BMJ Public Health

Picking the low-hanging fruit: the cost-effectiveness of opportunistic diabetes screening during tuberculosis contact investigations on the Texas–Mexico border

Robert A McGowan [1,2] Henry Shelton Brown [3] Juan Carlos Lopez-Alvarenga [4] Blanca I Restrepo [5,6,7]

To cite: McGowan RA, Brown HS, Lopez-Alvarenga JC, *et al*. Picking the low-hanging fruit: the cost-effectiveness of opportunistic diabetes screening during tuberculosis contact investigations on the Texas–Mexico border. *BMJ Public Health* 2024;**2**:e001189. doi:10.1136/bmjph-2024-001189

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjph-2024-001189).

Received 19 March 2024
Accepted 8 October 2024

For numbered affiliations see end of article.

Correspondence to
Dr Blanca I Restrepo;
blanca.i.restrepo@uth.tmc.edu

ABSTRACT

Objective There is a known association between type 2 diabetes (diabetes) and tuberculosis (TB), and TB clinics have become hubs for new diabetes diagnosis among active patients with TB. However, despite the potential to identify diabetes patients, resources limit diabetes screening opportunities to close TB contacts. We assessed the cost-effectiveness of adding opportunistic screening for diabetes during the routine TB contact investigations conducted at TB clinics.

Research design and methods We used a Markov-based model to simulate the costs of diabetes screening, management and health outcomes, including the incidence of complications and death. All costs were considered from a health system perspective. One-way sensitivity analyses were conducted to assess the robustness of the results to various assumptions. Interventions that fall below US$50 000 per quality-adjusted life years (QALYs) are commonly considered very cost-effective, while those between $50 000 and $100 000 are considered moderately cost-effective.

Results Simulation of diabetes screening among TB contacts resulted in not only increased survival and reduced complications but also increased costs of diabetes management. The resulting incremental cost-effectiveness ratio was $32 642 per QALY added, which is well within commonly used willingness-to-pay thresholds for cost-effectiveness. Compared with no screening, screening increased the costs by $8633 and resulted in an increase in QALYs by 0.26 per patient.

Conclusions In the base case analysis, screening was very cost-effective given that none of the sensitivity analyses resulted in a cost-effectiveness ratio above $50 000 per QALY. Our results indicate that the expansion of diabetes screening in TB clinics is a cost-effective strategy to improve health outcomes.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies on the cost-effectiveness of diabetes screening have shown a range of results, with interventions targeting high-risk populations generally having the highest cost-effectiveness.

WHAT THIS STUDY ADDS

⇒ We simulated the cost-effectiveness of diabetes screening in tuberculosis clinics along the Texas–Mexico border and included the costs of newer medications like glucagon-like peptide-1 agonists (GLP-1s). We find that opportunistic diabetes screening for tuberculosis contacts is cost-effective, reduces diabetes complications and improves survival of newly diagnosed patients.

HOW MIGHT THIS STUDY AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our results support the expansion of diabetes screening programmes into tuberculosis clinics in the Texas–Mexico border region and beyond and could ultimately reduce health disparities and improve population health.

Along the Texas–Mexico border, large disparities in income, education and healthcare access contribute to chronic disease rates higher than the national average.[1] Willacy County (18.8%) and Lavaca County (17.2%) have much higher rates of diagnosed type 2 diabetes (diabetes) than state (10.9%) or national (9.1%) rates.[2] In addition to the high rate of diagnosed diabetes, new diabetes is often identified when complications develop after years of preclinical disease progression. Among the lower socioeconomic strata (SES), 23% of the population in Cameron County, Texas, had diabetes and 39% of those were previously undiagnosed (new diabetes).[3]

Higher rates of infections are also more prevalent in regions of the world with low SES.[4] Such is the case for active tuberculosis (TB), a pulmonary disease that affects 10 million individuals and causes 1.6 million deaths per year worldwide.[5] Despite a historic reduction in the incidence of TB in the US and Mexico, this disease remains more prevalent in distinct population pockets including

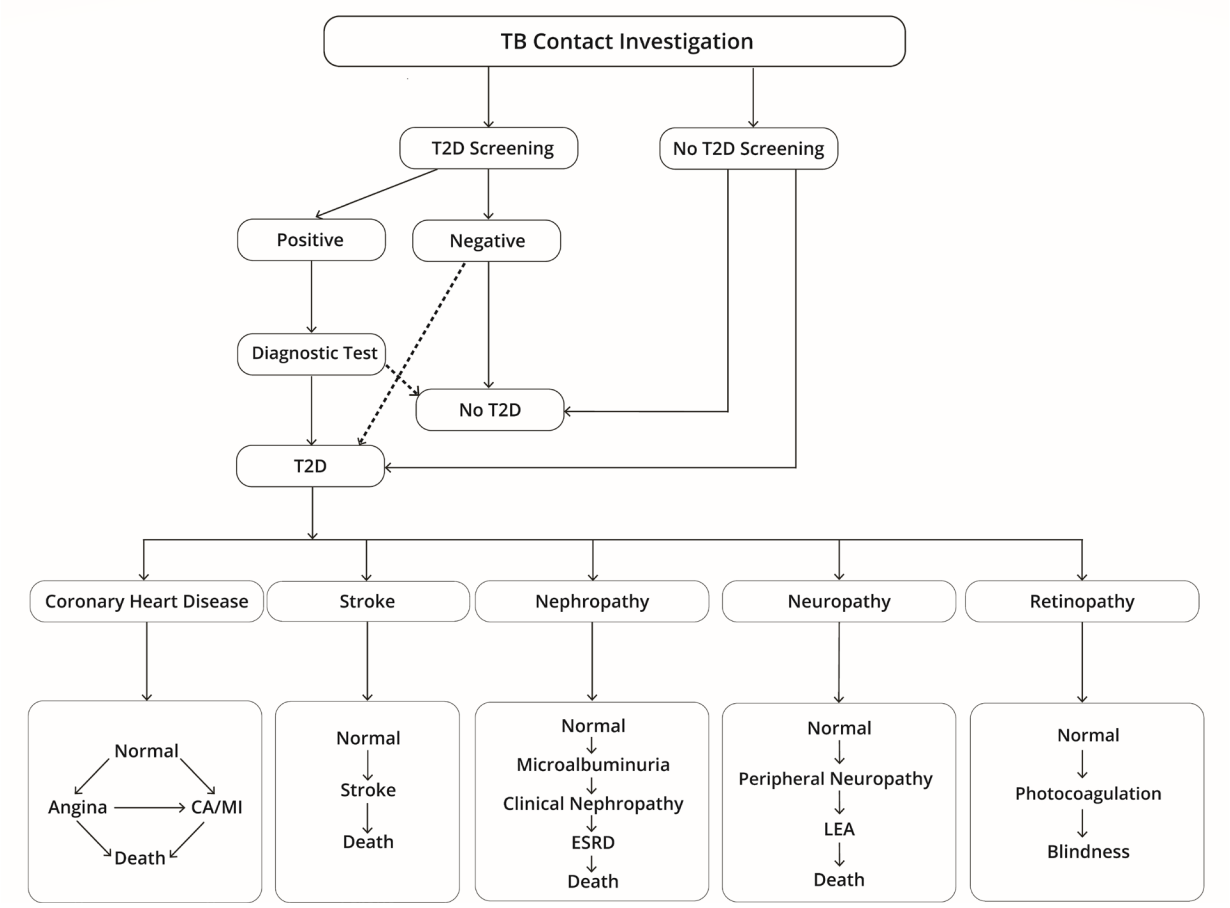

Figure 1 Progression through screening and diagnosis and Markov model of diabetes complications. Dashed lines represent false positive and false negative diabetes screening results. CA, cardiac arrest; ESRD, end-stage renal disease; LEA, lower extremity amputation; MI, myocardial infarction; TB, tuberculosis; T2D, type 2 diabetes.

states along the US border with Mexico.[6–9] TB is a reportable disease with new diagnosis centralised in reference clinics where contact tracing is also conducted among immediate family members and close contacts of new TB cases to identify and manage undiagnosed TB or those with latent TB infection at risk of progression to active disease.[6]

Given that diabetes is a risk factor for active TB, screening for diabetes among newly diagnosed patients with TB is recommended by the WHO[7] and others,[8] and TB clinics along the Texas–Mexico border are currently following this recommendation.[9] We previously found that the prevalence of diabetes among newly diagnosed patients with TB was 39% in Texas and 36% in Mexico, showing the significant opportunity for new diabetes diagnosis in active patients with TB.[10] One quarter of all TB cases in these communities are attributable to diabetes, so control of diabetes is critical to achieve TB eradication.[10]

While the diabetes screening programme has been implemented for patients with TB, there is still one area of untapped potential: TB contacts who come to the clinic for TB screening. TB generally affects individuals in the lowest SES of a community[4] and hence, TB contacts are rarely seen by a healthcare provider, and an important proportion may not be aware of their diabetes diagnosis. Several organisations have recommended opportunistic screening for individuals at high risk for diabetes.[8 11] Opportunistic screening is defined as screening carried out when a patient is seen for something other than the disorder in question. TB clinics serving populations with low SES and high rates of obesity and diabetes, such as those in the US–Mexico border,[10] provide an ideal setting for opportunistic diabetes screening. In one cohort, we found that 30% of TB contacts along the Texas–Mexico border had diabetes and 34% of those were newly diagnosed, indicating that a significant portion of the population could benefit if this screening was to be offered to all TB contacts.[12]

Determining whether to implement any programme requires consideration of its costs and benefits. For diabetes, we would consider the costs of screening, diagnosis and subsequent diabetes management against the improved health outcomes and averted costs due to delay of complications and death. Cost-effectiveness of diabetes screening programmes has been estimated at the national level in countries like USA and Brazil.[13–15] In USA, more targeted approaches have also been evaluated, such as screening among African Americans or in individuals with hypertension.[16] However, the

Table 1 Reference data for demographics and prevalence of new diabetes and cardiovascular risk factors among close contacts of patients with TB with diabetes on the Texas and Mexico border* †

Characteristics in TB contacts	n (%) in diabetes (n=296)
New diabetes	79 (26.7%)
Age, in years	52.8 (12.7)
Male	88 (29.7%)
HbA1c, % in new diabetes	7.6 (1.8)
HbA1c, % in known diabetes	9.1 (2.5)
Current smoking	35 (11.8%)
Self-reported hypertension	124 (41.9%)
Total cholesterol, mg/dl	179.0 (43.9)
HDL, mg/dL	42.3 (10.6)

*Categorical data expressed as n (column %) except for the total n (% of total with or without diabetes) .
†Continuous variables expressed as mean (SD).
HbA1c, glycated hemoglobin; HDL, high density lipoprotein cholesterol; TB, tuberculosis.

Hispanic-predominant demography and epidemiology of diabetes in patients attending TB clinics in south Texas and the adjacent Mexican border may yield different results. The impact of adding a diabetes screening step to the routine TB contact investigations has not been evaluated. To address this gap, we evaluated if a diabetes screening programme in clients attending TB clinics in south Texas would be cost-effective. For this, we modelled the long-term costs and health outcomes with data from TB contacts attending Texas–Mexico border clinics and using healthcare costs available for USA, and hence, relevant to South Texas and beyond.

RESEARCH DESIGN AND METHODS

Cost-effectiveness analysis

Cost-effectiveness analysis consists of comparing the incremental costs to deliver an intervention with the long-term benefits derived from it. In the case of the diabetes screening programme, the costs to deliver the intervention were compared with the incremental difference in healthcare expenditures and quality-adjusted life years (QALYs) between those receiving the intervention, and an otherwise identical cohort. The intervention includes screening and diagnosis, followed by standard care consisting of pharmaceutical and lifestyle change recommendations. The control group remains unaware of their diabetes status until they develop complications, at which point clinical diagnosis occurs and treatment begins (figure 1). Thus, we examined the incremental health-related benefits of the programme relative to the costs to deliver it.

Our approach is summarised by the following equation:

Incremental Cost – Effectiveness Ratio (ICER) = [(Cost of diabetes testing and treatment of contacts) – (averted medical costs due to early diagnosis)]/QALYs added

The first term of the numerator in the equation depends on the number of additional contacts screened and the cost of treating them if they screen positive for diabetes, and to a much smaller degree, the cost of negative screening results. The second term of the numerator in[1] depends on the costs of medical care averted or delayed in the Markov chain described below.

Screening parameters

We obtained data on the prevalence of diabetes among TB contacts from the Texas–Mexico border as part of an ongoing TB research programme.[3 10 12] Because we do not have sufficient data on this population, we used estimated sensitivity (68%) and specificity (89%) of screening for diabetes from a universal screening programme in Brazil, in which 47% of patients were in a fasting state for a blood glucose screening, and 53% were not, with cut-offs for a positive result of 100 mg/dL and 140 mg/dL, respectively.[13] A patient with a positive result would undergo a diagnostic oral glucose tolerance test (OGTT), which we assume has 100% accuracy and will detect a false positive from the screening stage. These data points were used to calculate the true-positive, true-negative, false-positive and false-negative rates for diabetes screening, which are all inputs to the model. These rates are relevant to the cost-effectiveness of the screening programme, because only true positive results will yield any benefit in terms of QALYs and averted costs. Screening those without diabetes (true negatives and false positives) as well as failing to detect those with diabetes (false negatives) would not prevent or delay complications but would incur the same screening costs as a true positive. Figure 1 represents the potential paths through a screening programme for those with and without diabetes.

Utilities for QALY calculations

Utilities for each health state are from Coffey[17] and are summarised in online supplemental table S1.1. In cases where a patient has progressed through multiple complications on the same pathway (clinical nephropathy and end stage renal disease), only the most severe QALY decrement from that pathway is used. In cases where a patient has developed complications along multiple pathways, the QALY decrements are additive.

Transition probabilities of disease states

Baseline transition probabilities of disease states were based on the literature, primarily on data from the United Kingdom Prospective Diabetes Study (UKPDS) and the Framingham Heart Study. The probabilities are based on data from individuals with glycated hemoglobin (HbA1c) values of 9.0% on average at the time of diabetes diagnosis, where probabilities will be generally lower on reductions in HbA1c and vice versa.[18] Baseline transition probabilities and hazard ratios for changes in HbA1c are presented in online supplemental table S1.2.

Table 2 Projected lifetime cumulative incidence per confirmed case identified during diabetes screen, by type of diabetes complication

Diabetes complication	No screening	Screening	Difference
Coronary heart disease	27.5%	27.4%	–0.1%
Stroke	14.0%	13.9%	–0.1%
Nephropathy	27.8%	24.9%	–2.9%
End-stage renal disease	7.4%	6.8%	–0.6%
Peripheral neuropathy	40.8%	37.4%	–3.4%
Lower extremity amputation	3.2%	3.0%	–0.2%
Blindness	9.3%	8.2%	–1.1%

Epidemiologic data

Demographic data, prevalence of cardiovascular risk factors (BMI, smoking, self-reported hypertension) and of new and known diabetes were based on data from close contacts of new patients with TB identified in TB clinics in South Texas and adjacent Mexican border communities as part of research studies described previously (table 1).[10 12 19]

Economic data

Three types of costs were considered: diabetes screening and diagnosis, diabetes treatment and diabetes complications. Costs associated with blood glucose screening and OGTT are based on the 2020 Q4 Medicare Clinical Laboratory Fee Schedule.[20] Costs of diabetes management are based on recent national literature and include two office visits, medications (non-insulin, insulin or both) and other diabetes equipment and supplies.[21 22] We assumed that 10% of the cohort took insulin alone, 67% non-insulin treatments only (oral anti-diabetic drugs or diet) and 23% both. These assumptions were based on unpublished data from a Texas-based cohort of diabetes patients. The cost of diabetes-related complications included the cost of nephropathy, neuropathy, retinopathy, coronary heart disease (CHD) and stroke. Event-year (year 1) and annual costs (years 2 and beyond, until death) of complications considered in the model are based on Ward[23] and updated to 2021 dollars using the Medical Care Index component of the Consumer Price Index (online supplemental table S1.3). All future costs were discounted to the current year at a rate of 3% per year.

Projecting healthcare

We used the Diabetes Cost-Effectiveness Model (CDC-RTI Model) that was jointly developed by the Centers for Disease Control and Prevention and Research Triangle Institute to build a Microsoft Excel-based simplified version and updated key parameters (all costs inputs are derived from more recent sources, and characteristics of TB contact population are used to adjust all transition probabilities) to reflect the population served and the impact of this specific intervention.[14 15 24] The CDC-RTI Model is a deterministic Markov simulation model of disease progression for diabetes that projects the cost-effectiveness of interventions designed to impact diabetes-related outcomes. It stimulates the development of diabetes-related microvascular (ie, nephropathy, neuropathy and retinopathy) and macrovascular (ie, CHD and stroke) complications along five separate pathways. Model outcomes include numbers and rates of complications, deaths, cost of care and QALYs. Markov models are state-transition models whereby progression between disease states is governed by transition probabilities that depend on risk factors. In our model, each model cycle represents 1 year. At the beginning of each cycle, an individual can experience a transition along each complication pathway or remain in the same state, and they cannot experience another transition until the following cycle. Relevant risk factors in this case include glycaemic level (HbA1c), blood pressure, cholesterol, smoking status and disease duration. Outcomes are projected from the year of diagnosis to either death or age 95, effectively a lifetime horizon. The primary mechanism through which the intervention impacts health outcomes in our model is through its impact on HbA1c, using data from the literature on rates of complications at different HbA1c levels.[18] Our previous research on diabetes screening among TB contacts from the Texas–Mexico border showed that the mean HbA1c at diagnosis of diabetes was 7.6% (table 1). We assume that clinical diagnosis of diabetes occurs 9–12 years after onset of initial metabolic abnormalities and decline of pancreatic beta cell function (mean: 10.5 years).[25] We further assumed that opportunistic screening would cut that in half to 5.25 years, under the assumption that screening is equally likely to detect metabolic abnormalities (ie, prediabetes) at any preclinical stage.[26] Prior to clinical diagnosis, HbA1c is assumed to increase by 0.2 percentage points per year to 8.7% at clinical diagnosis, comparable to the value found in the UKPDS (9.0%)[27] and that used by the CDC/RTI group (8.9%).[15] We conservatively estimated that HbA1c would decrease by 1.0 percentage points in the first 12 months, then increasing by 0.156 percentage points per year following diagnosis (for comparison, the UKPDS diet-only group saw an average HbA1c reduction of 2.1 percentage points in the first 12 months). The cost of the programme is calculated from a health system perspective, meaning that it does not differentiate between costs paid by different parties (government, insurance company, patient, etc). A 3% discount rate was applied to both QALYs and healthcare costs.[28] The full technical report on the model is available in online supplemental file 2.

Sensitivity analysis

Because our analysis projects outcomes into the future using estimates for several key data points, sensitivity analyses were carried out to test the effects of varying key parameters on the base model findings. Univariate and probabilistic sensitivity analyses were performed. For the univariate analysis, key parameters were adjusted by 20% and the low and high estimates were plugged into the model individually while holding all other parameters constant at base model levels to determine the extent to which they impacted the results. For the probabilistic analysis, random values were drawn from selected probability distributions (online supplemental table S2.16), as a Monte Carlo simulation with 1000 iterations of 1000 patients. The distributions were chosen either based on the literature, or when sources could not be found, so that the bounds of the 95% CI were 20% away from the mean.

Data and resource availability

The dataset analysed in the current study are available from the corresponding author on reasonable request.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting or dissemination plans of our research.

RESULTS

Programme impact on health outcomes and healthcare spending

Over a lifetime horizon, participation in the intervention is projected to result in a 0.1 percentage point (pp) reduction in the cumulative incidence of CHD, 0.1pp fewer strokes, 2.9pp fewer cases of nephropathy, 0.6pp fewer cases of end-stage renal disease, 3.4pp less peripheral nephropathy, 0.2pp fewer incidents of lower extremity amputation and 1.1pp fewer cases of blindness (table 2). On a per-person, discounted basis, individuals will gain 0.26 QALYs through participating in the programme and will have US$8633 greater lifetime healthcare spending than those who do not, on average. The difference in average lifetime healthcare spending is broken down as follows: a lifetime savings from reduced complications of $3129 per person and an incremental cost of $11 762 per person to administer the screening and diabetes management care (table 3).

Cost-effectiveness results

Table 3 details the estimated cost-benefit results from the model using data for the 296 adults with diabetes in the TB contact cohort. Under the health system perspective, the intervention increased lifetime costs primarily due to the earlier introduction of treatment. Screening all adult TB contacts increased lifetime costs by $8633 and resulted in a gain of 0.26 QALYs. The estimated incremental cost-effectiveness ratio (ICER) was $32 642 per QALY.

Sensitivity analyses

In the univariate analysis, the model was sensitive to parameters such as programme costs, QALY adjustments and HbA1c reduction attributed to the programme. Increasing and decreasing treatment costs by 20% resulted in a cost per QALY range from $23 827 to $41 456. For QALY adjustments, the range was $28 017–$40 802. When varying the HbA1c reduction, the range was $27 728 to $40 246. The model was not sensitive to the treatment adherence rate, because adherence affects both the numerator and denominator of the equation (ie, a non-adherent patient would not incur the costs of treatment nor improve health outcomes). The model was also not sensitive to the cost of complications. The discount rate ranged from 1% to 5%, and the cost per QALY ranged from $24 950 to $42 588 online supplemental figure S1.1.

The average results of the probabilistic sensitivity analysis yielded $6695 incremental costs and 0.26 incremental QALYs gained per screened patient. The ICER in the probabilistic sensitivity analysis was $25 321 per QALY gained. 7 out of 1000 simulations exceeded an ICER of $50 000/QALY. 54 of out 1000 resulted in negative incremental costs. Online supplemental figure S1.2 illustrates

Table 3 Diabetes screening cost-effectiveness analysis

	Cost (2021 US$) (discounted)				Health outcomes (discounted)	Incremental cost-effectiveness ratio
	Screening and diagnosis	Treatment	Complications	Total	Remaining QALYs	Total cost (US$)/ QALY
Per confirmed diabetes case						
No screening	$0	$37 412	$49 127	$86 539	9.38	
Screening	$105*	$49 068	$45 998	$95 172	9.64	
Difference	$105	$11 657	$(3129)	$8633	0.26	**$32 642**

All $ values and QALYs are discounted at 3% per year; all $ values are in 2021 USD.
*Screening and diagnosis costs are those for the entire screened population divided by the number of confirmed diabetes cases. Thus, the costs of false negatives and false positives accrue to the population of interest.
QALY, quality-adjusted life year.

the distribution of results from the probabilistic sensitivity analysis.

CONCLUSIONS

TB predominantly affects individuals in the lowest socioeconomic strata of a community, and TB programmes worldwide have well-established protocols guided by the WHO to invite family members and friends who are close to a newly diagnosed patients with TB to come to a nearby TB clinic to assess their active or latent TB status.[5] This visit opens avenues for individuals who usually receive little to no preventive healthcare to attain new information on their diabetes status, and when positive, to interact with healthcare workers who will guide them on approaches to seek further medical care. The WHO and International Union Against TB and Lung Disease recommend the screening of active patients with TB for diabetes,[12] but this has not been extended to TB contacts, most likely due to lack the resources. In a health system with limited resources, cost-effectiveness analysis can help policymakers prioritise interventions that provide the greatest benefit to patients. We evaluated one potential approach to expanding diabetes screening at TB clinics: opportunistic screening for diabetes among all adult TB contacts. While there is no universally accepted threshold for cost-effectiveness analyses in the USA, an intervention is generally considered cost-effective if it falls below a cost of $50 000 per QALY and moderately cost-effective if it falls below $100 000 per QALY.[29] Our model assumed that all adult TB contacts would be screened for diabetes, but screening could be directed to only high-risk individuals. We are currently developing models to guide TB clinic staff for the selection of contacts with the highest risk for undiagnosed diabetes.

We found that opportunistic screening for diabetes among adult TB contacts is cost-effective at a willingness-to-pay threshold of $50 000 per QALY. Our model showed that when screening was followed by glycaemic control, it delayed and/or prevented macrovascular and microvascular diabetes complications, resulting in increased lifespan and offsetting diabetes costs, including expenses for metformin or insulin. The mechanism by which this occurs is by lowering of HbA1c. At the time of treatment initiation, the treated cohort begins to experience improved glycaemic control relative to the control cohort, which results in lower risk of all complications that were modelled. This relative risk reduction persists until the control cohort is diagnosed after 5.5 years, at which point the controls also experience improved glycaemic control. The number of screenings required to identify a diabetes case are much lower in our study than under a universal, nationwide screening programme, which reduces the logistics, resources and costs used on patients who do not have a diabetes diagnosis. This is due to the high prevalence of undiagnosed diabetes referenced previously in TB clinics.[12] Thus, our strategy is comparable to a targeted screening programme even without imposing any targeting criteria.

Our findings are comparable to previous cost-effectiveness analyses that addressed diabetes screening and treatment. Siegel *et al* reviewed cost-effectiveness studies of diabetes treatment and management, including four papers which assessed screening for undiagnosed diabetes.[30] They first reviewed a CDC study, which examined a simulated opportunistic screening of persons over 24 years during routine medical care,[16] and found the cost per QALY was approximately $144,000/QALY in 2017 dollars.[16] Second, Hoerger *et al* assessed targeted screening based on a diagnosis of hypertension and then universal screenings at various ages. Screening for undiagnosed diabetes based on a diagnosis of hypertension was most cost-effective at $59 000–1 66 000 in 2017 dollars, and less so for progressively more universal screening.[14] Third, they reviewed Gillett *et al*, who targeted screening based on hypertension, and found that the cost per QALY was under $4500 for all age groups simulated.[31] Finally, Kahn *et al* simulated a universal screening at various ages and intervals (every 6 months, 1, 3 and 5 years). All were below $37 000 per QALY in 2017 dollars, and screening at older ages was the most cost-effective.[32] Figure 2 compares the incremental costs and the QALYs gained from our study against the aforementioned studies.[14–16 33–38]

Our model used healthcare costs adjusted to 2021 US dollars and health information from subjects undergoing contact investigations in TB clinics on the South Texas and adjacent Mexican border. We validated the simulated incidence of complications among diabetes patients by comparing results to the universal and targeted screening programmes evaluated by Hoerger[14] and the CDC Diabetes Cost-Effectiveness Group,[15] finding that our model predicts very similar incidence rates to the CDC/RTI model on which it is based. The difference in costs is attributable to medical inflation in the years since those studies.

Our model used healthcare cost data from the USA, which were readily available. However, the actual costs for diabetes patients living in south Texas may be lower than we estimated because it is common for people to go to the Mexican side of the border to obtain medications and medical care.[39] However, this latter option is not feasible for undocumented migrants, who are in the lowest SES and have limited access to healthcare. If a similar analysis was to be done for patients living on the Mexican side of the border, this would require the use of Mexico's costs and the use of a lower willingness-to-pay threshold, typically at one to three times Mexico's GDP per capita per the WHO's standards (up to $31 077/QALY based on Mexico's GDP per capita of $10 359 in 2021; note: the WHO's standard not typically used in US-based cost-effectiveness analyses).[40] Thus, the impact to the cost-effectiveness of the programme depends on the relative decreases in actual costs versus the cost-effectiveness threshold, as well as how much and which

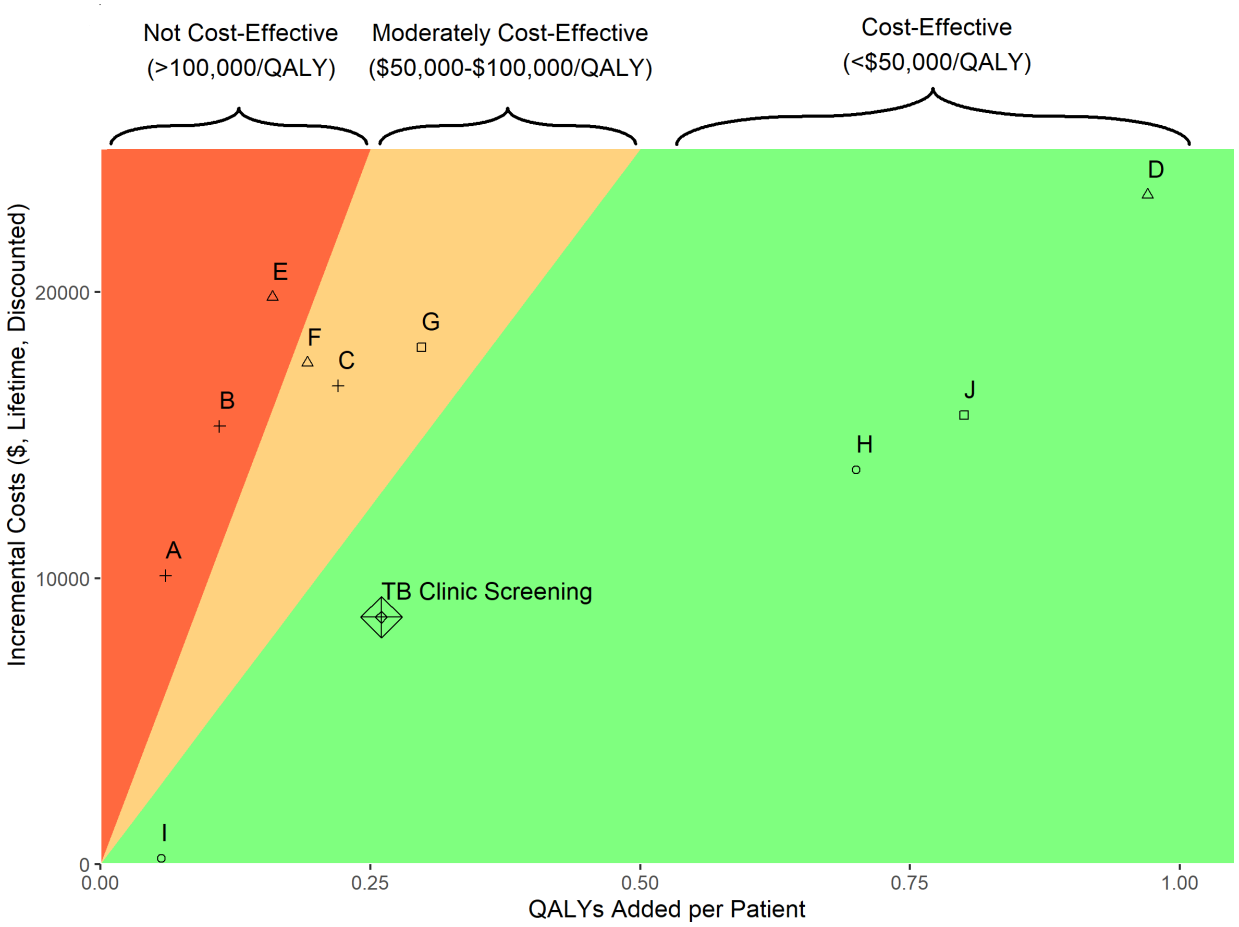

Figure 2 Cost-effectiveness of various diabetes interventions. Plot of per-patient cost versus added QALYs for different types of published diabetes interventions. ICER ratios are colour-coded: US$50 000/QALY are the most cost-effective (green), $50 000 to $100 000/QALY are moderately cost-effective (orange) and greater than $100 000/QALY are the least cost-effective (red). Types of interventions include: screening, (A),[16] (B)[14] and C)[14]; intensive glycaemic control, (D),[33] (E)[34] and F)[15]; a diabetes self-management programme, (G)[35]; education, (H)[36] and I)[37]; case management, (J).[38] ICER, incremental cost-effectiveness ratio; QALYs, quality-adjusted life years; TB, tuberculosis; T2D, type 2 diabetes.

aspects of healthcare are available for patients on each side of the border.

While the study considered costs from a healthcare system perspective, it is important to consider the scope of the programme from the perspective of the TB clinics, which includes only the administration of capillary blood glucose tests in the TB clinic setting. The only immediate resources needed to implement the programme are capillary blood glucose tests and additional staffing resources at TB clinics. Compared with the costs of treatment and complications, screening makes up less than 1% of the total costs considered in the study, which is an important point for TB clinic managers who may be unwilling to expand their services given their already limited resources.

On its own, this programme attempts to pick the low-hanging fruit by simply getting patients to interface with the healthcare system, and then allowing the system to function normally, for example, redirect the newly diagnosed diabetes patient to primary care. Given that this intervention relies on patients to navigate the healthcare system and adhere to their treatment, one might expect that adherence rate would be a key assumption in the model. However, a non-adherent patient would not incur significant diabetes treatment costs, and the cost of complications would be similar to a non-screened individual. The major variables that determine the cost-effectiveness are the incremental cost of treatment and averted complications, not the screening and diagnosis. This suggests that there is value in pursuing the lowest hanging fruit and nothing else, whether or not the new diabetes patient adheres to treatment.

We acknowledge some study limitations. First, it was assumed that patients who do not have diabetes at the time of screening will not develop diabetes in the future, but some will later in life. However, unless these individuals are exposed to an active TB patient for a second time, the progression of their diabetes would not be impacted by TB clinics, thus not affecting the cost-effectiveness of the programme.

The model does not include the benefits of identifying pre-diabetes and implementing lifestyle changes to prevent or delay the onset of diabetes, although glucose testing will screen for dysglycemia. Recent studies aimed

at identifying those at high risk of developing diabetes have suggested that screening followed by intensive treatment and lifestyle changes may not only be cost-effective but also cost-saving,[41] making our model slightly conservative. Finally, the model does not account for any benefits of TB prevention due to diabetes control. Good glucose control among diabetes patients will reduce their risk of developing TB,[42] so including this in the model would be expected to improve the cost-effectiveness of diabetes screening. However, the impact on the cost-effectiveness from a public health system perspective would be marginal given that only 5%–10% of TB contacts develop TB disease.[43]

Our findings are useful to TB clinics and the governments who fund them. The cost-effectiveness of this diabetes screening programme could inform policy decisions and ultimately improve the health of the population. These results are generalisable to other areas within USA, due to the use of national average costs. Other countries may find that their costs differ substantially from those used in this study, but we anticipate that the overall conclusion of the effectiveness of diabetes screening among TB contacts is likely to hold based on other available literature. Thus, we propose the expansion of the routine TB contact investigations, to include diabetes screening. TB clinics can provide an extended healthcare benefit to their community by becoming hubs for new diabetes diagnosis.

Author affiliations
[1]The University of Texas Health Science Center at Houston School of Public Health, Houston, Texas, USA
[2]Health Systems, Management, and Policy, University of Colorado Anschutz Medical Campus School of Medicine, Aurora, Colorado, USA
[3]Health Economics, The University of Texas Health Science Center at Houston School of Public Health, Houston, Texas, USA
[4]Population Health & Biostatistics, The University of Texas Rio Grande Valley, Edinburgh, Texas, USA
[5]Epidemiology, The University of Texas Health Science Center at Houston School of Public Health—Brownsville Campus, Brownsville, Texas, USA
[6]South Texas Diabetes and Obesity Institute, The University of Texas Rio Grande Valley, Edinburg, Texas, USA
[7]Population Health and iCARE, Texas Biomedical Research Institute, San Antonio, Texas, USA

Acknowledgements RAM, BIR, JCL-A and HSB were involved in the conception, design and conduct of the study and the analysis and interpretation of the results. RAM wrote the first draft of the manuscript, and all authors edited, reviewed and approved the final version of the manuscript.

Contributors RAM conducted the modelling, contributed to the discussion and wrote the first draft of the manuscript. HSB guided the health economics discussion, reviewed and edited the manuscript. JCL-A guided the medical aspects of diabetes to the discussion, reviewed and edited the manuscript. BIR conceived the idea and guided the discussion on TB and diabetes, provided data and edited the manuscript. All authors approved the last version of the manuscript. BIR accepts full responsibility for the finished work and is the guarantor of the work.

Funding We acknowledge funding support from IN-TRAC training grant (NIAID P30AI168439 to BIR) and NIAID R21AI144541 (to BIR).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplementary information. The dataset analysed in the current study is available from the corresponding author upon reasonable request.

ORCID iDs
Robert A McGowan http://orcid.org/0000-0001-9305-4910
Henry Shelton Brown http://orcid.org/0000-0001-9727-3432
Juan Carlos Lopez-Alvarenga http://orcid.org/0000-0002-0966-8766
Blanca I Restrepo http://orcid.org/0000-0002-3743-9098

REFERENCES

1 McMaughan DJ, Oloruntoba O, Smith ML. Socioeconomic Status and Access to Healthcare: Interrelated Drivers for Healthy Aging. *Front Public Health* 2020;8:231.
2 Centers for Diabetes Control and Prevention. Centers for Diabetes Control and Prevention Diagnosed Diabetes, 24 January 2023. Available: https://gis.cdc.gov/grasp/diabetes/DiabetesAtlas.html
3 Fisher-Hoch SP, Rentfro AR, Salinas JJ, *et al*. Socioeconomic status and prevalence of obesity and diabetes in a Mexican American community, Cameron County, Texas, 2004-2007. *Prev Chron Dis* 2010;7:A53.
4 Lönnroth K, Jaramillo E, Williams BG, *et al*. Drivers of tuberculosis epidemics: The role of risk factors and social determinants. *Social Science & Medicine* 2009;68:2240–6.
5 World Health Organization. Global tuberculosis report 2023. 2023. Available: https://iris.who.int/bitstream/handle/10665/373828/9789240083851-eng.pdf?sequence=1
6 Fair E, Miller CR, Ottmani SE, *et al*. Tuberculosis contact investigation in low- and middle-income countries: standardized definitions and indicators. *int j tuberc lung dis* 2015;19:269–72.
7 World Health Organization. Systematic screening for active tuberculosis: principles and recommendations. WHO; 2013. Available: https://apps.who.int/iris/handle/10665/84971
8 Harries AD, Kumar AMV, Satyanarayana S, *et al*. Addressing diabetes mellitus as part of the strategy for ending TB. *Trans R Soc Trop Med Hyg* 2016;110:173–9.
9 Abdelbary BE, Garcia-Viveros M, Ramirez-Oropesa H, *et al*. Tuberculosis-diabetes epidemiology in the border and non-border regions of Tamaulipas, Mexico. *Tuberculosis (Edinb)* 2016;101:S124–34.
10 Restrepo BI, Camerlin AJ, Rahbar MH, *et al*. Cross-sectional assessment reveals high diabetes prevalence among newly-diagnosed tuberculosis cases. *Bull World Health Organ* 2011;89:352–9.
11 World Health Organization. Chronic respiratory diseases and arthritis team. screening for type 2 diabetes: report of a world health organization and international diabetes federation meeting. WHO; 2003. Available: https://apps.who.int/iris/handle/10665/68614
12 Restrepo BI, Kleynhans L, Salinas AB, *et al*. Diabetes screen during tuberculosis contact investigations highlights opportunity for new diabetes diagnosis and reveals metabolic differences between ethnic groups. *Tuberculosis (Edinb)* 2018;113:10–8.
13 Toscano CM, Zhuo X, Imai K, *et al*. Cost-effectiveness of a national population-based screening program for type 2 diabetes: the Brazil experience. *Diabetol Metab Syndr* 2015;7:95.

14 Hoerger TJ, Harris R, Hicks KA, *et al*. Screening for type 2 diabetes mellitus: a cost-effectiveness analysis. *Ann Intern Med* 2004;140:689–99.
15 The CDC Diabetes Cost-effectiveness Group. Cost-effectiveness of Intensive Glycemic Control, Intensified Hypertension Control, and Serum Cholesterol Level Reduction for Type 2 Diabetes. *JAMA* 2002;287:2542.
16 The CDC Diabetes Cost-Effectiveness Study Group. The Cost-effectiveness of Screening for Type 2 Diabetes. *JAMA* 1998;280:1757–63.
17 Coffey JT, Brandle M, Zhou H, *et al*. Valuing health-related quality of life in diabetes. *Diabetes Care* 2002;25:2238–43.
18 Stratton IM, Adler AI, Neil HA, *et al*. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. *BMJ* 2000;321:405–12.
19 Scordo JM, Aguillón-Durán GP, Ayala D, *et al*. A prospective cross-sectional study of tuberculosis in elderly Hispanics reveals that BCG vaccination at birth is protective whereas diabetes is not a risk factor. *PLoS One* 2021;16:e0255194.
20 Clinical Laboratory Fee Schedule | CMS, Available: https://www.cms.gov/medicare/payment/fee-schedules/clinical-laboratory-fee-schedule-clfs
21 Zhou X, Shrestha SS, Shao H, *et al*. Factors Contributing to the Rising National Cost of Glucose-Lowering Medicines for Diabetes During 2005-2007 and 2015-2017. *Diabetes Care* 2020;43:2396–402.
22 Association AD. Economic Costs of Diabetes in the U.S. in 2017. *Diabetes Care* 2018;41:917–28.
23 Ward A, Alvarez P, Vo L, *et al*. Direct medical costs of complications of diabetes in the United States: estimates for event-year and annual state costs (USD 2012). *J Med Econ* 2014;17:176–83.
24 Hoerger T, Segel J, Zhang P, *et al*. Validation of the CDC-RTI diabetes cost-effectiveness model, 2009. Available: https://www.rti.org/rti-press-publication/diabetes-cost-effectiveness
25 Harris MI, Klein R, Welborn TA, *et al*. Onset of NIDDM occurs at least 4-7 yr before clinical diagnosis. *Diabetes Care* 1992;15:815–9.
26 Gómez-Peralta F, Abreu C, Cos X, *et al*. When does diabetes start? Early detection and intervention in type2 diabetes mellitus. *Rev Clin Esp (Barc)* 2020;220:305–14.
27 UK Prospective Diabetes Study Group. *Tight Blood Pressure Control and Risk of Macrovascular and Microvascular Complications in Type 2 Diabetes: UKPDS 38*. . UK Prospective Diabetes Study Group. BMJ, 1998:317. 703–13.
28 Sanders GD, Neumann PJ, Basu A, *et al*. Recommendations for Conduct, Methodological Practices, and Reporting of Cost-effectiveness Analyses: Second Panel on Cost-Effectiveness in Health and Medicine. *JAMA* 2016;316:1093–103.
29 Menzel PT. How Should Willingness-to-Pay Values of Quality-Adjusted Life-Years Be Updated and According to Whom? *AMA J Ethics* 2021;23:E601–606.
30 Siegel KR, Ali MK, Zhou X, *et al*. Cost-effectiveness of Interventions to Manage Diabetes: Has the Evidence Changed Since 2008? *Diabetes Care* 2020;43:1557–92.
31 Gillett M, Brennan A, Watson P, *et al*. The cost-effectiveness of testing strategies for type 2 diabetes: a modelling study. *Health Technol Assess* 2015;19:1–80.
32 Kahn R, Alperin P, Eddy D, *et al*. Age at initiation and frequency of screening to detect type 2 diabetes: a cost-effectiveness analysis. *The Lancet* 2010;375:1365–74.
33 Eastman RC, Javitt JC, Herman WH, *et al*. Model of complications of NIDDM. *Model constr and assump Diabetes Care* 1997;20:725–34.
34 Eddy DM, Schlessinger L, Kahn R. Clinical outcomes and cost-effectiveness of strategies for managing people at high risk for diabetes. *Ann Intern Med* 2005;143:251–64.
35 Brownson CA, Hoerger TJ, Fisher EB, *et al*. Cost-effectiveness of diabetes self-management programs in community primary care settings. *Diabetes Educ* 2009;35:761–9.
36 Ryabov I. Cost-effectiveness of Community Health Workers in controlling diabetes epidemic on the U.S.-Mexico border. *Public Health (Fairfax)* 2014;128:636–42.
37 Prezio EA, Pagán JA, Shuval K, *et al*. The Community Diabetes Education (CoDE) program: cost-effectiveness and health outcomes. *Am J Prev Med* 2014;47:771–9.
38 Gilmer TP, Roze S, Valentine WJ, *et al*. Cost-effectiveness of diabetes case management for low-income populations. *Health Serv Res* 2007;42:1943–59.
39 Su D, Richardson C, Wen M, *et al*. Cross-border utilization of health care: evidence from a population-based study in south Texas. *Health Serv Res* 2011;46:859–76.
40 World Bank Open Data. World Bank Open Data, Available: https://data.worldbank.org [Accessed 19 Jun 2024].
41 Zhuo X, Zhang P, Gregg EW, *et al*. A Nationwide Community-Based Lifestyle Program Could Delay Or Prevent Type 2 Diabetes Cases And Save $5.7 Billion In 25 Years. *Health Aff (Millwood)* 2012;31:50–60.
42 Leung CC, Lam TH, Chan WM, *et al*. Diabetic control and risk of tuberculosis: a cohort study. *Am J Epidemiol* 2008;167:1486–94.
43 Behr MA, Edelstein PH, Ramakrishnan L. Revisiting the timetable of tuberculosis. *BMJ* 2018;362:k2738.