.13	N/A*
Pharmacy technician	\$0.21	N/A*
Clinical supervisor	N/A*	\$1.24
Resources	\$0.63	\$0.63
Lab equipment	\$0.00†	\$0.00†
Lab reagents/test strips	\$0.63	\$0.63
Clinic space	\$0.30	\$0.15
Waiting room	\$0.22	\$0.04
Clinic room	\$0.06	\$0.09
Pharmacy area	\$0.02	\$0.02
Nurse area	\$0.00†	N/A*
Per patient per year		
Visits	\$99.04	\$45.74
Medications	\$25.79	\$44.69
Indirect costs	N/A‡	\$53.26
Total cost per patient per year	\$124.83	\$143.69

*Cost element was not a part of this particular care model.

†The per visit per patient cost of this cost element was estimated to be less than 1 US cent.

‡Centralised state-level administrative costs were assumed to be the same across both CESPEC and usual care and excluded from the analysis.

CESPEC, Compañeros En Salud Programa de Enfermedades Crónicas.

Sensitivity analysis

One-way sensitivity analyses demonstrated that CESPEC remained very cost-effective despite varying multiple parameters from 80% to 120% of their point estimates (figure 2). The ICER for CESPEC was most sensitive to changes in the estimated programme cost of CESPEC, which varied from CESPEC dominating usual care to an ICER of US\$6346 per QALY gained (online supplemental appendix table 2). In the scenario under which we assumed that all providers in CESPEC were higher paid general medical providers (not *pasantes*), we input a CESPEC programme cost of \$232 per patient per year. We calculated an ICER of US\$13 509 per QALY gained in this scenario, again considered cost-effective at the threshold of three times national GDP per capita. In the probabilistic sensitivity analysis, we calculated a mean ICER of US\$3770.33 (table 2). CESPEC was cost-effective in 83% of scenarios at the willingness-to-pay of three times GDP per capita (figure 3). We confirmed that our model converged

and produced stable probabilistic sensitivity analysis results after 10 000 simulations, as the mean incremental net monetary benefit 95% CI did not include zero (table 2).³⁶

DISCUSSION

In this economic evaluation of two diabetes care models in rural Chiapas, Mexico, we found that the novel CESPEC model of care provides high-value, cost-effective diabetes care relative to care as usual. We estimated that CESPEC costs US\$2940 per QALY gained when viewed over an individual's lifespan. The estimated ICER is similar to other ICERs in high-income countries for diabetes education and multicomponent interventions that have a median cost in the range of US\$2315–US\$5047 per QALY gained.¹⁴ Locally, estimates from Mexico suggest that intensively controlling diabetes would cost US\$12,500–US\$16 900 per QALY gained.³⁷ CESPEC compares favourably with these existing estimates from the literature. Using GDP-based ICER thresholds,¹⁶ CESPEC is considered very cost-effective and remains cost-effective even when limited to the first 5 years of treatment. To our knowledge, this is the first study measuring the economic value of a rural comprehensive diabetes management programme in an LMIC.³⁸

Our cost analysis found that CESPEC is more expensive compared with usual care within SSCH clinic. This is primarily due to indirect costs associated with CESPEC care delivery. CESPEC requires additional personnel and resources for all four components of the programme, including provider education, supply chain management, CHWs and active case finding. While these four components generate additional costs, they do not exist in usual care and are the high-value interventions that underly the clinical effectiveness of CESPEC in improving diabetes control. We posit that the CHW model and supply chain management components are particularly important, as previous research in rural Chiapas indicates a lack of trust in centralised health systems and supply shortages in medicines that undermine patient engagement.³⁹ Further work is needed to study the value of each CESPEC component individually and to determine whether they are additive or synergistic when combined.

The CESPEC care delivery model remained cost-effective in the context of multiple sensitivity analyses. This is particularly important because clinics using the CESPEC model are staffed exclusively by *pasante* physicians that are lower cost than typical licenced medical providers. By contrast, SSCH clinics that deliver standard care are usually staffed by non-*pasantes*. Our findings indicate that, even if CESPEC were staffed entirely by non-*pasantes*, it would remain cost-effective. This lends greater external validity to our cost-effectiveness findings as a potential model for scale up in other rural regions of Mexico.

Our findings have significant policy implications. In 2016, the Mexican government declared diabetes as a

Table 2 Cost-effectiveness analysis results

	Costs per person (2016 US\$)	QALYs per person (2016 US\$)	Incremental costs per person (2016 US\$)	Incremental QALYs per person	ICER (2016 US\$)	INMB* (2016 US\$)
Base case (lifetime time horizon)						
Usual care	\$12 044.99	15.26	Ref	Ref	Ref	Ref
CESPEC	\$12 440.76	15.40	\$395.77	0.13	\$2981.49	\$3084.65
5-year time horizon						
Usual care	\$1413.31	4.13	Ref	Ref	Ref	Ref
CESPEC	\$1575.39	4.15	\$162.08	0.02	\$10 444.29	\$3477.78
Probabilistic sensitivity analysis†						
Usual care	\$11 801.34	15.35	Ref	Ref	Ref	Ref
CESPEC	\$12 274.86	15.48	\$473.52	0.13	\$3770.33‡	\$2819.38 (95% CI \$2758 to \$2881)

*INMB calculated using a willingness-to-pay threshold of US\$26 219.28 (three times the gross domestic product per capita in Mexico).

†Outcomes reported are means of 10 000 Monte Carlo simulations.

‡95% CI not calculated for the ICER due to the challenge in calculating variance of a ratio of two variables. Instead, cost-effectiveness acceptability curves are presented elsewhere per CHEERS guidelines.⁴⁷

CESPEC, Compañeros En Salud Programa de Enfermedades Crónicas; ICER, incremental cost-effectiveness ratio; INMB, incremental net monetary benefit; QALY, quality-adjusted life year.

national public health emergency, devoting political and financial resources towards the prevention, identification and treatment of the disease.⁴⁰ Many public and private programmes have been launched in an effort to tackle the diabetes epidemic in Mexico,⁴¹ but rigorous evidence of programme effectiveness or economic value is limited. Furthermore, none of these existing programmes is focused on rural populations, despite a high prevalence of diabetes in both urban and rural Mexico.⁴² Delivering high-quality diabetes care to rural populations is critical as these groups face additional barriers in access to care⁴³ and suffer more catastrophic health expenditures

compared with urban populations.⁴⁴ CESPEC offers a clinically effective and high-value model of diabetes care for rural settings that can be achieved with targeted investments. All CES clinics operate within the existing public health infrastructure and do not operate as a parallel system. As such, CESPEC as a whole, or its key components, could supplement the existing public health system by improving health services delivered to historically marginalised communities without needing significant structural change.³⁹ In addition, our modelling of different time horizons found that CESPEC is cost-effective even on a short time horizon, which highlights

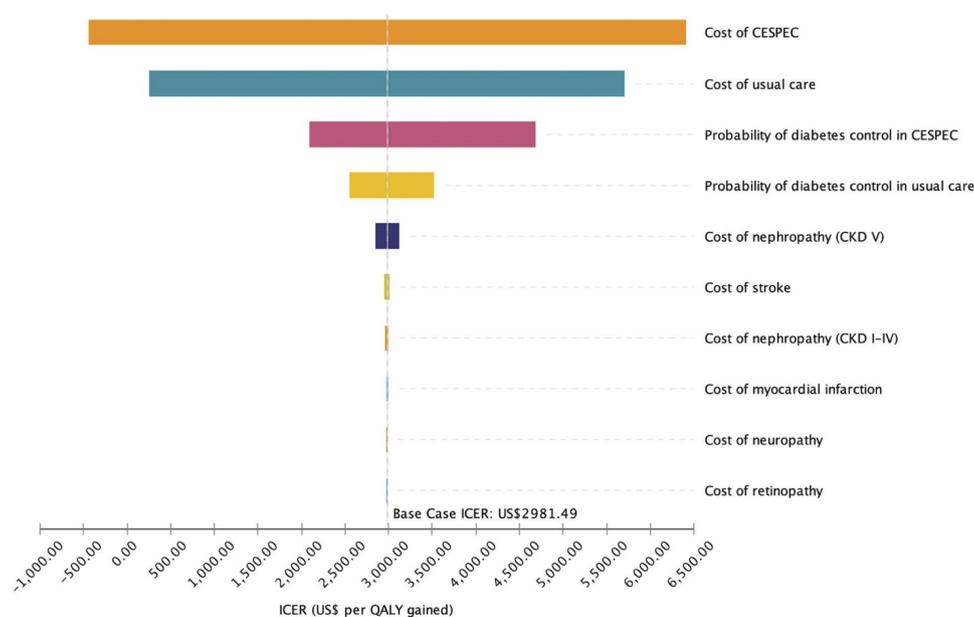


Figure 2 One-way deterministic sensitivity analysis results. CKD, chronic kidney disease; CESPEC, Compañeros En Salud Programa de Enfermedades Crónicas; ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year.

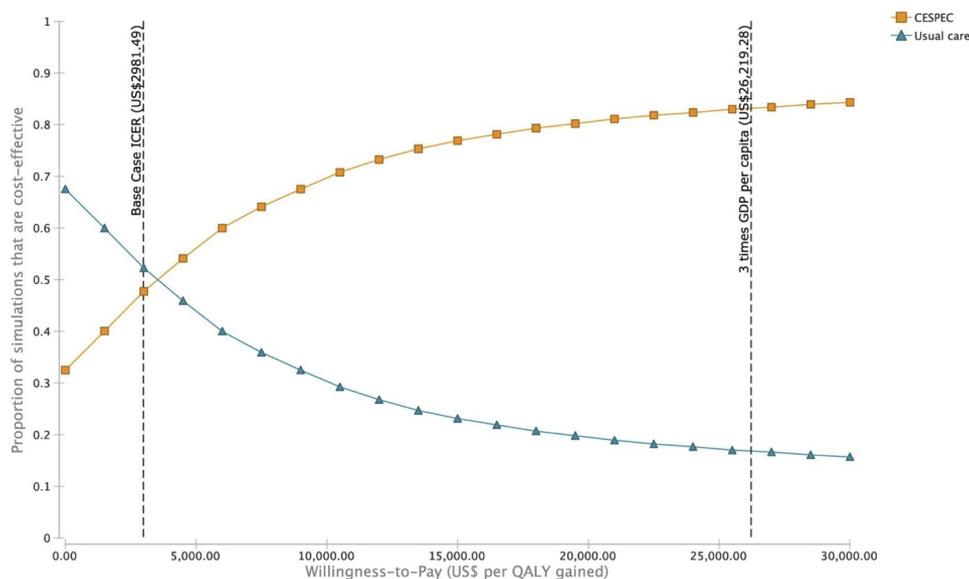


Figure 3 Probabilistic sensitivity analysis acceptability curve. CESPEC, Compañeros En Salud Programa de Enfermedades Crónicas; ICER, incremental cost-effectiveness ratio; GDP, gross domestic product; QALY, quality-adjusted life year.

the potential for this model to make an immediate impact in efforts to improve population health. Further study is needed to test the generalisability and scalability of CESPEC in other rural regions, especially given the heterogeneous populations throughout rural Mexico.⁴⁵ Efforts to scale CESPEC should also consider how the model would interface differently with each of Mexico's separately administered and financed public healthcare systems.

This study has several limitations. First, we used population-level data inputs for the Markov model. While valuable for policy decisions, a patient-level microsimulation approach may provide more precise estimates. This technique requires more granular data than were available for our study. Second, we made simplifying assumptions in our decision tree for the purposes of constructing the model, such as limiting the number of microvascular complications a patient could develop. However, we know from clinical experience that patients can suffer multiple complications from diabetes simultaneously.⁴⁶ Therefore, we expect that the ICER estimates in this study are likely conservative and may represent an upper bound. Third, one of the key parameters that differed between CESPEC and usual care was the probability of diabetes control. We used 1 year diabetes control figures based on previously identified estimates,¹⁵ but diabetes control figures greater than 1 year would provide more confidence in our estimates. This limitation was mitigated using sensitivity analyses to vary estimates of assumed clinical effectiveness. Fourth, we ascertained the duration of each activity for TDABC at 4 of 10 CES communities but only one usual care SSCH clinic. We accounted for this uncertainty with multiple sensitivity analyses. Fifth, we made the simplifying assumption that utility weights are equivalent to the inverse of disability weights due to limitations in utility weight data availability in LMICs. Based on past analyses

examining both QALYs and DALYs, the resulting estimates are unlikely to meaningfully change the overall interpretation.³⁴ Sixth, many of our transition probabilities were derived from studies in high-income countries since estimates were not available from Mexican settings. These transition probabilities may differ from those of Mexican patients and could influence our results. Despite these limitations, our study has significant strengths, including a societal cost perspective taking into account opportunity cost of patients, a rigorous TDABC costing approach, a Markovian framework for cost-effectiveness analysis with multiple time horizons and three sensitivity analyses to strengthen confidence in our estimates.

CONCLUSION

CESPEC is a novel and high-value diabetes care model in rural Mexico that focuses on community engagement, continuing medical education to health workers and community members, supply chain management and active case finding. The programme costs \$144 per patient per year and is highly cost-effective at US\$2981 per QALY gained. Further study is needed to evaluate whether CESPEC can be successfully scaled and evaluated in other rural regions of Mexico.

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APPENDIX

Supplemental Methods

Study selection

- Transition probabilities: To estimate the probability of achieving diabetes control with *Compañeros En Salud Programa de Enfermedades Crónicas* (CESPEC) compared to usual care, we utilized probabilities from our previous study that compared the two care models using a difference-in-differences approach.¹ For other transition probabilities, we sought high quality studies from Mexico that would provide the rate or probability of developing diabetes complications, stratified by whether diabetes was controlled or uncontrolled. This level of detail was available in a Mexican setting for mortality,² but was not available for other diabetes complications. To estimate the probability of developing these other diabetes complications, we selected three landmark diabetes trials conducted in Western nations.³⁻⁵ The three studies we selected also carry the three highest study weights in a Cochrane review.⁶ To assess the risk of developing a macrovascular diabetes complications after already having a microvascular complication, we identified a study based on the ADVANCE trial to derive transition probabilities.⁷
- Costs: The estimation of the cost of the CESPEC intervention and usual care are detailed in the main manuscript. The cost of diabetes complications were drawn from a report by Barraza-Lloréns et al. that is based in the Mexican health care setting. This is the only study we identified that estimates a per person or per event cost for diabetes complications in Mexico. Other estimates of diabetes costs in Mexico reported in the literature are population-level studies that only report aggregated total costs for the entire Mexican health care system.⁸
- Health states: To calculate quality-adjusted life years (QALYs) reported in Appendix Table 1, we used disability weights from the Global Burden of Disease study given their comprehensiveness and established use in global health settings.⁹ Full details of the derivation of QALYs is reported below in the “Primary outcome” section.

Transition probability calculation

For multiple model parameters, the original studies reported outcomes as rates (outcome events per unit time). For a given rate (r) and time period (t), a transition probability (p) was calculated using the following equation:¹⁰

$$p = 1 - e^{-rt}$$

For transition probability model parameters derived from multiple data sources (nephropathy, neuropathy, retinopathy, stroke and myocardial infarction), we then calculated a weighted average transition probability using the meta-analysis weights reported in a Cochrane analysis.⁶

Sensitivity analysis: uncertainty of model parameters

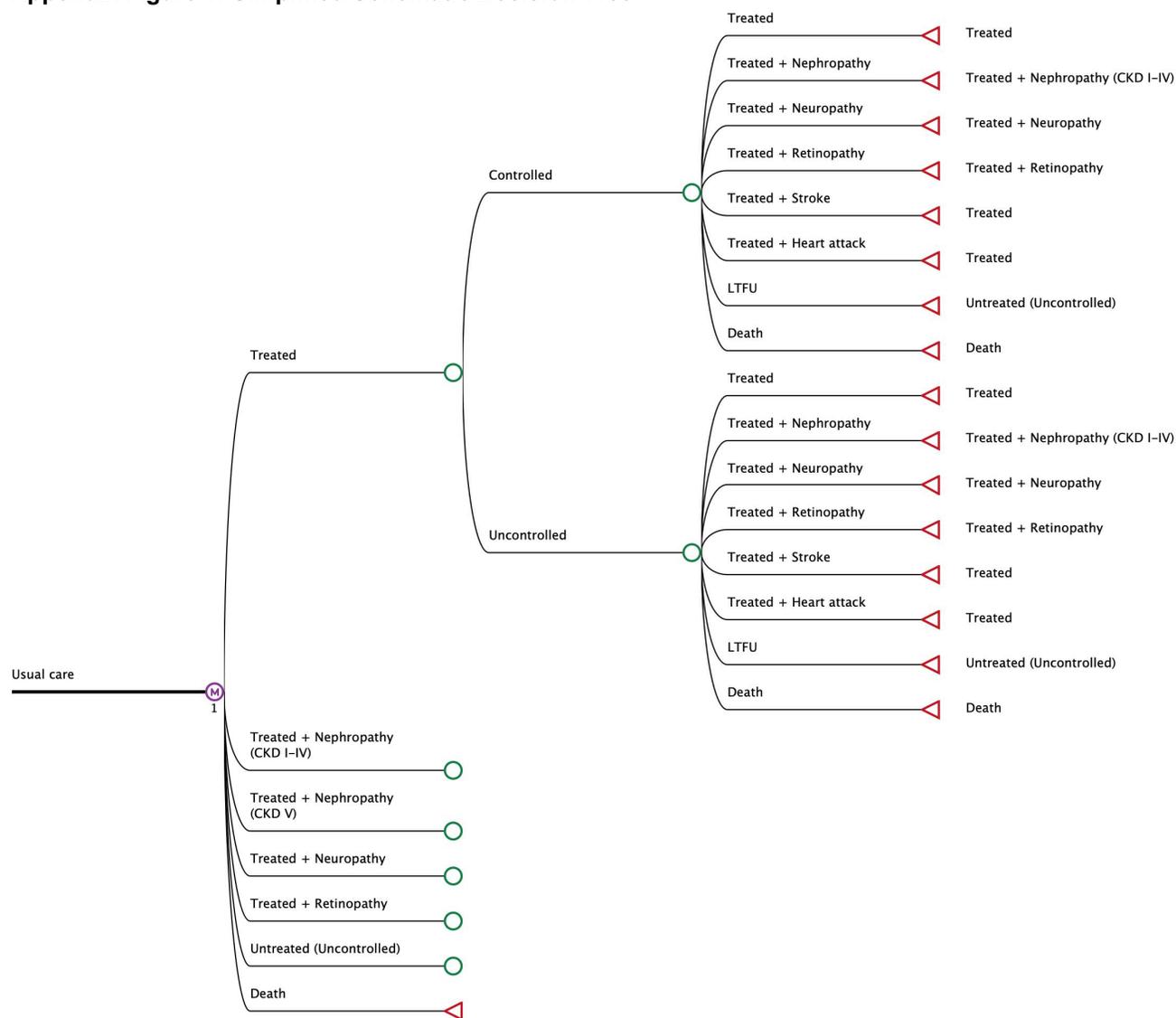
To characterize uncertainty in the probabilistic sensitivity analysis, we used beta distributions for binary outcomes and gamma distributions for costs. Distributions were fit for probabilistic sensitivity analysis by using the method of moments approach.¹⁰ Using this approach, we used the point estimate mean and standard errors reported by the selected studies to calculate distribution parameters. In one data source (Barraza-Lloréns et al.), no standard errors were reported for the cost point estimates. This report calculated per person costs utilizing multiple studies. Where possible, we reviewed the original, referenced studies to derive the standard errors. If not available, we used existing standard errors from other estimates in the report to calculate new standard errors that were proportional to the magnitude of the cost estimate.

Primary outcome

We selected QALYs as our primary outcome for the cost-effectiveness analysis, given our aim to measure the effectiveness of an intervention, as opposed to an assessment of disease burden (for which disability-adjusted life years may be preferred).¹¹ However, there is a lack of published utility weights for multiple diabetes health

states and from low- and middle-income countries that we needed for our decision analysis model. Most utility weights that exist for diabetes are derived in high-income countries.¹² Instead of using available utility-weights from high-income countries, we took the approach of utilizing disability weights under the assumption that $Q=1-D$, where Q is the utility weight and D is the disability weight. Though there are differences in how utility and disability weights are derived, this approach provided several advantages. First, it allowed us to calculate QALYs for the entire model using a uniform set of disability weights from the Global Burden of Disease study that were derived using the same methodology.⁹ Second, these disability weights were developed for use in global health settings and low- and middle-income countries. Our approach has been evaluated empirically,¹³ and has been utilized in other cost-effectiveness analyses.¹⁴ Furthermore, studies evaluating the use of both QALYs and DALYs to determine cost-effectiveness usually lead to similar interpretations and conclusions.¹⁵

Appendix Figure 1: Simplified Schematic Decision Tree



Appendix Table 1: Model Parameters for Cost-effectiveness Analysis

Model Parameter	Point Estimate (SE)	Distribution	Source
Costs of complications (2016 US dollars)			
<i>Per patient per year</i>			
Neuropathy	\$69.02 (6.11)	γ	Barraza-Lloréns et al (2015) ¹⁶
Retinopathy	\$369.08 (32.69)	γ	Barraza-Lloréns et al (2015) ¹⁶
Nephropathy (CKD I-IV)	\$346.18 (30.67)	γ	Barraza-Lloréns et al (2015) ¹⁶
Nephropathy (CKD V)	\$19,445.84 (1722.53)	γ	Barraza-Lloréns et al (2015) ¹⁶
<i>Per event</i>			
Stroke	\$13,328.20 (912.65)	γ	Barraza-Lloréns et al (2015) ¹⁶
Myocardial infarction	\$6,269.76 (681.44)	γ	Barraza-Lloréns et al (2015) ¹⁶
Costs of programs (2016 US dollars)			
<i>Per patient per year</i>			
CESPEC	\$143.69 (2.29)	γ	Table 1
Usual care	\$124.83 (5.98)	γ	Table 1
Transition probabilities (proportion of individuals per year)			
<i>Diabetes control^a</i>			
Controlled in CESPEC	0.526 (0.018)	β	Duan et al (2018) ¹
Controlled in usual care	0.277 (0.002)	β	Duan et al (2018) ¹
<i>Neuropathy</i>			
Diabetes controlled	0.081 (0.028) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Diabetes uncontrolled	0.083 (0.028) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
<i>Retinopathy</i>			
Diabetes controlled	0.014 (0.002) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Diabetes uncontrolled	0.015 (0.002) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
<i>Nephropathy (CKD I-IV)</i>			
Diabetes controlled	0.055 (0.036) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Diabetes uncontrolled	0.057 (0.036) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
<i>Nephropathy (CKD V)</i>			
Diabetes controlled	0.004 (0.001) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Diabetes uncontrolled	0.005 (0.002) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
<i>Stroke</i>			
Diabetes controlled	0.006 (0.001) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Diabetes uncontrolled	0.006 (0.001) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Existing microvascular disease	0.009 (0.003)	β	Mohammedi et al (2017) ⁷
<i>Myocardial infarction</i>			
Diabetes controlled	0.010 (0.003) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵

Diabetes uncontrolled	0.013 (0.004) ^b	β	UKPDS (1998), ³ ACCORD (2008), ⁴ ADVANCE (2008) ⁵
Existing microvascular disease	0.008 (0.003)	β	Mohammedi et al (2017) ⁷
<i>All-cause death</i>			
Diabetes controlled	0.010 (0.001)	β	Herrington et al (2018) ²
Diabetes uncontrolled	0.016 (0.001)	β	Herrington et al (2018) ²
Existing microvascular disease	0.026 (0.006)	β	Mohammedi et al (2017) ⁷
Quality of life (QALYs)			
<i>Diabetes (uncomplicated)</i>	0.951 (0.010)	β	IHME (2017) ⁹
<i>Neuropathy</i>	0.867 (0.025)	β	IHME (2017) ⁹
<i>Retinopathy</i>	0.866 (0.025) ^c	β	IHME (2017) ⁹
<i>Nephropathy (CKD I-IV)</i>	0.922 (0.015) ^c	β	IHME (2017) ⁹
<i>Nephropathy (CKD V)</i>	0.414 (0.084) ^c	β	IHME (2017) ⁹
<i>Stroke</i>	0.691 (0.049) ^c	β	IHME (2017) ⁹
<i>Myocardial infarction</i>	0.900 (0.019) ^c	β	IHME (2017) ⁹
Discount rate	0.03	N/A	N/A

SE=standard error; CKD=chronic kidney disease; CESPEC=*Compañeros En Salud Programa de Enfermedades Crónicas*; QALY=quality-adjusted life year; UKPDS=United Kingdom Prospective Diabetes Study; ACCORD=Action to Control Cardiovascular Risk in Diabetes; ADVANCE=Action in Diabetes and Vascular Disease; IHME=Institute of Health Metrics and Evaluation

^a Diabetes control is defined by the Secretariat of Health of Chiapas as a hemoglobin A1c below 7% or (if not available) a fasting blood glucose level below 7.16 mmol/l (130 mg/dl)

^b Weighted average based on meta-analysis weights in Hemmingsen et al (2013)⁶

^c Average of disability weights across disease state subcategories

Appendix Table 2: One-way Sensitivity Analysis results

Model Parameter	80% Base Case Value	Base Case Value	120% Base Case Value	ICER Low	ICER High	ICER Spread
Cost of CESPEC	\$114.95	\$143.69	\$172.43	Dominated	\$6,407.25	\$6,851.53
Cost of usual care	\$99.86	\$124.83	\$149.80	\$253.11	\$5,709.86	\$5,456.75
Probability of diabetes control in CESPEC	0.42	0.53	0.63	\$2,096.32	\$4,683.51	\$2,587.19
Probability of diabetes control in usual care	0.22	0.28	0.33	\$2,550.64	\$3,524.32	\$973.68
Cost of nephropathy (CKD V)	\$15,556.67	\$19,445.84	\$23,335.01	\$2,845.18	\$3,117.80	\$272.63
Cost of stroke	\$10,662.56	\$13,328.20	\$15,993.84	\$2,953.02	\$3,009.96	\$56.93
Cost of nephropathy (CKD I-IV)	\$276.94	\$346.18	\$415.42	\$2,963.47	\$2,999.51	\$36.04
Cost of myocardial infarction	\$5,015.81	\$6,269.76	\$7,523.71	\$2,968.56	\$2,994.42	\$25.86
Cost of neuropathy	\$55.22	\$69.02	\$82.82	\$2,976.57	\$2,986.40	\$9.83
Cost of retinopathy	\$295.26	\$369.08	\$442.90	\$2,978.24	\$2,984.74	\$6.50

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