Budget impact analysis of adopting primary care-based COPD case detection in the Canadian general population

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Abstract

Background: An estimated 70% of Canadians with chronic obstructive pulmonary disease (COPD) are undiagnosed, creating a barrier to early intervention. There is growing interest in the value of primary care-based opportunistic case detection for COPD. We build on a previous cost-effectiveness analysis by evaluating the budget impact of adopting COPD case detection in the Canadian general population.
Methods: We used a validated discrete-event microsimulation model of COPD in the Canadian general population ≥40 years to assess the costs of implementing eight primary care-based case detection strategies over a five-years (2022-2026) from the healthcare payer perspective. Strategies varied in eligibility criteria (based on age, symptoms, or smoking history) and testing technology (COPD Diagnostic Questionnaire (CDQ) or screening spirometry). Costs were determined from Canadian studies and converted to 2021 Canadian dollars. Key parameters were varied in one-way sensitivity analysis.
Results: All strategies resulted in higher total costs compared to routine diagnosis. The most cost-effective scenario (the CDQ for all patients) had an associated total budget expansion of $427 million, with administering case detection and subsequent diagnostic spirometry accounting for 86% of costs. This strategy increased the proportion of COPD individuals diagnosed from 30.4% to 37.8% and resulted in 4.6 million referrals to diagnostic spirometry. Results were most sensitive to uptake in primary care.
Interpretation: Adopting a national COPD case detection programme would be an effective method for increasing diagnosed COPD dependent on successful uptake, but it will require prioritisation by budget holders and substantial additional investment to improve access to diagnostic spirometry.

1. Introduction

Chronic obstructive pulmonary disease (COPD) affects 2.6 million Canadians and is the third leading cause of death worldwide (1,2). Despite being a major public health concern, 70% of Canadians with COPD remain undiagnosed, representing a missed opportunity to reduce symptoms and the risk of exacerbations through optimal preventative and therapeutic management, particularly smoking cessation (4,5). Studies have shown that individuals with undiagnosed COPD have similar levels of health service use compared to diagnosed patients yet experience worse long-term health outcomes through late recognition of their condition (4,6). An estimated one-third of COPD patients are initially diagnosed in hospital following an exacerbation-related admission (7). Although current guidelines recommend against routine screening of asymptomatic adults (8), there is growing interest in the value of opportunistic case detection in primary care (9,10), with emerging evidence from clinical trials and modelling studies that case detection improves long-term patient outcomes and is likely to be cost-effective (11,12,13). A recent cost-effectiveness analysis by Johnson *et al.* (2021) evaluated primary care-based COPD case detection strategies in the general Canadian population. At a willingness-to-pay (WTP) threshold of $50,000 per quality-adjusted life-year (QALY) gained, case detection with questionnaires or screening spirometry was cost-effective. The highest value strategy was regularly administering the COPD Diagnostic Questionnaire (CDQ) to all patients ≥40 years during routine primary care interactions (13).

However, given the high prevalence of undiagnosed COPD, investment in a national COPD case detection programme would require significant allocation of healthcare resources. In a time of intense pressure on healthcare budgets, we must consider the affordability of an intervention as well as its value. The aim of our study was to build on a previous cost-effectiveness analysis by evaluating the budget impact of adopting primary care-based COPD case detection in the general Canadian population (13). We assessed total medical costs from the healthcare payer perspective of implementing eight case detection strategies that vary in their eligibility criteria and testing technology over a five-year time horizon between 2022 and 2026.

2. Methods

This study was designed in accordance with ISPOR best practice guidelines for budget impact analysis (15).

2.1. Analytic framework

We used the Evaluation Platform in COPD (EPIC), a previously validated deterministic discrete-event microsimulation model of COPD in the general Canadian population aged ≥40 years. EPIC simulates the development and progression of COPD across the entire disease pathway, including demographics of the general Canadian population, smoking prevalence, COPD occurrence, symptoms, primary care visits, COPD diagnosis, lung function decline, exacerbations, COPD-related and background mortality, medical costs, and QALYs over a lifetime horizon (14). EPIC uses data from the Canadian Cohort of Obstructive Lung Disease (CanCOLD) study, a national prospective cohort of patients with COPD and at-risk of COPD, to model community diagnosis, primary care utilisation, and respiratory symptoms (16). Smoking status is based on Population Health Model, a validated microsimulation model developed by Statistics Canada (17). Each component of EPIC has passed rigorous tests of internal and external validity (14,13) (Appendix 1). This analysis simulated within EPIC the implementation of COPD case detection administered during routine primary care visits over a five-year time horizon (2022-2026).

2.2. Target population

Our analysis was carried out in an open population, meaning individuals enter and exit the target population throughout the time horizon. We defined the target population as the entire general Canadian population aged ≥40 years, which was 19.8 million in 2022 based on Statistics Canada projections (18). The eligible population was the subset of the target population that was eligible for case detection, which varied by strategy. We report the budget impact for the target population for comparability between strategies with different eligibility criteria.

2.3. Case detection

We evaluated eight case detection strategies used in the cost-effectiveness analysis by Johnson *et al.* (2021), all of which were found to be cost-effective at a WTP of $50,000/QALY (Table 1). We did not consider repeat testing of the same individual at specified intervals due to the short time horizon and to show the costs of a single implementation of each strategy. Strategies are grouped according to their eligibility criteria for selecting patients to receive case detection, either all patients (S1), symptomatic patients (any one of cough, phlegm, wheeze, or dyspnea) (S2), or patients aged ≥50 years with a smoking history (S3). The testing technologies considered are the CDQ (19) and the hand-held flow meter (20), which performs screening spirometry based on the ratio of forced expiratory volume in 1 second to forced expiratory volume in 6 seconds <0.7. All scenarios were compared to a baseline scenario of no case detection.

Although we replicated all eight strategies reported by Johnson *et al.* (2021), our reporting focuses on S1a (CDQ ≥ 17 points for all patients), the highest value strategy identified at a WTP threshold of $50,000/QALY gained. However, guidelines suggest that interventions with a large budgetary impact should be subject to lower cost-effectiveness thresholds (21). We recalibrated the cost-effectiveness plane in Johnson *et al.* (2021) (Appendix 3) and found that the WTP threshold must be reduced to $25,000/QALY for S1a to no longer be the preferred strategy, at which point S3b (CDQ ≥ 16.5 points for patients ≥50 years with a smoking history) becomes most cost-effective. Therefore, for comparison, we also report results for S3b.

Table 1: Summary of case detection strategies evaluated.

Testing technology	Eligibility criteria	Sensitivity (%) [a]	Specificity (%) [a]
(S1) *All patients*			
S1a: CDQ ≥ 17 points	None	91.0	49.0
S1b: Flow meter (with bronchodilator)		80.0	94.0
S1c: CDQ ≥ 17 points + Flow meter (with bronchodilator)		72.0	97.0
(S2) *Symptomatic patients*			
S2a: Flow meter (without bronchodilator)	≥ 1 respiratory symptom [b]	81.5	88.9
(S3) *Smoking history*			
S3a: CDQ ≥ 19.5 points	Past or current smoker Age ≥50 years	64.5	65.2
S3b: CDQ ≥ 16.5 points		87.5	38.8
S3c: Flow meter (without bronchodilator)		79.9	84.4
S3d: CDQ ≥ 17 points + Flow meter (with bronchodilator)		74.4	97.0

CDQ - COPD Diagnostic Questionnaire

[a] Sensitivity and specificity values are derived from the literature and further details have been provided previously (13).

[b] Respiratory symptoms defined as the presence of chronic cough in the absence of a cold, any wheeze, phlegm in the absence of a cold, or dyspnea, measured using the Medical Research Council dyspnea scale with a score of 2-5 indicating the presence of dyspnea, in the past year.

To be eligible for case detection an individual must fulfil the eligibility criteria and have visited primary care in the previous year (Figure 1). Patients testing positive at case detection were referred to outpatient diagnostic spirometry, which we assumed to have 100% accuracy. We modelled gradual market penetration of the case detection programme. We assumed a linear uptake from 5% in 2022 to 25% in 2026, based on participation in lung cancer and colon cancer screening programmes (22,23). Throughout the simulation, patients could also be diagnosed with COPD at primary care visits without the use of case detection or following an exacerbation-related admission to hospital.

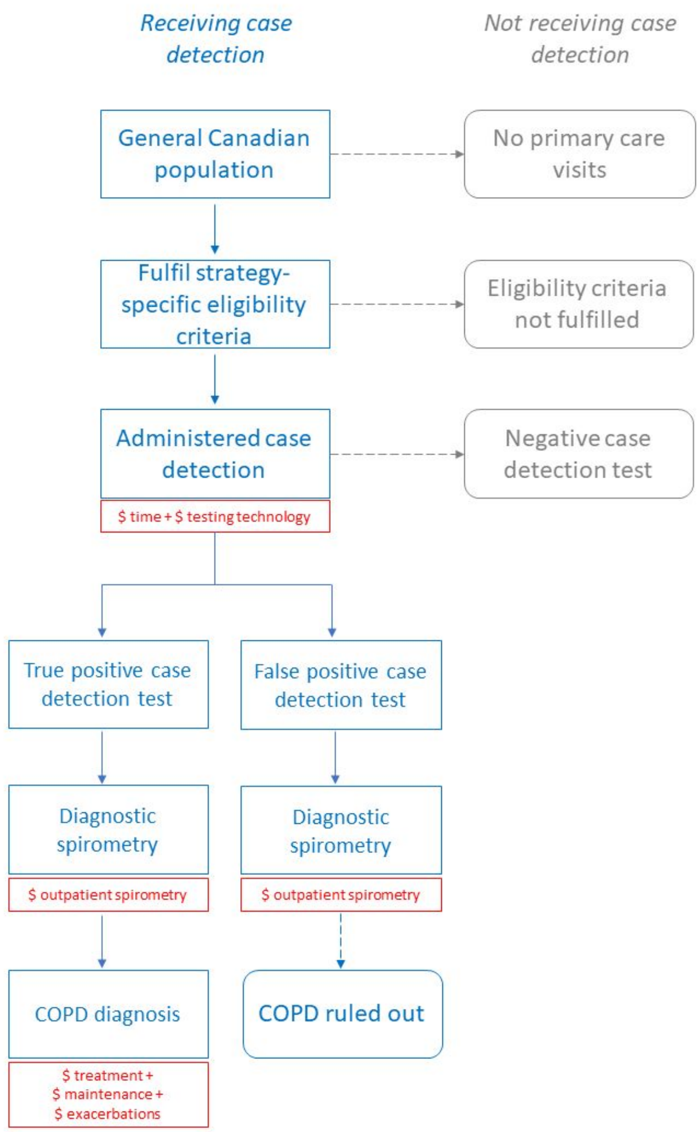

Figure 1: Schematic for administration of case detection programmes. Individuals receiving case detection are shown in blue, those not receiving case detection are shown in grey. Costs associated with case detection, diagnosis, and treatment that are included in the budget impact analysis are shown in red.

2.4. Inputs

We conducted the analysis from the Canadian healthcare system perspective, therefore only direct healthcare costs were included (Table 2). Costs were converted to 2021 Canadian dollars ($) using the healthcare component of the Consumer Price Index (24) and were not discounted over the time horizon (15).

Administering case detection was costed at 34% of a 15-minute routine primary care visit (25,26). The CDQ is only assigned the time-related cost whereas flow meter strategies incur the additional cost of screening spirometry. Outpatient diagnosis includes the cost of diagnostic spirometry plus a primary care visit to interpret the results. Unit costs of utilisation were determined from the British Columbia fee schedule (27).

Within EPIC, inhaled therapies are assigned to individuals according to the Global Initiative for COPD (GOLD) ABCD criteria following diagnosis or an exacerbation (3). Average annual costs of treatment with inhaled therapies were determined from medication dispensation records in British Columbia health administrative data (28). Three months of nicotine replacement therapy (NRT) was administered to all newly diagnosed patients who were current smokers. Adherence to both treatments was set at 70%. The associated effect of treatment on health outcomes is summarised in Table 2.

The medical costs of exacerbations and background medical costs (outside of exacerbations and treatment) were determined from published Canadian studies and applied by exacerbation severity and GOLD grade (29,30,31,32)

Table 2: Costs and parameter input values relevant to evaluation of case detection.

Item	**Value**	**References**
Global parameters		
Time horizon	5 years	
Population size	19.6 million	(18)
Case detection initial uptake	0.1	(22)
Annual increase in case detection uptake	0.1	
Discount for costs	0	(15)
Case detection costs		
Administration of CDQ	$11.91	(27)
Flow meter with bronchodilator	$30.81	
Flow meter without bronchodilator	$24.68	
Outpatient diagnosis	$62.19	
Treatment		
Costs (annual per-patient)		
SABA	$55.17	(28)
LAMA	$366.55	
LAMA/LABA	$670.44	
ICS/LAMA/LABA	$1,185.23	
NRT	$382.63	(36)
Rate reduction for exacerbations		
SABA	0	
LAMA	0.22	(33)
LAMA/LABA	0.23	(34)
ICS/LAMA/LABA	0.34	(35)
NRT odds ratio for successful smoking cessation	1.38	(37,38)
Medication adherence	0.7	

Exacerbation costs [a]		
Mild	$31.68	(29,30)
Moderate	$793.08	
Severe	$10,063.13	
Very severe	$22,033.60	
Maintenance costs (annual per-patient) [b]		
GOLD 1	$147.48	(31,32)
GOLD 2	$360.49	
GOLD 3	$943.83	
GOLD 4	$1,286.84	

CDQ - COPD Diagnosis Questionnaire; NRT - Nicotine Replacement Therapy; SABA - Short-acting beta-agonists; LAMA - Long-acting muscarinic antagonist; LABA - Long-acting beta-agonist; ICS - Inhaled corticosteroids; GOLD - Global Initiative for COPD.
General EPIC model parameters have been reported previously (14,13).
All costs are in 2021 Canadian dollars ($).
[a] Mild exacerbations are defined as an intensification of symptoms that does not require an encounter with the health care system and so are only assigned the cost of increased medication, moderate exacerbations are those in which the patient visits a physician or emergency department but is not hospitalised, severe exacerbations are assumed to result in a hospital admission, and very severe exacerbations in admission to the intensive care unit.
[b] Maintenance costs include physician visits (generalist and specialists), rehabilitation programmes, laboratory tests and devices, and oxygen therapy. Treatment costs have been deducted from maintenance costs to avoid double counting (39).

2.5. Analysis

Budget impact was calculated for each strategy and year as the difference in total costs from the baseline scenario, where negative budget impact indicates additional healthcare resources are required (budget expansion). We also evaluated cost subcategories of case detection, treatment (inhaled therapies and NRT), and exacerbation-related hospitalisations. In addition, we evaluated the performance of each strategy by reporting the size of the eligible population, number of case detections administered, number of referrals to outpatient diagnostic spirometry, and number of additional true COPD diagnoses.

We conducted one-way sensitivity analysis to assess the impact of model assumptions. We evaluated low case detection uptake (2% to 10% range; 2%/year increase) and high uptake (8% to 40% range; 8% /year increase) scenarios. We ran separate analyses for reduced adherence to inhaled therapies of 0.5 and 0.3, following previous population assessments (40), and removing the administration of NRT following diagnosis since guidelines recommend smoking cessation for all current smokers irrespective of COPD diagnosis (3).

3. <u>Results</u>

The starting population size was 19.8 million. Over the time horizon, 2.3 million individuals entered the model and 940,000 left from death/emigration. At baseline the COPD prevalence among Canadians aged ≥40 years was 11.9% and 30.4% of individuals with COPD were diagnosed. These are similar to the COPD prevalence (11.2%) and proportion undiagnosed (29.7%) observed in the CanCOLD study (41,4) (Appendix 1).

The most inclusive strategies (S1 – all patients ≥40 years) resulted in 40.4% of the target population administered case detection after five years, compared to 16.7% under the least inclusive strategies (S3 – patients ≥50 years with a smoking history) (Table 3). In S1a (CDQ ≥17 points for all patients), an additional 146,412 individuals with COPD were diagnosed after five years compared to routine diagnosis in the no case detection scenario, which increased the proportion of COPD individuals diagnosed to 37.8% (from 30.4%) by 2026. The diagnosed proportion increased to 34.2% under S3b (CDQ ≥16.5 points for patients ≥50 with a smoking history). However, S1a also resulted in 4.6 million referrals to diagnostic spirometry, 96% of which were false positives.

Table 3: Five-year (2022-2026) cumulative results on scope and performance of case detection strategies.

	Eligible [a] (% of target population)	**Administered case detection** (% of target population)	**Referred for OP spirometry**		**Additional diagnoses** [b] (% target population)
			True positives (% of tested)	**False positives** (% of tested)	
(S1) *All patients*					
S1a: CDQ ≥ 17	20,467,519 (92.4%)	8,942,130 (40.4%)	175,900 (2.0%)	4,465,334 (49.9%)	146,412 (0.66%)
S1b: Flow meter			85,554 (1.0%)	770,846 (8.6%)	68,485 (0.31%)
S1c: CDQ ≥ 17 + Flow meter			58,379 (0.7%)	412,323 (4.6%)	45,164 (0.20%)
(S2) *Symptomatic patients*					
S2a: Flow meter	18,762,133 (84.7%)	5,794,210 (26.2%)	86,587 (1.5%)	1,160,933 (20.0%)	69,591 (0.31%)
(S3) *Smoking history*					
S3a: CDQ ≥ 19.5	8,492,353 (38.3%)	3,707,894 (16.7%)	27,879 (0.8%)	1,383,738 (37.3%)	22,131 (0.10%)
S3b: CDQ ≥ 16.5			86,608 (2.3%)	2,118,887 (57.1%)	76,508 (0.35%)
S3c: Flow meter			55,313 (1.5%)	749,266 (20.2%)	47,441 (0.21%)
S3d: CDQ ≥ 17 + Flow meter			42,433 (1.1%)	184,331 (5.0%)	35,492 (0.16%)

OP – outpatient.

[a] Eligible defined as meeting the eligibility criteria and having visited primary care within the same year over the time horizon.

[b] Additional diagnoses compared to routine diagnosis under the baseline scenario of no case detection, after 5 years.

All strategies resulted in higher total costs compared to no case detection (Table 4). The greatest budget expansion was $427 million for S1a, with 86% of costs attributed to administering case detection and subsequent diagnostic spirometry. The corresponding results for S3b were $198 million and 84%. The costs of case detection began to plateau by the end of the time horizon as the proportion of eligible patients not already tested was depleted, whereas treatment costs continued to increase as more patients were diagnosed (Figure 2). Minor cost-savings were observed from exacerbation-related admissions and outpatient care from fewer mild and moderate exacerbations, respectively saving $5 million/year and $10 million/year under S1a by 2026.

Table 4: Total budget impact (no case detection – case detection) results. Negative budget impact indicates budget expansion.

Outcome	S1a	S1b	S1c	S2a	S3a	S3b	S3c	S3d
No case detection strategy costs (million $)								
Case detection	0							
Treatment	2,306							
Hospitalisation	4,803							
Outpatient [a]	6,826							
Total	13,935							
Case detection strategy costs (million $)								
Case detection	402	338	423	226	135	185	145	178
Treatment	2,371	2,331	2,318	2,334	2,311	2,342	2,326	2,319
Hospitalisation	4,789	4,796	4,799	4,794	4,801	4,794	4,798	4,799
Outpatient [a]	6,800	6,809	6,813	6,808	6,822	6,814	6,817	6,819
Total	14,362	14,274	14,449	14,161	14,068	14,133	14,086	14,115
Budget impact (million $)								
Case detection	-402	-338	-423	-226	-135	-185	-145	-178
Treatment	-65	-25	-12	-28	-5	-36	-20	-13
Hospitalisation	14	7	4	9	3	10	6	4
Outpatient [a]	27	17	14	19	4	13	9	7
Total	-427	-339	-418	-226	-133	-198	-150	-179

S1a CDQ ≥ 17 points for all patients; S1b flow meter (with bronchodilator) all patients; S1c CDQ ≥ 17 points + flow meter (with bronchodilator) all patients; S2a flow meter (without bronchodilator) among symptomatic patients; S3a CDQ ≥ 19.5 points among patients aged ≥50 years with a smoking history; S3b CDQ ≥ 16.5 points among patients aged ≥50 years with a smoking history; S3c flow meter (without bronchodilator) among patients aged ≥50 years with a smoking history, S3d CDQ ≥ 17 points + flow meter (with bronchodilator) among patients aged ≥50 years with a smoking history.

[a] Outpatient care are the remaining costs not included in case detection, treatment or hospitalisation and includes COPD maintenance costs, routine diagnosis, and costs associated with mild and moderate exacerbations which are assumed not to result in hospitalisation.

Sensitivity analyses showed minimal change in the ranking of strategies across analyses (Figure 2). Total budget impact decreased by a maximum of 4.5% when NRT was removed or medication adherence was decreased since case detection administration, which comprises the majority of costs, was unaffected. Results were most affected by uptake, with higher uptake rates (8% to 40% range; 8% /year) increase resulting in greater budget expansion ($603 million under S1a) but also a greater proportion of COPD patients diagnosed (40.1% by 2026 under S1a) compared to the reference analysis.

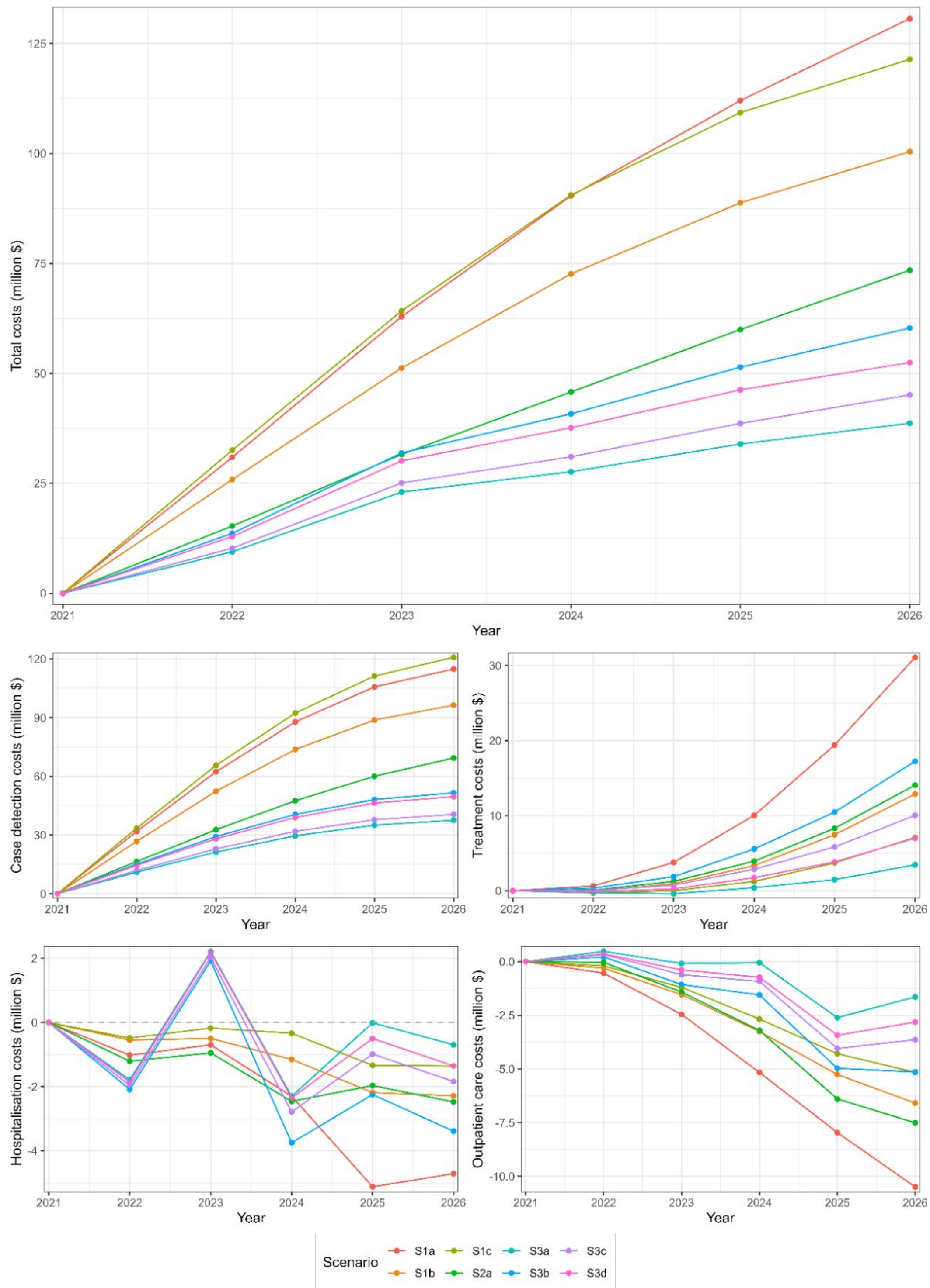

Figure 2: Annual total (top), case detection (middle left), treatment (middle right), hospitalisation (bottom left), and outpatient care (bottom right) additional costs (million $) compared to no case detection baseline scenario. Negative additional costs indicate cost savings. S1a CDQ ≥ 17 points for all patients; S1b flow meter (with bronchodilator) all patients; S1c CDQ ≥ 17 points + flow meter (with bronchodilator) all patients; S2a flow meter (without bronchodilator) among symptomatic patients; S3a CDQ ≥ 19.5 points among patients aged ≥50 years with a smoking history; S3b CDQ ≥ 16.5 points among patients aged ≥50 years with a smoking history; S3c flow meter (without bronchodilator) among patients aged ≥50 years with a smoking history, S3d CDQ ≥ 17 points + flow meter (with bronchodilator) among patients aged ≥50 years with a smoking history. Corresponding results tables can be found in Appendix 2.

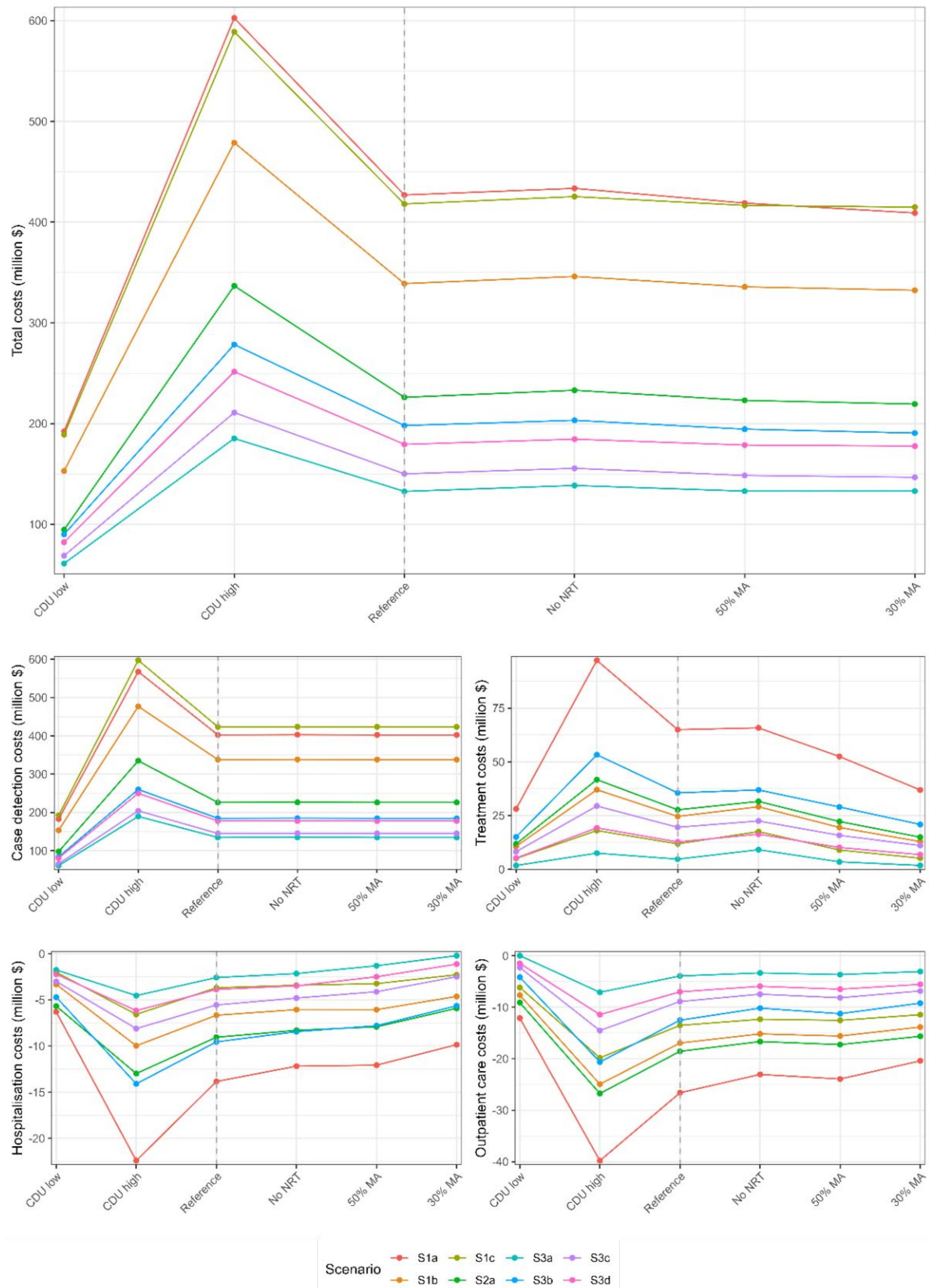

Figure 3: Sensitivity analysis of total additional costs of case detection strategies compared to no case detection. Negative additional costs indicate cost savings. Grey dashed line indicates the reference case analysis. CDU – case detection uptake (low uptake defined as 2% to 10% range with 2%/year increase and high uptake as 8% to 40% range with 8% /year increase); NRT – nicotine replacement therapy; MA – medication adherence. S1a CDQ ≥ 17 points for all patients; S1b flow meter (with bronchodilator) all patients; S1c CDQ ≥ 17 points + flow meter (with bronchodilator) all patients; S2a flow meter (without bronchodilator) among symptomatic patients; S3a CDQ ≥ 19.5 points among patients aged ≥50 years with a smoking history; S3b CDQ ≥ 16.5 points among patients aged ≥50 years with a smoking history; S3c flow meter (without bronchodilator) among patients aged ≥50 years with a smoking history, S3d CDQ ≥ 17 points + flow meter (with bronchodilator) among patients aged ≥50 years with a smoking history.

4. Interpretation

We used a validated whole disease microsimulation model of COPD in the general Canadian population to evaluate the budget impact to the Canadian healthcare system of adopting primary care-based early detection strategies for COPD. Our results indicate that questionnaire-based case detection for all patients ≥40 years during routine primary care visits, although most effective at increasing the diagnosed prevalence, would have a large budgetary impact of $427 million over five years. The majority of the budget expansion can be attributed to the cost of case detection itself while the contribution of treatment costs from identifying additional patients is relatively minor. Savings in hospitalisation costs from exacerbation reduction were minimal but would increase over a longer time horizon. The key feature in determining the affordability of case detection was the rate of uptake in primary care.

Total healthcare spending in Canada was estimated at $331 billion in 2022, representing 12.2% of the country's GDP (42). Implementing a country-wide COPD case detection programme would require significant additional investment of healthcare resources, accounting for an estimated 0.04% of the healthcare budget by 2026 and an additional 4.6 million referrals for spirometry over five years. If the budget impact of a more inclusive strategy is deemed too high, then we must accept a lower cost-effectiveness threshold. At a reduced WTP, the CDQ at a low threshold remains the preferred testing technology but paired with stricter eligibility criteria (aged ≥50 years with a smoking history). The budget expansion would still be substantial ($198 million and 2.2 million spirometry referrals over five years) but is less than half that of a more inclusive strategy. However, COPD has been declared a public health emergency, with rising prevalence and healthcare costs (43). It is also considered an ambulatory-sensitive condition, meaning that hospitalisations could be avoided through optimal outpatient management, which depends on a diagnosis (44). Strategies targeting a more limited population increase the proportion of diagnosed patients by 3.8%, compared to 10.1% for the most inclusive strategy with high uptake.

Our results highlight the need for increased diagnostic spirometry capacity, which may be the greatest barrier to implementing COPD case detection. A COPD diagnosis can only be confirmed using spirometry (45) yet there is massive underutilisation of this diagnostic test globally (46). In Canada, estimates for the proportion of patients with a community diagnosis of COPD who have never received spirometry range from 30% to 42% (46,47). A principal reason for this is a lack of equipment and trained personnel for spirometry in primary care where 80% of patients with COPD in Canada are managed (31). Primary care practitioners often refer patients to specialised pulmonary function laboratories, which can have long waiting lists and create further access barriers for rural and remote parts of Canada (49,50). Most strategies considered in this analysis would require at least one million diagnostic spirometry tests over five years, which we assume to be referred to outpatient services. Future research and discussions must consider solutions for upskilling primary care to perform diagnostic spirometry if COPD case finding strategies in the entire Canadian population are to be feasible.

This study has several limitations. First, our analysis based uptake on general population participation in lung cancer and colon cancer screening in Canada (22,23). Spirometry is a comparatively less invasive procedure so may have higher uptake, but given major issues with spirometry access, we do not exceed 40% per year as the upper limit in sensitivity analyses (47). Nonetheless, sensitivity analysis shows uptake to be a significant determinant in affordability and our analysis should be updated when results from empirical studies are available. Second, our model only accounts for the effect of inhaled therapies on exacerbation rate and not the indirect improvement in lung function (51,52). We may observe more cost-saving if this latter mechanism was accounted for as patients would be less likely to progress to more severe disease stages. Third, we assume perfect recognition and reporting of symptoms. Many individuals at risk of COPD avoid activities that aggravate symptoms and fail to report symptoms during primary care visits (10). Therefore, we may have overestimated the number of individuals that would receive case detection under the symptomatic eligibility criteria. Finally, since EPIC is deterministic, we could not explore parameter uncertainty.

Adopting a national primary care-based case detection programme for COPD will require prioritisation by budget holders and significant additional investment to facilitate access to diagnostic spirometry. Case detection is an effective method for increasing the proportion of COPD patients diagnosed but depends on uptake of the programme in primary care.

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Supplementary Material

Budget impact analysis of adopting primary care-based COPD case detection in the Canadian general population

Contents

Appendix 1: EPIC validation

The Evaluation Platform in COPD (EPIC) is a previously developed model and has undergone rigorous validation including replicating the rate and severity of exacerbations and COPD-related mortality rate in two external cohort studies. Details have been previously described elsewhere (1,2). Below we summarise the key elements relevant to the budget impact analysis.

Population size and demographics are based on population projections from Statistics Canada (3). Figures 1 shows results of the validation of population size and Figure 2 shows the population pyramid for 2025, near the end of the study time horizon.

The diagnosis module has been calibrated to yield a stable proportion of diagnosed patients among COPD individuals approximately equal to that observed in Canadian Cohort of Obstructive Lung Disease (CanCOLD) (29.7%) (4,5). Further, overdiagnosis is calibrated to yield a stable proportion of false positive diagnoses among non-COPD individuals at 3% in accordance with the observed input CanCOLD data source (2) and similar to previous studies (6). Figures 3 and 4 shows results of the validation over a 20-year time horizon for 150,000 individuals simulated in EPIC.

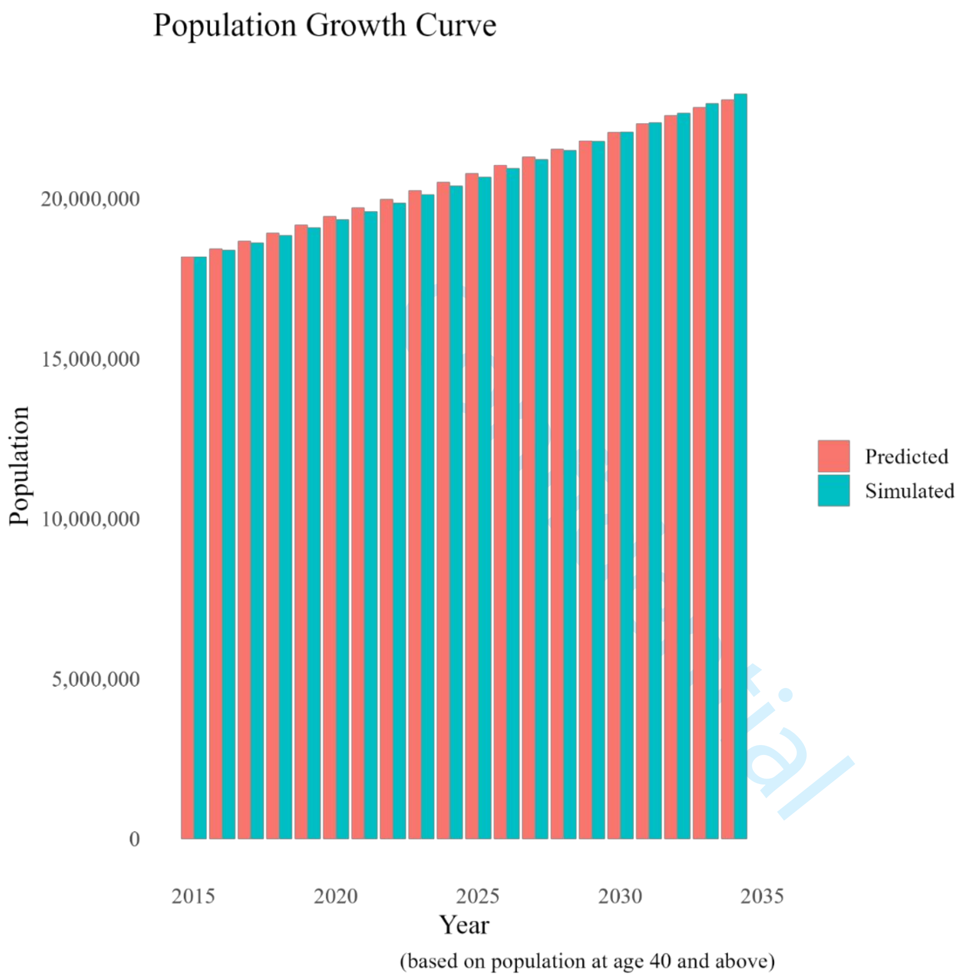

Figure 1: EPIC-simulated population growth compared with population projections between 2015-2035.

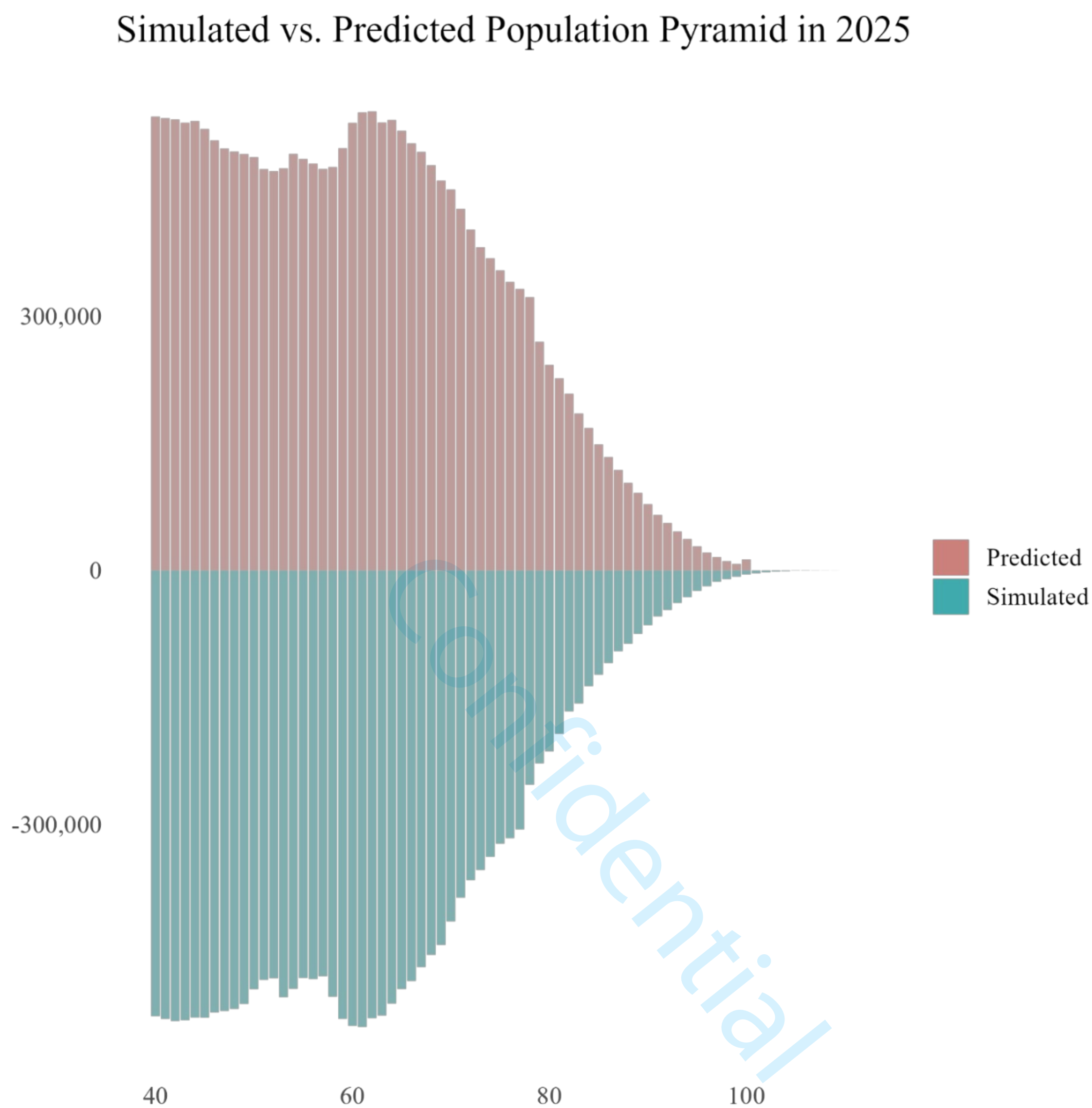

Figure 2: Comparison of EPIC-simulated and predicted population pyramid in 2025.

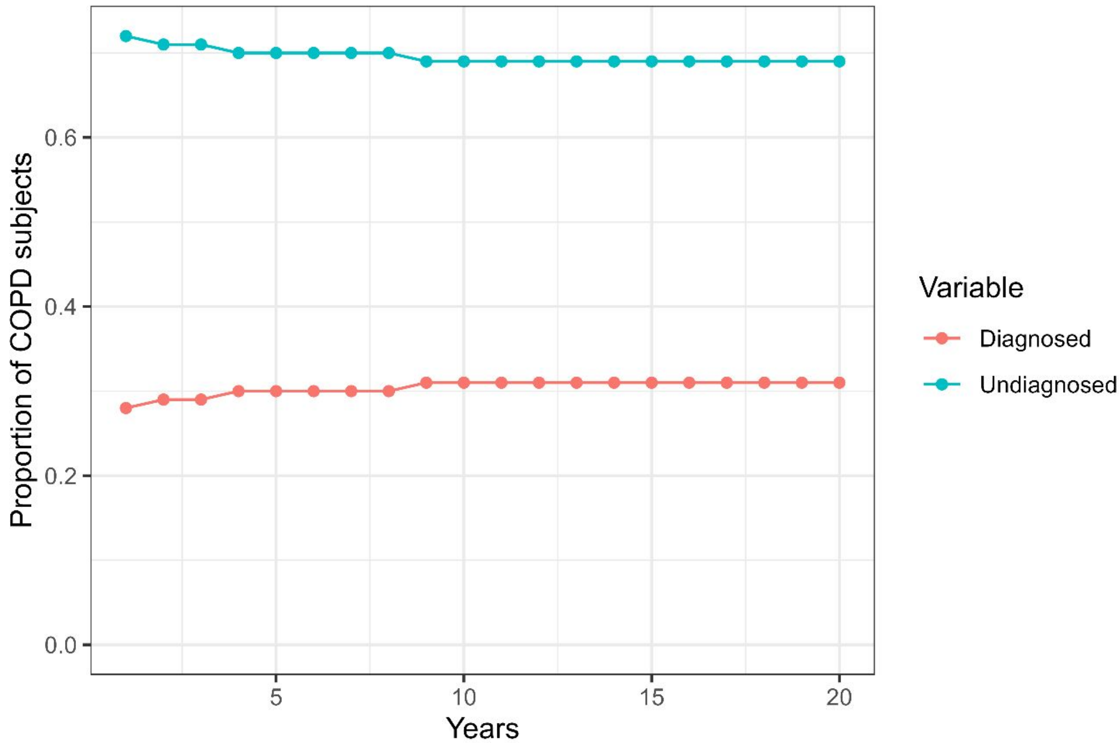

Figure 3: Proportion of COPD individuals diagnosed over a 20-year time horizon.

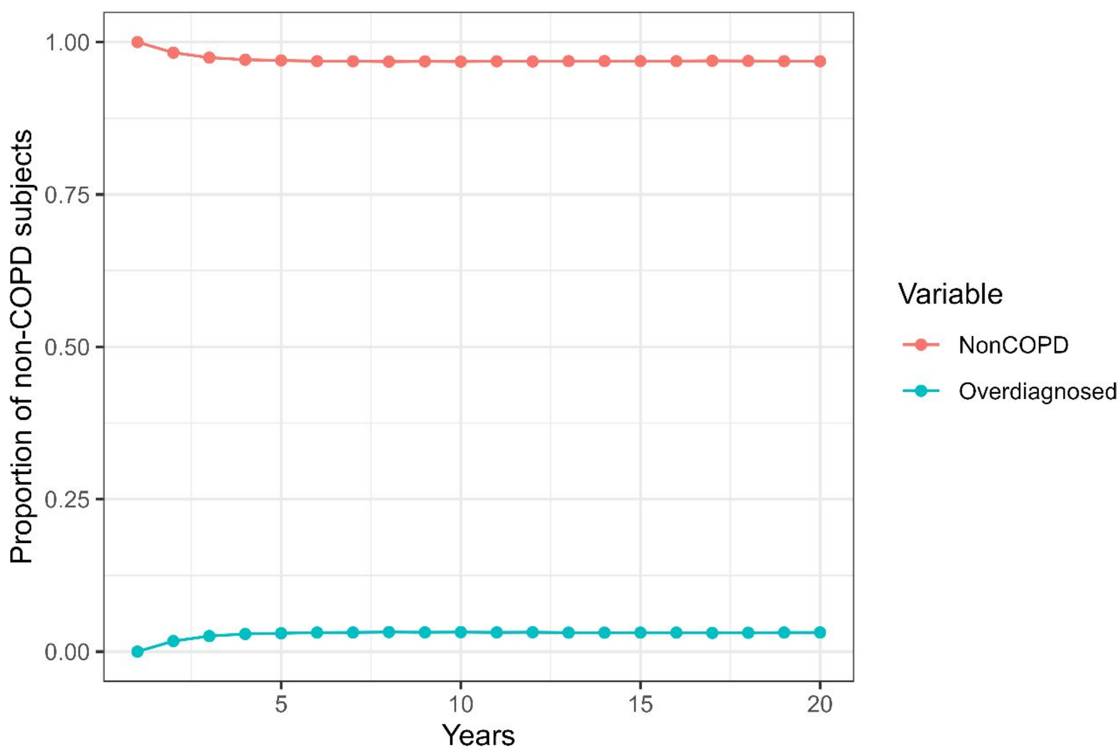

Figure 4: Proportion of non-COPD individuals overdiagnosed over a 20-year time horizon.

Appendix 2: Budget impact results tables

Tables 1-8 show the extended annual budget impact results for each strategy compared to a baseline scenario of no case detection.

Table 1: Annual budget impact results for case detection strategy S1a.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	31,843,232	62,308,330	87,774,451	105,707,025	114,791,770
Treatment	394,085,160	418,294,420	443,806,303	471,779,227	502,008,400	535,093,501
Hospitalisation	865,204,886	887,775,922	917,658,968	958,099,983	989,693,750	1,036,054,776
Outpatient	1,228,997,220	1,270,323,883	1,313,524,083	1,355,690,755	1,405,624,803	1,454,425,244
Total	2,488,287,266	2,608,237,457	2,737,297,683	2,873,344,416	3,003,033,978	3,140,365,291
Budget impact						
Case detection	0	-31,843,232	-62,308,330	-87,774,451	-105,707,025	-114,791,770
Treatment	0	-638,095	-3,771,612	-10,033,033	-19,409,311	-31,090,881
Hospitalisation	0	1,017,479	695,917	2,295,570	5,120,394	4,711,613
Outpatient	0	541,208	2,457,467	5,161,436	7,960,499	10,496,104
Total	0	-30,922,639	-62,926,558	-90,350,478	-112,035,443	-130,674,934

Table 2: Annual budget impact results for case detection strategy S1b.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	26,771,844	52,338,339	73,700,833	88,762,218	96,383,570
Treatment	394,085,160	417,605,147	440,973,965	465,084,313	490,066,870	516,888,008
Hospitalisation	865,204,886	888,245,202	917,857,512	959,245,187	992,631,795	1,038,481,663
Outpatient	1,228,997,220	1,270,556,982	1,314,444,751	1,357,596,500	1,408,327,455	1,458,334,739
Total	2,488,287,266	2,603,179,175	2,725,614,567	2,855,626,833	2,979,788,338	3,110,087,980
Budget impact						
Case detection	0	-26,771,844	-52,338,339	-73,700,833	-88,762,218	-96,383,570
Treatment	0	51,179	-939,274	-3,338,118	-7,467,781	-12,885,388
Hospitalisation	0	548,200	497,372	1,150,365	2,182,350	2,284,726
Outpatient	0	308,109	1,536,799	3,255,691	5,257,846	6,586,609
Total	0	-25,864,357	-51,243,441	-72,632,896	-88,789,803	-100,397,623

Table 3: Annual budget impact results for case detection strategy S1c.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	33,502,161	65,562,911	92,312,444	111,207,751	120,817,576
Treatment	394,085,160	417,369,211	440,054,434	462,987,980	486,309,575	511,113,662
Hospitalisation	865,204,886	888,308,966	918,183,061	960,061,379	993,478,497	1,039,410,750
Outpatient	1,228,997,220	1,270,664,201	1,314,782,836	1,358,178,872	1,409,298,120	1,459,761,789
Total	2,488,287,266	2,609,844,539	2,738,583,242	2,873,540,675	3,000,293,944	3,131,103,777
Budget impact						
Case detection	0	-33,502,161	-65,562,911	-92,312,444	-111,207,751	-120,817,576
Treatment	0	287,115	-19,742	-1,241,786	-3,710,487	-7,111,043
Hospitalisation	0	484,436	171,823	334,173	1,335,648	1,355,639
Outpatient	0	200,890	1,198,714	2,673,319	4,287,182	5,159,559
Total	0	-32,529,721	-64,212,117	-90,546,737	-109,295,408	-121,413,420

Table 4: Annual budget impact results for case detection strategy S2a.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	16,468,918	32,700,712	47,510,047	60,006,493	69,363,873
Treatment	394,085,160	417,729,278	441,288,591	465,679,452	490,922,954	518,075,224
Hospitalisation	865,204,886	887,588,943	917,408,945	957,939,073	992,850,133	1,038,291,546
Outpatient	1,228,997,220	1,270,827,310	1,314,562,192	1,357,647,591	1,407,190,502	1,457,412,660
Total	2,488,287,266	2,592,614,448	2,705,960,439	2,828,776,163	2,950,970,082	3,083,143,303
Budget impact						
Case detection	0	-16,468,918	-32,700,712	-47,510,047	-60,006,493	-69,363,873
Treatment	0	-72,952	-1,253,900	-3,933,257	-8,323,866	-14,072,605
Hospitalisation	0	1,204,459	945,940	2,456,479	1,964,012	2,474,843
Outpatient	0	37,781	1,419,357	3,204,600	6,394,799	7,508,688
Total	0	-15,299,630	-31,589,314	-45,782,225	-59,971,547	-73,452,947

Table 5: Annual budget impact results for case detection strategy S3a.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	11,016,653	21,275,147	29,592,076	35,074,130	37,568,301
Treatment	394,085,160	417,390,389	439,649,740	462,152,198	484,078,502	507,454,085
Hospitalisation	865,204,886	887,006,443	920,567,873	958,095,345	994,804,347	1,040,071,251
Outpatient	1,228,997,220	1,271,345,131	1,315,891,141	1,360,800,695	1,410,976,346	1,463,274,395
Total	2,488,287,266	2,586,758,616	2,697,383,900	2,810,640,315	2,924,933,324	3,048,368,033
Budget impact						
Case detection	0	-11,016,653	-21,275,147	-29,592,076	-35,074,130	-37,568,301
Treatment	0	265,936	384,952	-406,004	-1,479,413	-3,451,466
Hospitalisation	0	1,786,958	-2,212,989	2,300,208	9,798	695,138
Outpatient	0	-480,040	90,408	51,495	2,608,956	1,646,953
Total	0	-9,443,798	-23,012,775	-27,646,377	-33,934,789	-38,677,677

Table 6: Annual budget impact results for case detection strategy S3b.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	15,149,413	29,168,195	40,534,328	48,151,651	51,581,576
Treatment	394,085,160	418,010,823	441,914,423	467,311,634	493,083,232	521,251,968
Hospitalisation	865,204,886	886,707,092	920,273,683	956,647,523	992,567,380	1,037,379,638
Outpatient	1,228,997,220	1,271,084,387	1,314,916,497	1,359,300,812	1,408,614,322	1,459,777,394
Total	2,488,287,266	2,590,951,716	2,706,272,797	2,823,794,298	2,942,416,585	3,069,990,577
Budget impact						
Case detection	0	-15,149,413	-29,168,195	-40,534,328	-48,151,651	-51,581,576
Treatment	0	-354,498	-1,879,732	-5,565,440	-10,484,144	-17,249,349
Hospitalisation	0	2,086,309	-1,918,798	3,748,029	2,246,765	3,386,751
Outpatient	0	-219,296	1,065,053	1,551,379	4,970,980	5,143,954
Total	0	-13,636,897	-31,901,672	-40,800,360	-51,418,050	-60,300,220

Table 7: Annual budget impact results for case detection strategy S3c.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	11,862,684	22,933,817	31,883,149	37,834,395	40,536,614
Treatment	394,085,160	417,680,104	440,779,754	464,609,702	488,439,453	514,049,544
Hospitalisation	865,204,886	886,830,831	920,377,953	957,610,386	993,830,117	1,038,927,093
Outpatient	1,228,997,220	1,271,198,601	1,315,370,381	1,359,932,416	1,409,537,107	1,461,288,483
Total	2,488,287,266	2,587,572,220	2,699,461,904	2,814,035,653	2,929,641,071	3,054,801,734
Budget impact						
Case detection	0	-11,862,684	-22,933,817	-31,883,149	-37,834,395	-40,536,614
Treatment	0	-23,779	-745,063	-2,863,508	-5,840,364	-10,046,924
Hospitalisation	0	1,962,571	-2,023,068	2,785,167	984,028	1,839,296
Outpatient	0	-333,510	611,169	919,775	4,048,195	3,632,865
Total	0	-10,257,402	-25,090,779	-31,041,715	-38,642,535	-45,111,377

Table 8: Annual budget impact results for case detection strategy S3d.

Outcome	2021 (Baseline)	2022	2023	2024	2025	2026
No case detection strategy costs						
Case detection	0	0	0	0	0	0
Treatment	394,085,160	417,656,325	440,034,691	461,746,194	482,599,088	504,002,620
Hospitalisation	865,204,886	888,793,402	918,354,884	960,395,553	994,814,145	1,040,766,389
Outpatient	1,228,997,220	1,270,865,091	1,315,981,550	1,360,852,191	1,413,585,302	1,464,921,348
Total	2,488,287,266	2,577,314,818	2,674,371,125	2,782,993,938	2,890,998,535	3,009,690,357
Case detection strategy costs						
Case detection	0	14,513,907	28,077,627	38,986,891	46,347,700	49,631,396
Treatment	394,085,160	417,545,263	440,277,104	463,488,097	486,443,450	511,005,784
Hospitalisation	865,204,886	886,940,785	920,537,886	958,045,366	994,313,181	1,039,414,469
Outpatient	1,228,997,220	1,271,227,559	1,315,593,561	1,360,120,664	1,410,155,038	1,462,106,008
Total	2,488,287,266	2,590,227,514	2,704,486,177	2,820,641,018	2,937,259,370	3,062,157,657
Budget impact						
Case detection	0	-14,513,907	-28,077,627	-38,986,891	-46,347,700	-49,631,396
Treatment	0	111,062	-242,412	-1,741,903	-3,844,362	-7,003,164
Hospitalisation	0	1,852,617	-2,183,001	2,350,187	500,964	1,351,920
Outpatient	0	-362,468	387,989	731,527	3,430,264	2,815,340
Total	0	-12,912,696	-30,115,052	-37,647,080	-46,260,835	-52,467,300

Appendix 3: Recalibrating the cost-effectiveness plane

The cost-effectiveness plane used by Johnson *et al.* (2021) was recalibrated at lower willingness-to-pay (WTP) thresholds. The preferred case detection strategy using the efficiency frontier approach with a WTP threshold of $25,000/QALY gained was S3b (questionnaire-based screening for adults aged ≥ 50 years with a smoking history) (Figure 5).

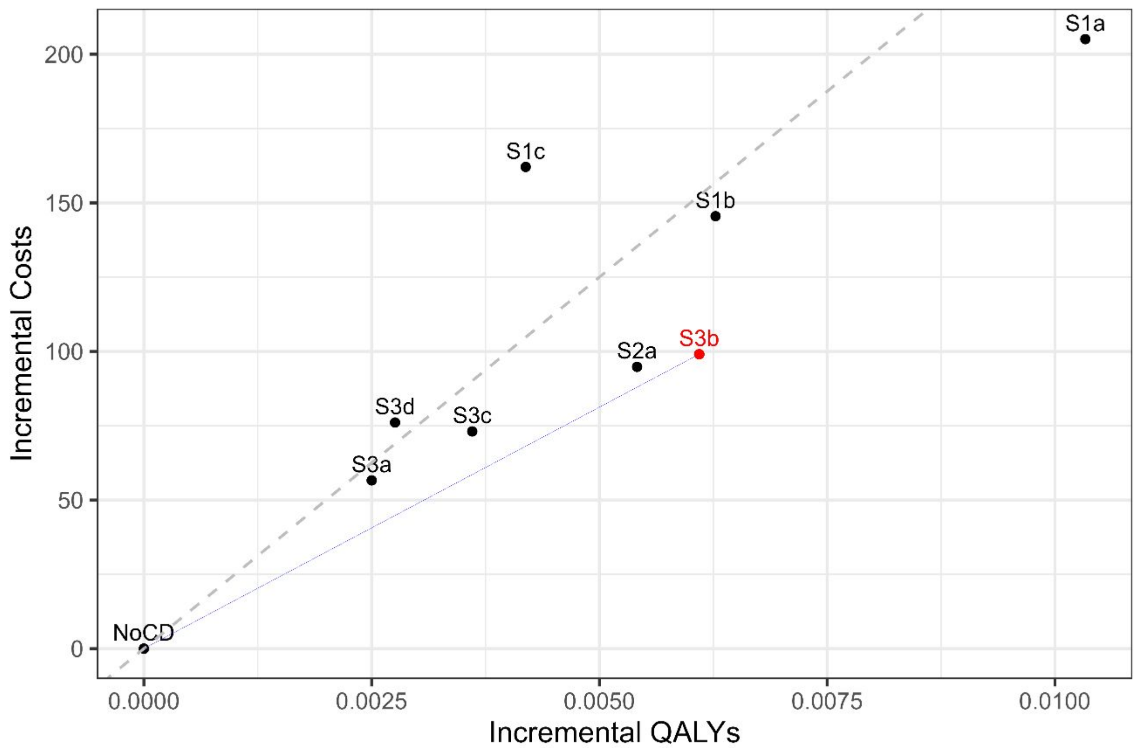

Figure 5: Cost-effectiveness plane for case detection scenarios. Solid blue line indicates the efficiency frontier and the grey dashed line indicated the WTP threshold ($25,000/QALY gained). The highest value scenario is highlighted in red.

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