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Pulmonary Rehabilitation for Postacute Exacerbations of Chronic Obstructive Pulmonary Disease (COPD): A Cost-Effectiveness and Budget Impact Analysis

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Health Quality Ontario strives to promote health care that is supported by the best available scientific evidence. The Evidence Development and Standards branch works with expert advisory panels, clinical experts, scientific collaborators, and field evaluation partners to conduct evidence-based reviews that evaluate the effectiveness and cost-effectiveness of health interventions in Ontario.

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ABSTRACT

Background

Pulmonary rehabilitation (PR) is a cornerstone treatment for chronic obstructive pulmonary disease (COPD) composed of supervised exercise, education, and psychosocial support.

Objectives

We assessed the economic implications of PR programs for COPD patients after hospitalization for an acute exacerbation in 3 settings (outpatient hospital, community, and home) compared with usual care (i.e., no PR), considering both the costs of the PR programs and the potential savings from reduced COPD-related rehospitalizations.

Methods

A decision analytic model was constructed for the cost-effectiveness analysis. A standardized PR program was developed through consulting with experts, considering pertinent clinical guidelines, and conducting a comprehensive literature search. Data from a recent PR survey in Ontario were also considered for empirical PR resource use. The theoretical and empirical resource use of PR was used to estimate the number of additional health care professionals needed to support the entire target population in Ontario. On the basis of the results of the cost-effectiveness analysis, a budget impact analysis was conducted to assess the potential economic impact of implementing PR programs for the target COPD population in Ontario.

Results

The total cost (professional time) per patient is $1,635 (Cdn) (29 hours) for the standardized outpatient hospital- or community-based PR and $3,498 (62 hours) for home-based PR. Compared with usual care, outpatient hospital- or community-based PR dominates with cost savings of $1,098 per patient and reduced hospitalizations of 256 admissions in 1,000 patients in 1 year. Home-based PR is associated with incremental costs of $765 per patient, and the incremental cost per rehospitalization avoided is $2,989. Factors influencing incremental cost included PR setting, duration of PR, and COPD disease history. To deliver the standard PR program to COPD patients (where 90% of target patients receive outpatient hospital- or community-based PR, and 10% receive home-based PR) after discharge for an acute exacerbation, 155 additional health care professionals are needed in Ontario. Using empirical data increases the number of health care professionals required to 213. The budget impact analysis shows that implementation of PR for the entire target population would lead to theoretical cost savings of approximately $7.7 million (Cdn) for fiscal year 2012–2013.

Limitations

Additional clinical benefits and resource use was not captured, nor were additional costs (such as capital investments, equipment costs, or costs incurred by patients and caregivers).

Conclusions

Outpatient hospital or community PR costs approximately half of a home-based program and is preferred for access to equipment and psychosocial peer support. Outpatient hospital or community PR dominates usual care, while home-based PR costs more than usual care.

Although postdischarge PR after an acute exacerbation can lead to substantial cost savings, actual cost savings largely depend on the expansion of current PR capacity in Ontario.

PLAIN LANGUAGE SUMMARY

Chronic obstructive pulmonary disease (COPD) is a lung disease that causes worsening breathlessness. The symptoms fluctuate from stable to flare-ups that might need hospital care. Pulmonary rehabilitation (PR) is a key treatment for COPD that includes supervised exercise, education, and peer-group support to help improve symptoms and increase your quality of life. In Ontario, PR programs vary a lot, and how much costs vary according to where programs are located is unknown. This study focused on a PR program for COPD patients who have just left the hospital after a flare-up. The study examined PR in 3 places: an outpatient hospital centre, a community-based centre, and patients' homes. We wanted to know how much the 3 programs cost and if the health care system can save money by keeping patients from having to return to hospital later.

To find out which place is best, COPD experts helped develop a standard PR program. An economic model was created, though this type of model cannot capture every benefit of PR or every doctor visit. For the standard PR program, outpatient hospital or community PR costs were about half the cost of a home-based program. Outpatient hospital- or community-based PR is also preferred because of access to exercise equipment and the peer support of groups. Compared with no PR, outpatient hospital- or community-based PR is better and cheaper because COPD patients might not have to return to hospital as often. It is uncertain whether or not home-based PR is cost effective compared with no PR, given it is better but also more expensive. An additional 155 to 213 health care professionals are required in Ontario to deliver PR to all patients after they leave hospital for a COPD flare-up. Considering the cost of PR and rehospitalizations avoided, potential savings could be around $8 million (Cdn) annually if fully implemented in the first year.

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LIST OF ABBREVIATIONS

AECOPD	Acute exacerbation of chronic obstructive pulmonary disease
CI	Confidence interval(s)
COPD	Chronic obstructive pulmonary disease
CPP	Canadian Pension Plan
CTS	Canadian Thoracic Society
CUA	Cost-utility analysis
FTE	Full-time equivalent
FY	Fiscal year
HRQOL	Health-related quality of life
ICES	Institute for Clinical Evaluative Sciences
IRR	Incidence rate ratio
LHIN	Local Health Integration Network
OHTAC	Ontario Health Technology Advisory Committee
PATH	Programs for Assessment of Technology in Health
PR	Pulmonary rehabilitation
PSA	Probabilistic sensitivity analysis
RCT	Randomized controlled trial
RT	Respiratory therapist
SGRQ	St. George's Respiratory Questionnaire
THETA	Toronto Health Economics and Technology Assessment Collaborative

BACKGROUND

The Toronto Health Economics and Technology Assessment (THETA) Collaborative was commissioned by Health Quality Ontario to evaluate the cost-effectiveness and predict the long-term costs and effects of pulmonary rehabilitation for chronic obstructive pulmonary disease. Published economic evaluations are reviewed, and the structure and inputs of the economic model used to estimate cost-effectiveness are summarized. The results of the economic analyses are presented for pulmonary rehabilitation versus usual care, and the budget impact of implementing each intervention is estimated.

Health Quality Ontario conducts full evidence-based analyses, including economic analyses, of health technologies being considered for use in Ontario. These analyses are then presented to the Ontario Health Technology Advisory Committee, whose mandate it is to examine proposed health technologies in the context of available evidence and existing clinical practice, and to provide advice and recommendations to Ontario health care practitioners, the broader health care system, and the Ontario Ministry of Health and Long-Term Care.

DISCLAIMER: Health Quality Ontario uses a standardized costing method for its economic analyses. The main cost categories and associated methods of retrieval from the province's perspective are described below.

Hospital costs: Ontario Case Costing Initiative cost data are used for in-hospital stay, emergency department visit, and day procedure costs for the designated International Classification of Diseases diagnosis codes and Canadian Classification of Health Interventions procedure codes. Adjustments may be required to reflect accuracy in the estimated costs of the diagnoses and procedures under consideration. Because of difficulties in estimating indirect costs in hospitals associated with a particular diagnosis or procedure, Health Quality Ontario normally defaults to a consideration of direct treatment costs only.

Nonhospital costs: These include physician services costs obtained from the Ontario Schedule of Physician Benefits, laboratory fees from the Ontario Schedule of Laboratory Fees, drug costs from the Ontario Drug Benefit Formulary, and device costs from the perspective of local health care institutions whenever possible, or from the device manufacturer.

Discounting: For cost-effectiveness analyses, a discount rate of 5% is applied (to both costs and effects/QALYs), as recommended by economic guidelines.

Downstream costs: All reported downstream costs are based on assumptions of population trends (i.e., incidence, prevalence, and mortality rates), time horizon, resource utilization, patient compliance, health care patterns, market trends (i.e., rates of intervention uptake or trends in current programs in place in the province), and estimates of funding and prices. These may or may not be realized by the Ontario health care system or individual institutions and are often based on evidence from the medical literature, standard listing references, and educated hypotheses from expert panels. In cases where a deviation from this standard is used, an explanation is offered as to the reasons, the assumptions, and the revised approach.

The economic analysis represents *an estimate only*, based on the assumptions and costing methods explicitly stated above. These estimates will change if different assumptions and costing methods are applied to the analysis.

Objective of Analysis

This study aimed to evaluate the economic implications of early pulmonary rehabilitation (PR) programs (within 1–4 weeks after discharge) for chronic obstructive pulmonary disease (COPD) patients after hospitalization for an acute exacerbation. We considered PR conducted in 3 settings: outpatient hospital-based, community-based, and home-based PR programs, compared with usual care (i.e., no PR). We estimated the costs of the PR programs and the potential savings from reductions in COPD-related rehospitalizations. Our specific objectives were:

- to estimate the resource use (health care professionals' time) and the associated costs of 3 standardized PR programs
- to evaluate the cost-effectiveness of 3 PR programs versus usual care

- to estimate the number of additional health care professionals needed and the associated costs of expanding PR programs to support the entire target population in Ontario
- to assess the potential budget implications of expanding PR programs in Ontario

Clinical Need and Target Population

Description of Disease

Chronic obstructive pulmonary disease is characterized by airflow limitation that is not fully reversible. The airflow limitation is usually both progressive and associated with an abnormal inflammatory response by the lungs to noxious particles or gases. The airflow limitation is caused by disease of the small airways (obstructive bronchiolitis) and parenchymal destruction (emphysema), both of which contribute to the disease to varying degrees. Chronic inflammation causes structural changes in the lungs and narrowing of the small airways. Inflammatory processes also cause destruction of the lung parenchyma, which leads to the loss of alveolar attachments to the small airways and decreases lung elastic recoil. These changes reduce the ability of the airways to remain open during expiration.

As a progressive disease, COPD can worsen over several years or several decades, depending on such factors as continued exposure to noxious particles (e.g., tobacco smoke). Sudden exacerbations of COPD contribute greatly to morbidity and mortality, which in turn increase resource use and costs. In Canada, the average cost for treating a moderate exacerbation is reported to be $641 (Cdn), $10,086 for a major exacerbation. (1)

Ontario Context

Estimates of COPD prevalence vary depending on the methods and diagnostic criteria used to identify cases. Many prevalence estimates are believed to underestimate totals because of underdiagnosis and under-recognition of mild cases, as individuals often do not require health care services until they reach the moderate to severe stages of COPD.

In the 2012 Canadian Community Health Survey, 4.2% of Canadians aged 35 and older reported they had been diagnosed with COPD by physicians. (2) According to a report by the Institute for Clinical Evaluative Sciences (ICES), the age- and sex-adjusted prevalence rate increased from 7.7 to 9.9 per 100 Ontario adults aged 35 years or older from fiscal year (FY) 1996–1997 to FY 2009–2010. (3) The number of hospitalizations due to acute exacerbations also increased from 22,109 in FY 2009–2010 to 25,258 in FY 2012–2013. (4) To reduce the long-term effects of COPD, interventions are aimed at preventing disease progression and exacerbations, relieving symptoms, increasing exercise tolerance, and reducing mortality.

Interventions Under Evaluation

Pulmonary rehabilitation is considered one of the most important interventions for COPD patients. It has been shown to control symptoms of COPD through improvements in dyspnea, exercise capacity, functional status, and health-related quality of life (HRQOL). (5) Pulmonary rehabilitation programs vary in duration and can be broad in nature, usually combining supervised exercise or endurance training with other components (such as nutrition counselling, patient self-management and education, breathing and energy conservation strategies, and psychosocial support). An examination of the literature revealed an apparently stronger positive effect on HRQOL that was achieved with longer PR programs. (6) By focusing on physical and psychological patient needs, PR addresses the chronic and disabling aspect of COPD.

Pulmonary rehabilitation is considered the standard of care for treating and rehabilitating patients with COPD who continue to have symptoms despite treatment with bronchodilators. The Ontario Health Technology Advisory Committee (OHTAC) and the Canadian Thoracic Society (CTS) clinical guidelines for optimizing PR recommend that COPD patients start PR within 1 to 4 weeks postdischarge for an acute exacerbation. (7)

Despite the recognized benefits of PR, the current capacity of PR in Ontario can serve less than 2% of all (stable, moderate to severe, or postacute exacerbation) COPD patients requiring PR. (8) To date, most PR programs are outpatient hospital-based, with other possible programs being community-based, hospital inpatient-based, or home-based. On the basis of a survey of PR capacity in Ontario, OHTAC recommended increasing the availability of PR resources for postdischarge patients who have had an acute exacerbation of COPD. (8) We seek to address the location of PR to maximize use and access and to estimate costs associated with the recommended expansion of PR.

Evidence Base

Health Quality Ontario conducted an evidence-based analysis in 2012 to determine whether early PR (within 1 month of hospital discharge) in patients who had an acute exacerbation of COPD (AECOPD) improved outcomes compared with usual care (i.e., no PR). An excerpt (9) of the results and conclusions follows.

> *Hospital Readmissions*
> *All studies reported hospital readmissions as an outcome. Three of the studies reported COPD-related readmissions, while 2 of the studies reported general admissions. There was a decrease in all hospital readmissions as seen by the pooled relative risk of 0.50 (95% confidence interval, 0.33–0.77; P= 0.001) favouring pulmonary rehabilitation versus usual care. When admissions were subgrouped by type, the effect observed was greater for COPD-related readmissions than for general readmissions.*
>
> *Health-Related Quality of Life*
> *Three studies reported results of Health-Related Quality of Life (HRQOL) assessments based on the St. George's Respiratory Questionnaire (SGRQ). All studies compared the difference in the mean change scores from baseline to follow-up between the pulmonary rehabilitation and usual care groups. Based on the minimal clinically important difference, there was a statistically and clinically significant improvement in quality of life for the pulmonary rehabilitation group as compared to the usual care group reflected in the total (P < 0.001), impact (P < 0.001), and activity scores (P = 0.001) of the SGRQ.*
>
> *Pulmonary rehabilitation (within 1 month of hospital discharge) after acute exacerbation significantly reduces hospital readmissions (relative risk, 0.50; 95% confidence interval, 0.33–0.77; P = 0.001) and leads to a statistically and clinically significant improvement in HRQOL.*

ECONOMIC ANALYSIS

Primary Economic Evaluation

Health Quality Ontario has previously published 2 economic reports for COPD patients: an economic analysis of various COPD interventions (10) and an economic rapid review of PR in different settings. (11) However, neither report addressed our research questions. Thus, a primary economic evaluation was conducted for the resource use and economic impact of PR programs in 3 settings for COPD patients postdischarge for an acute exacerbation.

Research Methods

Type of Analysis

We conducted a cost-effectiveness analysis, using cost per COPD-related rehospitalization avoided as the primary outcome. Although several randomized controlled trials (RCTs) reported that PR improved COPD-specific and generic health-related quality of life (HRQOL), (12-17) it is challenging to transform these various treatment effect measurements into utility data ranging from 0 to 1 through a rigorous approach for the cost-utility analysis (CUA). In particular, most RCTs reported only the summarized HRQOL at baseline and at a single follow-up visit at 6 weeks and 3 months, (14-17) while reliable longitudinal utility data of a couple of visits in 1-year follow-up are needed for a CUA.

Interventions Evaluated

Although the duration, staff, and structures of PR programs vary considerably in different health care systems and centres, most PR programs share essential features (18) in which core components are consistent with the CTS PR guidelines. (19) To accurately estimate resource use, a standardized outpatient hospital-based, community-based, and home-based PR program was developed in consultation with the Expert Advisory Panel on Postacute, Community-Based Care for COPD Patients and considering pertinent clinical guidelines. (18-20) It should be noted that the standardized PR program cannot be considered the "optimal" program, as PR programs are highly individualized in practice, (8) and longer programs often show greater benefits than shorter programs. (18) Because of practical constraints, both guidelines and empirical data for the standardized PR program were considered. For instance, consistent with the average total time for outpatient PR reported in Canada, (10;19) approximately 40 hours was used in the standardized PR program. In another instance, we limited the professional time for respiratory therapists (RTs) in the standardized PR program because of their currently low numbers in Ontario, even though RTs are appropriate health care providers for PR.

Standardized PR Program

Details of the standardized PR program are as follow:

- **Duration:** 40 hours over 8 weeks
- **Intensity:** 1.5 to 2.0 hours per session at 3 sessions per week
- **Core components are education, exercise, and psychosocial support:**
  - Education includes self-management, patient education, smoking cessation counselling, nutritional support, and medication information.
  - Exercise is supervised, is group-based or individualized, and includes aerobic and strength training.
  - Psychosocial support includes motivation and social connectedness (not necessarily explicit, but can be the result of supervised exercise in a group environment).

- **Additional support components:** In addition to core PR, patients could receive individualized support for comorbidities and so forth.
- **Health care provider:** multiple health care professionals
- **Main assumptions are as follow:**
  - The intensity and duration of the standardized PR program are similar across 3 settings.
  - For outpatient hospital or community PR, group sizes are 4 for exercise training and 8 for education.
  - For home PR, a single health care professional provides all PR components at each visit.
  - Except for setting, outpatient hospital and community PR are the same.
  - Patients are supervised for the entire PR program (i.e., no unsupervised sessions for safety reasons).
  - Some health care professionals involved in PR delivery are interchangeable (e.g., RT, physiotherapist, or kinesiologist for exercise).

The CTS clinical practice guideline for PR (7) states that "there are no differences in major patient-related outcomes of PR between nonhospital (community or home sites) or hospital-based sites" based on their highest level of evidence (Level 1A). If we assume equal intensity and duration of PR programs across the 3 settings, it is reasonable to expect the clinical effectiveness of PR in these different settings to also be the same. Thus, our cost-effectiveness analysis compared PR in each setting with usual care, and not with each other.

Perspective

The analysis was conducted from the perspective of the Ontario Ministry of Health and Long-Term Care.

Discounting and Time Horizon

It is generally accepted that the effects of PR can be sustained for 1 year. (10) Thus, a 1-year time horizon was used in all analyses. No discounting was applied. Costs are expressed in 2014 Canadian dollars. (21)

Target Population

The target population was COPD patients who had recently been discharged for an acute exacerbation, with > 1 year life expectancy, and who were eligible to receive exercise training and other PR components.

Variability and Uncertainty

The 1-way and 2-way sensitivity analysis was conducted to assess factors that affect the incremental cost of outpatient hospital-based, community-based, and home-based PR versus usual care, including the following:

- cost of various PR programs: 4-week PR, 12-week PR, core components of PR only (excluding additional support from other health care professionals), and so forth
- conservative estimate of the effectiveness of PR
- background rehospitalization rate, assuming the incidence rate ratio (IRR) is constant

- aside from health care professionals' wages, the additional costs for community or outpatient hospital PR programs
- costs of COPD-related rehospitalization

We also conducted probabilistic sensitivity analyses (PSAs) to explore parameter uncertainty (second-order uncertainty) by considering inputs as random variables associated with a probability distribution.

Generalizability

The findings of this economic analysis cannot be generalized to all patients with COPD. Results can, however, be used to guide decisions for the specific target patient population of interest, postdischarge patients for an acute exacerbation of COPD.

Model Structure

A simple economic model was developed to assess the cost-effectiveness of PR program in 3 settings versus usual care (Figure 1). A previous HQO analysis (9) showed no convincing evidence that PR reduced mortality or emergency department visits. Thus, those outcomes were not incorporated in the model. It was assumed that COPD-related rehospitalizations in 1 year would follow a Poisson distribution. For simplicity, only the cost of PR programs and the cost for rehospitalization were considered in our study for cost estimates. The primary outcome was the incremental cost per COPD-related rehospitalization avoided.

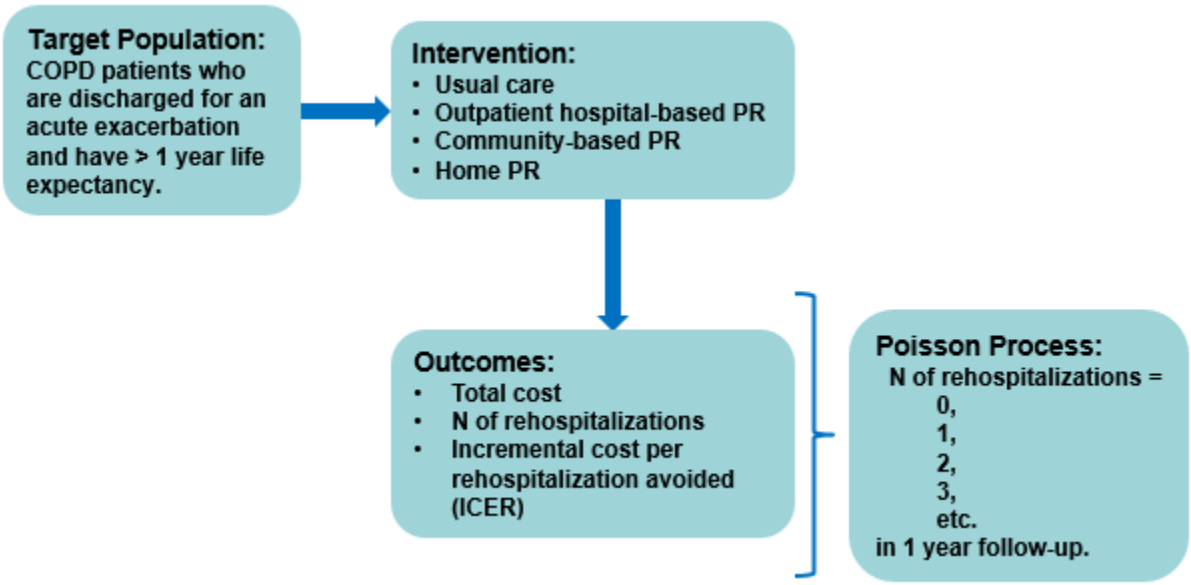

Figure 1: Conceptual Health Economic Model

Abbreviations: COPD, chronic obstructive pulmonary disease; N, number; PR, pulmonary rehabilitation.

Principal Assumptions

- Pulmonary rehabilitation reduces the risk of COPD-related rehospitalization.
- The clinical effectiveness of the standardized PR program is the same across all 3 settings and can be sustained for 1 year.

- The clinical effectiveness of the standardized PR program is based on the IRR, which is a pooled estimate of the IRR from 3 RCTs with various follow-up durations (13;14;16), assuming that IRR is constant over a 1-year period.
- Each patient attended PR only once within 1 year (i.e., no repeat PR or maintenance PR), regardless of the number of rehospitalizations for subsequent acute exacerbations within the 1 year.
- One patient with 2 rehospitalizations or 2 patients with one rehospitalization each was treated as the same (i.e., count of rehospitalizations).
- Patients' COPD severity level does not progress over 1-year follow-up.
- Patient survival is 100% during 1-year follow-up.

Model Input Parameters

A comprehensive literature search was conducted to identify the most reliable model inputs, and the expert advisory panel was consulted to validate our parameter estimates.

Model Input Parameters: Professional Time and Cost of Standardized PR Program

Although the capital depreciation and utilities per visit are different for PR programs in the 3 settings, we did not find any reliable data for their quantification. A United Kingdom study showed that equipment costs contributed only about 0.6% of the total PR cost, at £1.75 per session. (22) For simplicity, we excluded the capital depreciation, equipment costs, and other facility costs, and focused on the costs of health care professional services (salary plus benefits) and transportation (for home-based PR only) in the PR cost estimation. Thus, the cost of outpatient hospital-based PR and community-based PR was identical in our estimate.

We estimated the average amount of health care professionals' time per patient for the standardized PR programs (Tables 1 and 2) and then valued them using their unit price. The average of the minimum and maximum salary of health care professionals in family health teams in Ontario was used to approximate the average salary. (23) Employee benefits, such as Employment Insurance, Canadian Pension Plan (CPP), and health insurance, were estimated to be about 33% of salaries. (24). The total cost of professional time was the combination of salary and employee benefits. We estimated that there are 235 working days annually (weekends: 102 days; public holidays: 11 days; vacation days: 15 days), (25) and 7.5 hours are worked per day. Thus, on average, one health care professional could offer approximately 1,762.5 hours of service annually. The unit price was the total cost divided by 1,762.5 hours (Table 3). When more than 1 health care professional might be involved in PR delivery, the cost was weighted by the proportion of services offered by each professional.

The expert advisory panel suggested 40 minutes per round trip (20 minutes each way) as an average for 1 home-based PR visit. The travel distance was estimated to be about 30 kilometres per visit, in a combination of highway and local driving. According to the current reimbursement policy, the rate is about $0.5 per kilometer. Thus, we estimated transportation costs of $15 per visit and $360 per program (24 sessions) for home-based PR.

All resource use data were validated by the expert advisory panel. The costs of the standardized PR programs are reported in the Results section.

Table 1: Average Professional Time per Patient for Core Services of Standardized PR Program

Core PR Services	Outpatient Hospital- or Community-Based PR	Home-Based PR
Professional time per session		
Education	Total: 30 min; Group size = 8	90 min, individualized RT: 10%; PT 90% Single health care professional provides both education and exercise components of PR
Health care provider	RT: 80%; Nurse or CRE: 20%	
Resource use	12.5 (20/8 + 10) min; 20 min group, and 10 min individualized	
Exercise	Total: 1 h; Group size = 4	
Health care provider	RT: 20%; PT: 75%; Kinesiologist: 5%	
Resource use	26.25 (45/4 + 15) min; 45 min group, and 15 min individualized	
Psychosocial support	Included in group-based program	No group-based psychosocial support
Transportation	0	40 min
Total professional time per patient per session (weighted)	38.75 (12.5 + 26.25) min	130 (90 + 40) min
Number of sessions per PR program	27 (24, 30)[a]	24
Professional time per PR program (h)		
RT	6.86	5.20
Nurse/CRE	1.13	NA
PT	8.86	46.80
Kinesiologist	0.59	NA
Total professional time PR program (h)	**17.44**	**52**

Abbreviations: CRE, certified respiratory educator; FTE, full time equivalent; min, minutes; h, hour; NA, not applicable; PR, pulmonary rehabilitation; PT, physiotherapist RT, respiratory therapist.

[a]A range of 24–30 sessions was estimated because most patients participate in 24 or more sessions.

Table 2: Average Professional Time per Patient for Additional Health Care Support for Standardized PR Program

Health Care Provider	Outpatient Hospital- or Community-Based PR	Home-Based PR
GP: 50%; Respirologist: 50% (Exchangeable)	2 h 15 min (1 h 45 min for oversight of patients and 30 min for 1 follow-up visit)	2 h (1 h 30 min for oversight of patients and 30 min for 1 follow-up visit)
Dietitian	2 h 15 min (30 min × 4.5 visits)	2 h (30 min × 4 visits)
OT	2 h 15 min (30 min × 4.5 visits)	2 h (30 min × 4 visits)
Administration	4 h 30 min (10 min × 27 visits)	4 h (home-based PR, 10 min × 24)
Total professional time (h)	**11.25**	**10**

Abbreviations: GP, general practitioner; h, hours; min, minutes; OT, occupational therapist; PR, pulmonary rehabilitation.

Table 3: Unit Cost of Professional Time

Health Care Professional	Cost per Hour ($Cdn)	Annual Salary Plus Benefits, Mean (Minimum, Maximum) ($Cdn)	Reference
Physiotherapist	45.96	81,010 (73,484, 88,535)	(23)
Respiratory therapist	45.96	81,010 (73,484, 88,535)	(23)
Occupational therapist	45.96	81,010 (73,484, 88,535)	(23)
Registered nurse	45.96	81,010 (73,484, 88,535)	(23)
Registered dietitian	42.96	75,717 (68,683, 82,751)	(23)
Kinesiologist[a]	32.51	57,290 (51,915, 62,666)	(23)
Administration[a]	32.51	57,290 (51,915, 62,666)	(23)
General practitioner	125.74	221,617	(26)
Respirologist[b]	314.00	--	(27)

[a]We used the salary of a registered practical nurse.
[b]Cost of 1 respirologist visit (on average 30 minutes) is $157. This cost was doubled to estimate the cost per hour for a respirologist.

Model Input Parameters: Incidence Rate Ratio of PR Versus Usual Care

A previous review (9) identified 5 RCTs for PR to improve outcomes for discharged patients for acute exacerbations of COPD. No new studies were found in an informal updated literature search via PubMed in April 2014. In some of the identified RCTs, 1 patient had up to 3 hospitalizations. (16) We considered rehospitalization as count data, that is, the number of rehospitalizations per patient-year. We excluded 2 studies that reported only all-cause rehospitalizations (i.e., no data for COPD-related rehospitalizations), (9) and included 3 studies in the final meta-analysis (13;14;16) (Figure 2). The random effects model showed that PR was associated with a statistically significant lower incidence rate of rehospitalization ($p < 0.05$). The pooled rate ratio (95% confidence interval [CI]) of PR versus usual care was 0.36 (0.16, 0.81). Although the IRR is rather low, the relatively wide 95% prediction interval (0.11, 1.21) of IRR (in comparison to the 95% CI) and the heterogeneity test results ($I^2 = 40\%$) reflect the inconsistency of effects across studies.

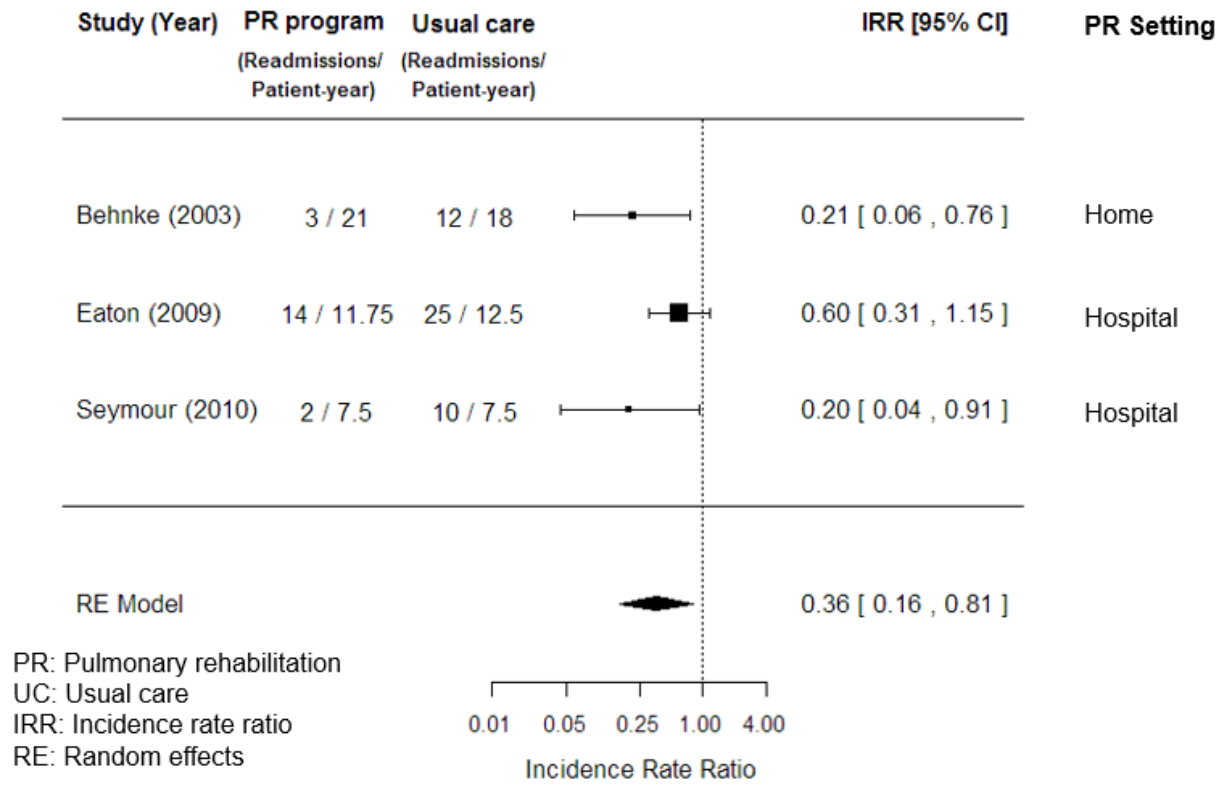

Figure 2: Effect of PR on Reduction of Rehospitalization Rate

Abbreviations: CI, confidence interval; IRR, incidence rate ratio; PR, pulmonary rehabilitation; RE, random effects.

Model Input Parameters: Number of Rehospitalizations in 1 Year for Usual Care
Published data showed large variability for COPD-related rehospitalizations for patients postdischarge for an acute exacerbation (Appendix 1). One possible explanation was the various definitions of COPD-related rehospitalization across studies. On the basis of published data and in consultation with the expert advisory panel, rehospitalization rate was estimated to be 0.4 (range 0.3–0.5) per patient-year in Ontario. The expected probability of the number of rehospitalizations for PR and usual care in 1 year can be found in Appendix 2.

Model Input Parameters: Cost of COPD-Related Rehospitalization
According to Mittmann et al (1), the total cost per acute severe hospitalized exacerbation was approximately $10,634 (Cdn in 2014).

Distribution of Model Inputs for Probabilistic Sensitivity Analysis
Distributions of major parameters are listed in Table 4. Additional details of the parameter inputs for the PSA are available on request.

Table 4: Distributions of Parameters

Parameter	Distribution
Unit cost of professional time	Uniform
Effectiveness of PR program, incidence rate ratio of PR vs. usual care	Log normal
Cost of hospitalization for acute exacerbation	Gamma
Rehospitalization rate in usual care	Uniform

Abbreviation: PR, pulmonary rehabilitation.

Software

Economic analyses were conducted using Excel 2013 (Microsoft, Redmond, Wash). Visual Basic for Applications (VBA) in Excel 2013 was used for the Monte Carlo Simulation (N iterations: 10,000). Also, we used the "metafor" package (version 1.9) in R 3.0.2 (R Development Core Team, Vienna, Austria) for the meta-analysis and SAS 9.3 (SAS, Cary, NC) for selected plots.

Results of the Primary Economic Evaluation

Cost of PR Program

The total cost (professional time) per patient for outpatient hospital or community PR and home PR, including core PR services and additional support, was $1,635 (28.69 hours) and $3,498 (62 hours) respectively. The cost of other types of PR programs as sensitivity analyses can be found in Table 5.

Table 5: Cost of Various PR Programs

Type of PR Program	Outpatient Hospital or Community-Based PR		Home-Based PR	
	N of Sessions[a]	Cost ($Cdn)	N of Sessions[b]	Cost ($Cdn)
Reference: standardized 8-week PR program, core PR plus additional support	**27 ([3 × 8] + 3)**	**1,635**	**24 (3 × 8)**	**3,498**
Core PR only, excluding additional support (8 weeks)	27 ([3 ×8] + 3)	940	24 (3 × 8)	2,880
Upper limit of professional wages, core PR plus additional support (8 weeks)	27 ([3 × 8] + 3)	1,768	24 (3 × 8)	3,773
4-week PR program, core PR plus additional support	14 ([3 × 4] + 2)	908	12 (3 × 4)	1,749
12-week PR program, core PR plus additional support	41 ([3 × 12] + 5)	2,482	36 (3 × 12)	5,247

Abbreviation: PR, pulmonary rehabilitation.

[a]N of sessions = 3 sessions per week × number of weeks + number of additional sessions offered.

[b]N of sessions = 3 sessions per week × number of weeks.

Base Case Analysis

The outpatient hospital- or community-based PR strategy dominates the usual care strategy, with lower costs (cost savings of $1,098 per patient) and reduced number of hospitalizations (number of rehospitalizations avoided of 256 per 1,000 patients) in 1-year follow-up (Table 6). Compared with usual care, home-based PR is more costly (incremental cost of $765), and the corresponding incremental cost per COPD-related rehospitalization avoided is $2,989. Given there is no well-accepted maximum willingness to pay for 1 rehospitalization avoided, it is unclear whether home-based PR is cost-effective.

Table 6: Base Case Analysis Results

Strategy	Average Total Costs (cost of PR, cost for RH) in 1 year, ($Cdn)	Incremental Cost, (PR vs. UC), ($Cdn)	N of RH per 1,000 patients in 1 y	N of RH avoided per 1,000 patients (PR vs. UC)	ICER
UC	4,270 (0, 4,270)	--	400	--	--
Outpatient hospital- or community-based PR	3,172 (1,635, 1,537)	−1,098	144	256	Dominant
Home-based PR	5,035 (3,498, 1,537)	765	144	256	2,989

Abbreviations: ICER, incremental cost-effectiveness ratio (incremental cost per rehospitalization avoided); PR, pulmonary rehabilitation; RH, rehospitalization; UC, usual care; y, year.

Deterministic Sensitivity Analysis

We examined several factors that could affect the incremental cost of outpatient hospital or community or of home PR versus usual care.

Background Rehospitalization Rate and the Conservative Estimate of the Effectiveness of PR

The effectiveness of PR for the base case analysis was based on the pooled estimate of 3 small RCTs with relatively short follow-up. Although the studies suggested a large benefit for PR (pooled IRR of 0.36), publication bias cannot be excluded. To avoid overestimating the effectiveness of PR, a conservative estimate of the upper limit of the 95% CI of the pooled IRR, 0.81, was used in the sensitivity analysis.

The incremental cost decreased as the rehospitalization rate increased in the usual care arm. When the rehospitalization rate is greater than 0.8 per patient-year, the conservative estimate of PR effectiveness also results in cost savings for community-based PR (Figure 3). For home-based PR, the conservative estimate of PR effectiveness results in cost savings if the rehospitalization rate is more than 1.7 per patient-year (Figure 4).

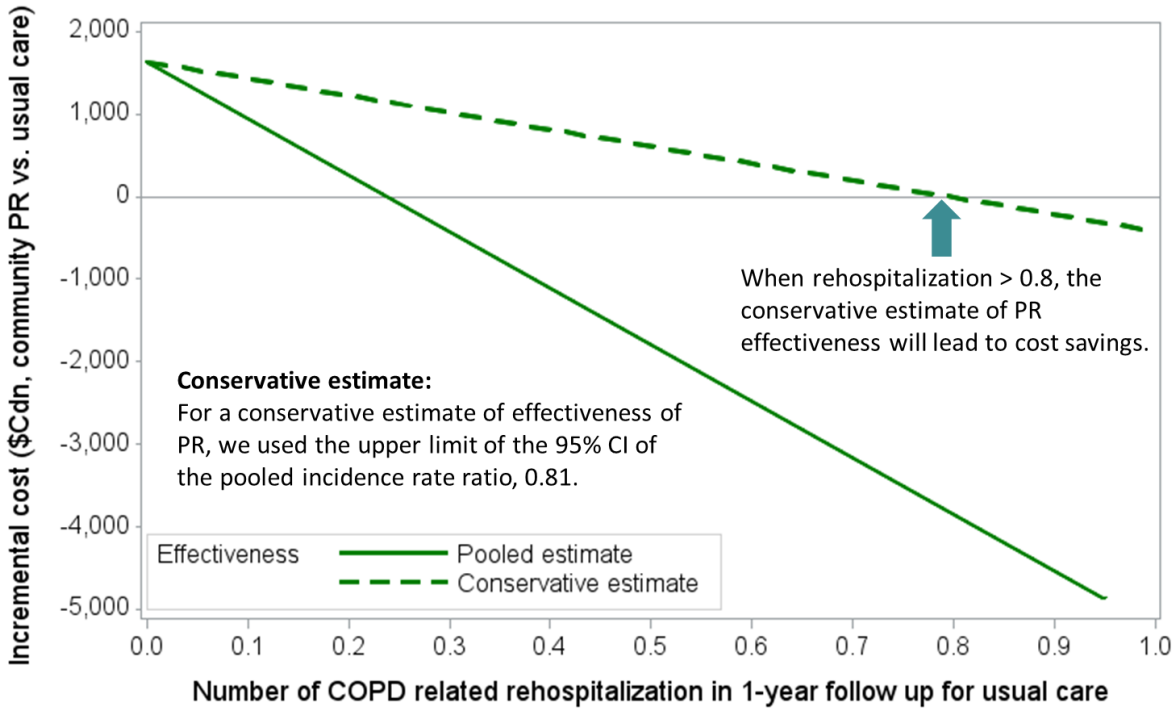

Figure 3: Incremental Cost Versus Background Rehospitalization Rate for Community-Based PR

Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; PR, pulmonary rehabilitation.

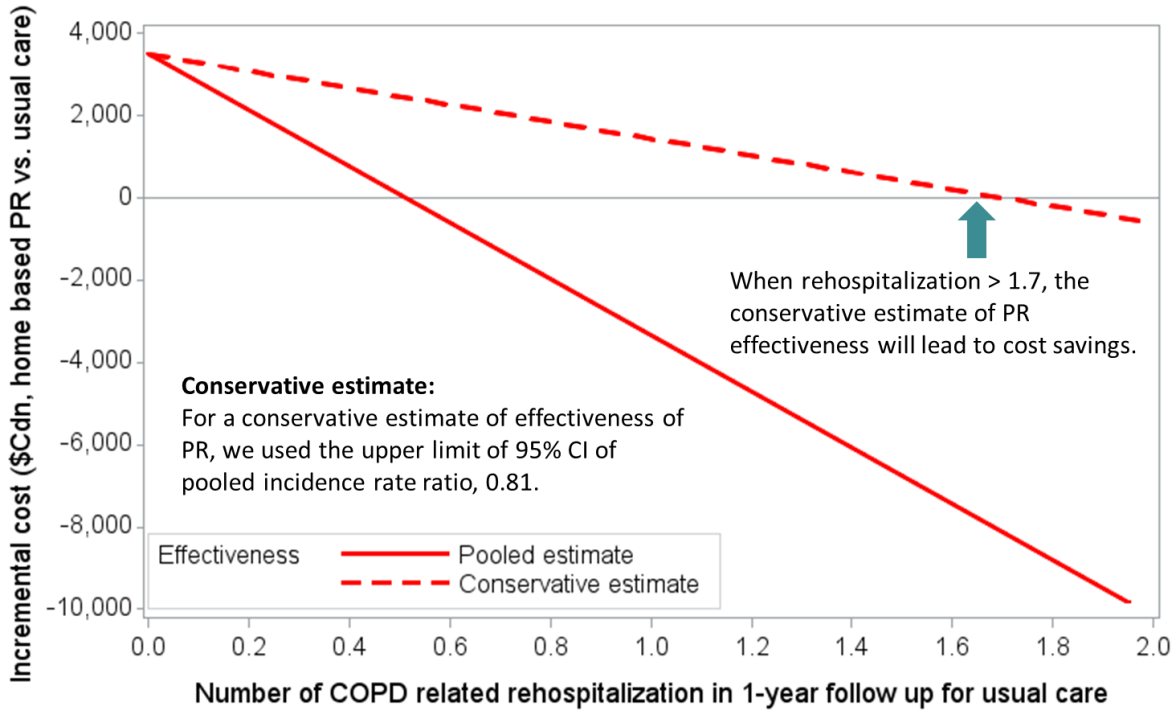

Figure 4: Incremental Cost Versus Background Rehospitalization Rate for Home-Based PR

Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; PR, pulmonary rehabilitation.

Other Types of PR Programs and the Conservative Estimate of Effects of PR Programs
In practice, PR programs vary considerably. Thus, the incremental cost of various PR programs was estimated, using both the pooled estimate and the conservative estimate of PR effectiveness (Table 7). Although the CTS PR guidelines recommend that the duration of PR be at least 6 to 8 weeks in duration, (7) according to the Programs for Assessment of Technology in Health (PATH) PR survey, the duration for 48% patients in PR programs was ≤ 4 weeks in Ontario. (8). If the 4-week PR program has the same intensity as the standard 8-week program, it is reasonable to assume its clinical effectiveness is also decreased. If the conservative estimate of PR effectiveness is used, the incremental cost of outpatient hospital- or community-based PR is $86 per patient, and home-based PR leads to incremental costs of $927. Compared with the 8-week standard PR program (the base case), a 4-week PR program of the same intensity is associated with higher total health care costs for all 3 types of PR settings.

Table 7: Sensitivity Analysis Results for Various Types of PR Programs

Type of PR Program	Incremental Cost of Outpatient Hospital/Community-Based PR vs. Usual Care ($Cdn)		Incremental Cost of Home-Based PR vs. Usual Care ($Cdn)	
	Pooled Estimate[a]	Conservative Estimate[b]	Pooled Estimate[a]	Conservative Estimate[b]
Reference: standardized 8-week PR program, core PR plus additional support	−1,098	813	765	2,676
Core PR only, excluding additional support (8 weeks)	−1,791	118	149	2,058
Upper limit of professional wages, core PR plus additional support (8 weeks)	−963	947	1,042	2,951
4-week PR program, core PR plus additional support	−1,823	86	−982	927
12-week PR program, core PR plus additional support	−249	1,660	2,515	4,425

Abbreviations: CI, confidence interval; IRR, incidence rate ratio; PR, pulmonary rehabilitation.
[a]Effectiveness of PR is based on pooled estimate of IRR, 0.36.
[b]Effectiveness of PR is based on the upper limit of 95% CI of pooled IRR, 0.81.

Including Other Potential Costs of PR Programs
The present base case analysis considered only the costs for hiring health care professionals. If other costs (e.g., capital depreciation and utilities, overhead, exercise equipment) total $40 per session per patient (or $1,080 per program), outpatient hospital- or community-based PR and usual care strategies have approximately the same total costs. The non-salary operating cost is estimated to be approximately 30% of the cost of professional staff. Thus, an additional $20 per session per patient (or $540 per program) results in cost savings of about $556 per patient for outpatient hospital- or community-based PR. For home-based PR, including the operating cost of $45 per session per patient (or $1,080 per program), the incremental cost increases to $1,847 per patient (Appendix 3).

Cost for Rehospitalization
Compared with no PR, if the cost of rehospitalization is greater than $7,000, outpatient hospital- or community-based PR results in cost savings; if the cost of rehospitalization is greater than $14,000, home-based PR results in cost savings.

Incremental Cost With Previous Hospitalized Acute Exacerbation
For patients with 1 or more previous hospitalizations for acute exacerbations of COPD, either outpatient hospital- or community-based PR or home-based PR can lead to cost savings (Appendix 4).

Probabilistic Sensitivity Analysis

The PSA showed that the mean (standard deviation [SD]) cost savings is $968 ($861) for outpatient hospital- or community-based PR versus usual care, and the probability of cost savings from outpatient hospital- or community-based PR is rather large, 0.88. The mean (SD) of the incremental cost is $898 ($858) for home-based PR versus usual care, and the probability of cost savings from home-based PR is 0.14. See Appendix 5 for the distribution plot of the incremental cost.

Budget Impact Analysis

A budget impact analysis was conducted from the perspective of the Ministry to estimate the cost burden in FY 2012–2013 and over the next 3 years for expanding PR to the entire target population of postdischarge COPD patients for an acute exacerbation. All costs are reported in 2014 Canadian dollars.

Research Methods

Affected Population

Using the most responsible diagnosis of COPD for adults 35 years and older based on ICES' cohort definition, the number of hospitalizations gradually increases over time, from 22,109 in FY 2009–2010 to 25,258 in FY 2012–2013. (4) It should be noted that the numbers would be about 50% higher if we used the expanded COPD diagnosis, which includes cases with pre-admission and postadmission comorbid diagnoses of COPD. Assuming an annual 3% increase in hospitalizations, we estimated the number of hospitalizations for the next 3 years. The expert advisory panel suggested that 65% of all hospitalized COPD patients would be eligible for PR. However, because the present aggregate data that were available to us did not include information on the number of unique patients for each year, the previous estimate that approximately 50% of hospitalizations are unique COPD patients who require PR was used (Table 8). (10)

Table 8: Target Population

Fiscal Year	Hospitalizations[a]	Target Patients[b]
2009–2010	22,109	11,055
2010–2011	23,946	11,973
2011–2012	23,949	11,975
2012–2013	25,258	12,629
2013–2014[c]	26,016	13,008
2014–2015[c]	26,796	13,398
2015–2016[c]	27,600	13,800

Abbreviations: COPD, chronic obstructive pulmonary disease; PR, pulmonary rehabilitation.
[a]The target population was COPD patients who have been discharged for an acute exacerbation (based on the most responsible diagnosis of COPD in hospital discharge data) and eligible for PR. This excluded stable COPD patients and patients with secondary diagnoses of COPD or the expanded definition of COPD in hospital discharge data.
[b]Assuming that about 50% of hospitalizations are unique COPD patients who require PR.
[c]Expected value: assuming annual 3% increase in hospitalizations.

Resources

The recent PATH PR survey (8) showed that 4,524 patients received PR annually in 14 Local Health Integration Networks (LHINs) in Ontario, including inpatient PR for 260 patients, outpatient PR for 3,280 patients, maintenance PR for 849 patients, and telehealth PR for 290 patients. The current capacity of outpatient hospital-, community-, and home-based PR programs is about 4,234 patients per year, excluding inpatient PR. We assumed that the entire PR capacity was used for our target population of postdischarge acute exacerbation COPD patients. Holding capacity constant, the (minimal) gaps between supply and demand were estimated (Table 9).

Table 9: Gaps Between Pulmonary Rehabilitation Supply and Demand for Postdischarge Acute Exacerbation of Chronic Obstructive Pulmonary Disease

Fiscal year	Capacity	(Minimum) Gaps
2012–2013	4,234	8,395
2013–2014	4,234	8,774
2014–2015	4,234	9,164
2015–2016	4,234	9,566

Expected Number of Additional Health Care Professionals Needed and Costs

The expert advisory panel estimated that 10% of the target population would receive home-based PR for various reasons, and the remaining patients would receive outpatient or community-based PR. We estimated the number of additional health care professionals needed to support the entire target population on the basis of the theoretical resource use of our standardized PR program and of empirical data from the recent Ontario PATH PR survey. (8)

Estimate Based on Theoretical Resource Use Data

We used the professional time per patient per PR program (Table 4) to calculate the total professional time required for each health care professional. The number of health care professionals were estimated using the ceiling function, as the total professional time in hours divided by the ideal service hours per year (i.e., Ceiling [43,680 ÷ 1,762.5] = 25). The main assumptions included the following:

- Health care professionals for selected core PR (e.g., RT, physiotherapist, and kinesiologist) services are interchangeable, within their home care group or their outpatient hospital or community care group.
- Health care professionals who provide additional support (general practitioner or respirologist, registered dietitian, occupational therapist, and administrative staff) are not interchangeable.
- The professional service time is 1,762.5 hours annually (1 full-time equivalent [FTE]).
- Professionals' entire working time is dedicated to PR services (i.e., no other non-PR activities are performed).

The total cost of hiring new health care professionals was estimated by the number of additional professionals multiplied by their annual cost (salary plus benefits).

Estimate Based on Empirical Data in Recent Survey

Twelve of 14 LHINs reported the number of professional FTEs and the number of patients treated annually. (8) The number of patients treated per FTE annually was estimated, without any differentiation between the types of PR programs. Variation in number of patients per FTE

annually was large, ranging from 10 (25 FTE for 260 patients) to 138 (3.36 FTE for 464 patients). Excluding the potential outlier with the lowest number of patients per FTE, there were 102.82 FTEs for 4,055 patients. The corresponding number of patients treated by the different types of PR programs was approximately 39 per FTE. The number of additional professionals required was calculated by the gap between supply and demand divided by 39 patients per FTE. The cost for hiring the additional professionals was also approximated.

Canadian Costs

Given the results of the cost-effectiveness analysis, we estimated the net budget impact under a couple of assumptions:

- Excluding inpatient PR, all other existing PR capacity (4,234 patients annually) was used to offer PR to the target population, and not for other indications (for simplicity, it is assumed that those patients do not have net budget impact).
- The expanded PR capacity covers the entire remaining target population.
- Ten percent of patients receive home-based PR and 90% of outpatient hospital- or community-based PR (sensitivity analysis: 20% of patients receive home PR; 80% of patients receive outpatient hospital or community PR).
- The annual net budget impact was estimated by considering both the cost of PR and the potential savings by reducing the risk of COPD-related rehospitalization.

Expansion of Current PR Capacity

The assumption that all part-time PR centres offer full-time PR services was the most realistic method of PR capacity expansion according to expert consultation. On the basis of the recent PATH PR survey, (8) we used the following formula to estimate the potential expanded capacity:

- Expected Additional Number of Patients Treated Annually = Reported Number of Patients Treated Annually × ([Total Number of PR Centres ÷ Number of FTE Centres] − 1)

  Number of FTE Centres = Number of Full-Time Centres + Sum of Weight of Service Time Out of Full-Time Service for Part-Time Centres
- An example: LHIN 2 (South West) has 1 full-time centre and 3 part-time centres (days of operation: 2 days, 2 days, and 4 days per week), and treated 115 patients annually.

  Estimated Number of FTE Centres = 2.6 (1 + 2/5 + 2/5+ 4/5)
  Expected Additional Number of Patients Treated Annually = 115 × (4/2.6 − 1) = 62

Results of Budget Impact Analysis

Expected Number of Additional Health Care Professionals Needed and Costs

Estimate Based on Theoretical Resource Use Data

Under the assumptions outlined in the methods section of the budget impact analysis, the expected number of additional health care professionals needed to support the entire target population is 100 full-time professionals (or 100 FTE), and associated costs are approximately $8 million (Cdn) for core PR services in FY 2012–2013 (Table 10). When considering support from other professionals (i.e., general practitioner or respirologist, registered dietitian, occupational therapist, and administrative staff), the total additional professionals and costs are 155 FTE and $15 million (Cdn) in FY 2012–2013 (Table 11). These costs assume 100% uptake in Year 1. Alternative rates of uptake could be considered, but the actual cost savings realized

would depend on the extent of the uptake. The breakdown of each type of professional needed is presented in Table 12.

Table 10: Additional Health Care Professionals Needed and Costs for Core PR Services to Support Entire Target Population in Ontario

Fiscal Year	Outpatient Hospital/ Community-Based PR		Home-Based PR		All (Core PR)	
	Target Patients	Professionals Needed	Target Patients	Professionals Needed	Total Professionals Needed	Cost (Salary Plus Benefit) $Cdn
2012–2013	7,555	75	840	25	100	7,885,576
2013–2014	7,897	79	877	26	105	8,290,624
2014–2015	8,248	82	916	28	110	8,851,762
2015–2016	8,609	86	957	29	115	9,100,721

Abbreviation: PR, pulmonary rehabilitation.

Table 11: Additional Health Care Professionals Needed and Costs for Core and Support Pulmonary Rehabilitation Services for Entire Target Population in Ontario

Fiscal Year	Support Professionals		Core and Support Professionals	
	Professionals	Cost ($Cdn Salary Plus Benefit)	Professionals	Cost ($Cdn Salary Plus Benefit)
2012–2013	55	7,247,112	155	15,132,688
2013–2014	59	7,848,650	164	16,139,274
2014–2015	60	7,905,940	170	16,757,702
2015–2016	64	8,507,478	179	17,608,199

Table 12: Breakdown of the Number of Additional Health Care Professionals Needed

Fiscal Year	RT	PT	RN	Kin	GP/Resp	RD	OT	Admin	Sum
2012–2013	33	61	5	3	11	11	11	22	157
2013–2014	34	64	6	3	12	12	12	23	166
2014–2015	36	67	6	3	12	12	12	24	172
2015–2016	37	70	6	3	13	13	13	25	180

Abbreviations: admin, administrative staff; GP, general practitioner; kin, kinesiologist; OT, occupational therapist; PT, physiotherapist; resp, respirologist; RD, registered dietitian; RN, registered nurse; RT, respiratory therapist.

Note: Since we defined the interchangeability for select PR health care professionals, the sum of the breakdown numbers for types of professionals required could differ slightly from the total number reported in Table 11. For example, if providers were not interchangeable, we would need 3 full-time RTs for 4,368 hours and 23 PTs for 39,312 hours (26 professionals in total) to offer home-based PR services per year. However, only 25 full-time RTs or PTs for the 43,680 (4,368 + 39,312) hours of service would be required when assuming RTs and PTs are interchangeable.

Estimate Based on Empirical Data in Recent Survey

Empirical data from the recent PATH PR survey (8) shows 1 FTE can offer PR services to approximately 39 patients per year. Thus, the expected number of additional professionals would be 213 to support 8,395 patients in FY 2012–2013, and the corresponding cost would be approximately $21 million (Cdn) (Table 13). Additionally, we estimated the breakdown number of the professionals needed, assuming that they are proportional to the types of professionals in the recent survey (Table 14). (8)

Table 13: Additional Health Care Professionals Needed and Costs, According to Data Reported From the PATH PR Survey

Fiscal Year	Target Patients	Additional Professionals	Estimated Cost ($Cdn)[a]
2012–2013	8,395	213	20,795,242
2013–2014	8,774	223	21,945,476
2014–2015	9,164	233	22,967,909
2015–2016	9,566	243	23,903,867

Source: Data reported from the PATH PR survey. (8)

Abbreviations: FTE, full-time equivalent; N, number; PATH, Programs for Assessment of Technology in Health; PR, pulmonary rehabilitation.

[a]Average cost per FTE is assumed to be same as that used for the theoretical data calculations. For example: Average cost per FTE in fiscal year 2012–2013 = $97,630 (15,132,688 ÷ 155).

Table 14: Types of Additional Health Care Professionals Needed, According to Data Reported From the PATH PR Survey

Fiscal Year	PT	RT	RN	Kin	Admin	RD	Other[a]
2012–2013	51	42	25	19	16	16	44
2013–2014	54	44	26	19	16	16	48
2014–2015	56	46	27	20	17	17	50
2015–2016	58	48	28	21	18	18	52

Source: Data reported from the PATH PR survey. (8)

Abbreviations: admin, administrative staff; kin, kinesiologist; PATH, Programs for Assessment of Technology in Health; PT, physiotherapist; RD, registered dietitian; RN, registered nurse; RT, respiratory therapist.

[a]Other professionals can include physiotherapy/occupational therapy assistant, social worker, pharmacist, occupational therapist, respirologist, etc.

Canadian Costs

According to the cost-effectiveness analysis, outpatient hospital- or community-based PR leads to substantial cost savings, while home-based PR is associated with higher costs, relative to usual care. Given 90% of target patients were assumed to receive outpatient hospital or community PR, the results of the budget impact analysis are largely determined by the outpatient hospital or community PR strategy. It was estimated that implementation of PR for the entire target population would lead to theoretical cost savings of $7.7 million (Cdn) in FY 2012–2013 (Table 15). When assuming 20% of the target population receives home-based PR, the theoretical cost savings are reduced to $6.1 million (Cdn) in FY 2012–2013. It is unclear whether these savings can be achieved in reality, as the potential health care resource savings could be reallocated to other patients in the Ontario health care system.

Table 15: Annual Net Budget Impact

Fiscal Year	Outpatient Hospital/Community-Based PR		Home-Based PR		All PR
	Target Patients	Budget Impact ($Cdn)	Target Patients	Budget Impact ($Cdn)	Budget Impact ($Cdn)
2012–2013	7,555	−8,294,696	840	642,753	−7,651,942
2013–2014	7,897	−8,670,180	877	671,065	−7,999,115
2014–2015	8,248	−9,055,546	916	700,907	−8,354,639
2015–2016	8,609	−9,451,891	957	732,280	−8,719,611

Expansion of Current PR Capacity

Assuming that all part-time PR centres offer full-time services, the potential expanded PR capacity is approximately 1,454 patients annually.

Limitations

Additional Benefits of PR

While PR can reduce health care use for COPD-related rehospitalizations, this economic evaluation could not capture all the clinical benefits of PR, such as improvements in disease symptoms, exercise capacity, functional status, health-related quality of life, and mortality. Through comprehensive PR programs that include psychological and behavioural interventions, PR can lead to lifestyle modifications that can be maintained for longer than the exercise capacity and functional status gains from the program. Thus, if patients modify their behaviour and attitudes through education and better self-management of their disease, these gains can extend past the model's follow-up period of 1 year. While emergency department visits were not considered as an outcome given the limited evidence, better management and education through PR could also reduce the number of moderate exacerbations that otherwise would present to the emergency department. In addition, the clinical effectiveness of PR could reduce other nonhospital health care visits or resource use (e.g., primary care visits) that could not be accounted for in this economic model.

Additional Costs

This economic evaluation was from a narrow perspective of the Ontario health care system in the form of hospital rehospitalization costs; the true cost savings of PR could be lower. Other costs that could have resulted in the underestimation of PR costs include the following:

- *Capital investment costs*: Given the lack of data, capital depreciation per visit and overhead costs were not considered. The standard operating costs for offering a PR program in an outpatient hospital or community setting vary and can be considerable. Given that only health care professional time and transportation cost of PR program costs were considered, the difference in costs between outpatient hospital and community programs could not be determined. Community programs likely have more limited resources than outpatient hospital programs (28) and could also be less costly.
- *Equipment and material costs*: Only 1 PR study estimated the amount of equipment costs per patient per session for PR, which were found to be negligible (22). These costs were therefore excluded in our analyses; however, equipment costs in practice would have to be considered for facilities that have PR programs, and home PR patients would have to either rent or purchase equipment themselves to participate in the exercise training component of PR. The cost of the supporting materials required for PR programs were also not included.
- *Family or caregiver burden and out-of-pocket expenses*: While transportation costs for health care professionals were considered for home PR, patients who travel to outpatient hospital or community PR would have to pay out-of-pocket transportation expenses, which were also excluded within this model. Family or caregiver burden for supporting these patients to attend PR also could not be captured.

Economic Analysis

We could have underestimated the cost of health care professionals, because their average salary in Ontario is often higher than the average of the minimum and maximum salary due to a large proportion of senior staff. We assumed that 50% of annual COPD hospitalizations were unique COPD patients who were eligible for PR. In reality, this could differ. Also, the ideal composition between PR programs is unknown and multifactorial. Our assumption of 90% need

for outpatient hospital or community PR and 10% need for home PR was based on expert consultation.

Empirical data from the PATH PR survey captured approximately 90% of the PR centres in Ontario. (8) Although other Ontario PR programs exist, information about them was unavailable. Consequently, empirical data could have overestimated the demand if additional programs are available to support COPD patients.

Only 1-year follow-up was considered; in reality, the benefits of PR might be sustained for more or less than 1 year. The quality-adjusted life year was not used as an outcome measure, which made determination of cost-effectiveness difficult. In addition, these cost savings are assumed to be realized. In practice health care professionals might not be able to dedicate their entire time to PR services and might not be divisible in time or interchangeable between multiple programs because of geographic location and other constraints. Our current need for additional health care professionals indicates a possible shortage of adequately educated and trained staff to support the required expansion within Ontario. Patient referral, rolling enrolment, dropout, and withdrawal would also affect the number of patients that PR programs are able to support.

Discussion

There are some strengths of this economic evaluation. First, a practical standardized PR program was proposed and resource use quantified, which can be adapted to other settings. Further, we estimated the effectiveness of PR on the basis of 3 RCTs, without using external data to ensure the internal validity of our findings. Comprehensive sensitivity analyses were also conducted to address the uncertainties of the results, which could help other groups approximate the cost-effectiveness of the PR program of interest.

Canadian Thoracic Society guidelines for PR recommend PR programs for both stable moderate to severe COPD patients and those who have been discharged from a hospitalized acute exacerbation. (7) However, the current total PR capacity is very low, at less than 2% for all COPD patients (stable moderate to severe, and postacute exacerbation) in Ontario, and it is difficult to prioritize patients. Treating higher-risk patients is generally associated with greater absolute health benefits and is often more cost-effective than treating the average population. Compared with stable COPD patients, postdischarge COPD patients have an increased risk of subsequent COPD-related rehospitalizations. (29) Fortunately, recent hospitalization has been considered the most common indicator for PR prioritization in Ontario. (8)

We assumed equal duration and intensity between the 3 PR settings. However, current home PR programs are limited in the number of visits provided and duration, so this assumption might not reflect current practice. A home care physiotherapist or RT might visit the home and provide education and exercise for a patient, but this individualized visit is unlikely to be the same duration as a session in a centre-based program. The CTS PR guidelines recommend a minimal duration of 6 to 8 weeks, but do not mention the possibility that duration will vary between settings. Clinical evidence suggests that longer-duration PR programs are often associated with greater health benefits. (18) Thus, considering the shorter duration for home-based PR that is common in practice, effectiveness compared with outpatient hospital- and community-based PR would be reduced. This finding could be potentially misleading, as the difference in effectiveness for home PR is not driven by the setting, but rather by duration and intensity of PR services provided.

Another assumption was that no patients died within 1-year follow-up, given that patients who are too ill might not even be eligible for PR. Current small RCTs lack reliable data on the mortality rate of this target population, making mortality estimation difficult. Additional assumptions would have to be made if accounting for mortality, creating more uncertainty in the model. For example, there would be no rehospitalization cost if mortality occurs before a COPD-related rehospitalization because mortality and rehospitalization would be competing risk events in the model. Similarly, if death occurs during the PR program, only the cost of the completed PR portion would be considered for the patient. Thus, for simplicity, the economic model addresses relatively healthy patients expected to live more than 1 year postdischarge for an acute exacerbation.

Our economic model also does not address several issues. Exercise equipment available within the home can also be limited because it would have to be either rented or purchased by the patient as out-of-pocket expenses and likely would not be as comprehensive or advanced as that offered in a centre-based program. Home-based PR also lacks the psychosocial support and social connectedness that can be provided only in a group setting. While our economic analysis assumed fully supervised PR programs in all 3 settings for safety reasons, additional unsupervised exercise (such as walking) can be performed by patients in parallel with a formal supervised PR program. While there is no associated cost for unsupervised exercise, it can provide additional clinical benefits for the patient and is often recommended to increase the level of physical activity.

According to the recent survey by PATH, most PR programs are outpatient hospital-based, 29 (67%) of a total 43 reported PR sites in Ontario. Only 8 (19%) and 6 (14%) of PR programs are offered by family health teams and community health centres, respectively. (8) This limits patients' access to PR programs; alternative locations, such as community and home programs, would increase access. However, because outpatient PR programs are attached to hospitals, they have more direct access to specialized respiratory services and additional health care groups than community PR or home programs might have.

A systematic review from Australia found that access to transport is one of the key barriers to attending and completing PR. (30) Community health centres are often located in residential areas, which can reduce travel distance. Although not quantified in our economic analysis, community PR programs are likely less expensive than outpatient hospital-based programs if capital investments (such as building and equipment costs) are also considered. (28)

Home-based PR can be provided for select patients who cannot access centre-based PR programs because of potential barriers (e.g., geographical remoteness, unavailability or inability to afford transportation, cognitive impairment, language). Home-based PR services can be consolidated under the role of a single health care professional with expertise in PR. While PR location is mutually exclusive in the economic model, in reality home PR can act as a transition bridge to centre-based PR in Ontario; for example, for patients waiting for centre-based PR or those not yet able to engage in a vigorous program who would benefit from some preparation. Thus, the cost of the combined PR program can be estimated by weighting the proportion of each type of PR based on location. Although home-based PR does not offer any economic advantages and is associated with intensive resource use, PR in different settings is not competitive, but complementary. Each location is able to address specific patients' needs.

Another alternative setting for PR that was not included in this analysis was inpatient PR. Because inpatient PR and outpatient or community PR are likely to serve patients with various disease severities and comorbidity, it was inappropriate to compare them directly. Patients with

multiple comorbidities could be too unwell or complex to attend or complete outpatient hospital or community PR and could instead benefit from inpatient PR. Inpatient PR can also serve as a complementary setting, as impaired COPD patients are most likely to be found among the postdischarge population, and increased access to multidisciplinary teams for treatment in an inpatient setting would be beneficial. Just as home PR can be a transitional bridge to outpatient hospital or community PR, complex patients can ideally transition to an outpatient hospital PR program to access additional health care and psychosocial support.

Realizing and sustaining the benefits of PR relies on long-term behaviour changes (e.g., smoking cessation, physical activity) that are initiated during the program. It is well documented that physical and quality of life improvements that arise from PR diminish over the course of a year, (31) and it cannot be assumed that a single PR program will pervasively alter decades of behavioural patterns. Evidence for the effectiveness of both maintenance PR programs (e.g., exercise with or without education or psychological components) or supervised exercise programs after PR to maintain benefits is weak. (9) However, attitudinal and behavioural change requires long-term and ongoing support (32) that falls outside the capability of a 1-year PR program and thus was not assessed.

Although this economic model was not able to capture all the important features of each PR program setting nor to optimize PR resource allocation, it suggests that generally outpatient hospital- or community-based PR can be regarded as a cost-effective PR strategy and can be recommended for most target patients. Outpatient hospital PR could be more appropriate for patients with more severe COPD because of the increased access to additional health care groups, and inpatient PR could be a complementary setting for very complex COPD patients; home PR could be more appropriate for COPD patients with accessibility issues and serve as a transitional bridge to centre-based (outpatient hospital or community) PR.

CONCLUSIONS

- Pulmonary rehabilitation (PR) in any setting can significantly reduce chronic obstructive pulmonary disease (COPD)-related rehospitalization and its associated costs. Centre-based pulmonary rehabilitation is preferred for access to exercise equipment and psychosocial peer support. The cost of outpatient hospital- or community-based PR is about 50% that of home-based PR. Outpatient hospital- or community-based PR dominates usual care (i.e., no PR), with lower costs and reduced number of hospitalizations, while home-based PR is associated with higher costs than usual care.
- An estimated 155 (based on theoretical resource use data) or 213 (based on empirical data) additional health care professionals are needed to deliver PR services to the entire target population in Ontario of patients postdischarge for an acute exacerbation of COPD in fiscal year 2012–2013. When considering both the costs of the PR program and rehospitalization costs avoided, the potential cost savings are approximately $7.7 million (Cdn) annually for the target COPD population in Ontario, assuming 100% PR uptake in the first year. However, how much can actually be saved depends largely on the expansion of current PR capacity.

RECOMMENDATIONS

Note: These recommendations apply to COPD patients after hospitalization for an acute exacerbation, and not for patients with stable moderate to severe COPD.

- The Ontario Health Technology Advisory Committee reaffirms the recommendation of the use of PR in COPD patients after an acute exacerbation (within 1–4 weeks of discharge).
- Further, based on the PATH PR field evaluation study, OHTAC recommends increased availability of resources for PR following discharge for patients who have had an acute exacerbation of COPD.
- Outpatient hospital- or community-based PR is preferred for the following:
  - accessibility of equipment for exercise
  - additional group-based psychosocial support
  - lower cost than home-based PR
- However, home-based PR could be recommended for select patients with barriers to accessing centre-based PR programs, or as a transitional bridge to outpatient hospital- or community-based PR.

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APPENDICES

Appendix 1: COPD-Related Rehospitalization for Patients Hospitalized for an Acute Exacerbation

Data Source	COPD-Related Rehospitalization Rate
Behnke et al, 2003 (13)	0.67/patient-year For the 12 patients in the control arm, 9 patients had 12 COPD-related readmissions within 18 months
Eaton et al, 2009 (16)	2.0/patient-year For the 50 patients in the control arm, 16 patients had 25 COPD-related readmissions within 3 months
Seymour et al, 2010 (14)	≥ 1.33/patient-year For the 30 patients in the control arm, 10 patients had COPD-related readmissions (did not report the number of readmissions) within 3 months
Suissa et al, 2012 (33)	COPD-related readmissions: 0.38/patient-year
CIHI, 2013 (34)	All readmissions: 18.8% in 30 days, of those 56.3% for COPD
Jencks et al, 2009 (35)	All readmissions: 22.6% in 30 days, of those 36.2% for COPD
Kawasumi et al, 2013 (36)	COPD-related readmissions: 0.35–0.36/patient-year
Moullec et al, 2012 (37)	COPD-related readmissions: 1.3–1.5/patient-year
Elixhauser et al, 2011 (38)	Readmissions with COPD as the main diagnosis: 7.1% in 30 days Readmissions with COPD as any diagnosis: 17.3% in 30 days All readmissions: 20.5% in 30 days
Dewan et al 2011 (39)	COPD-related admissions: 0.4/patient-year; all readmissions: 1.7/patient-year
Estimate in our model	Average COPD-related readmission per patient-year: 0.4 (range: 0.3–0.5)

Abbreviations: CI, confidence interval; CIHI, Canadian Institute for Health Information; COPD, chronic obstructive pulmonary disease.

Appendix 2: Probability of COPD-Related Rehospitalizations for PR and Usual Care Strategies in 1 Year

Poisson distribution

$$P = \frac{e^{-\mu} * \mu^{d}}{\mathrm{d!}}$$

P: probability of d occurrences
μ: mean number of occurrences in a given period
d: number of occurrences

Number of Occurrences	Usual Care[a]	Pulmonary Rehabilitation (Any Setting)[b]
0	0.670320046	0.865769091
1	0.268128018	0.124789398
2	0.053625604	0.008993388
3	0.007150080	<0.001
4	<0.001	<0.001

Abbreviations: COPD, chronic obstructive pulmonary disease; PR, pulmonary rehabilitation.
[a]μ in usual care = 0.40.
[b]μ in PR in any setting = 0.14.

Appendix 3: Incremental Cost, When Considering Additional Costs of PR

Table 3A: Incremental Cost, When Considering Additional Costs of PR

Total Additional Cost per Patient per Session ($Cdn)	Additional Cost per Patient per Program ($Cdn)	Incremental Cost vs. Usual Care ($Cdn)
Outpatient Hospital- or Community-Based PR (27 Sessions)		
0	0	−1,096
5	135	−961
10	270	−826
15	405	−691
20	540	−556
25	675	−421
30	810	−286
35	945	−151
40	1,080	−16
45	1,215	119
50	1,350	254
Home-Based PR (24 Sessions)		
0	0	767
5	120	887
10	240	1,007
15	360	1,127
20	480	1,247
25	600	1,367
30	720	1,487
35	840	1,607
40	960	1,727
45	1,080	1,847
50	1,200	1,967

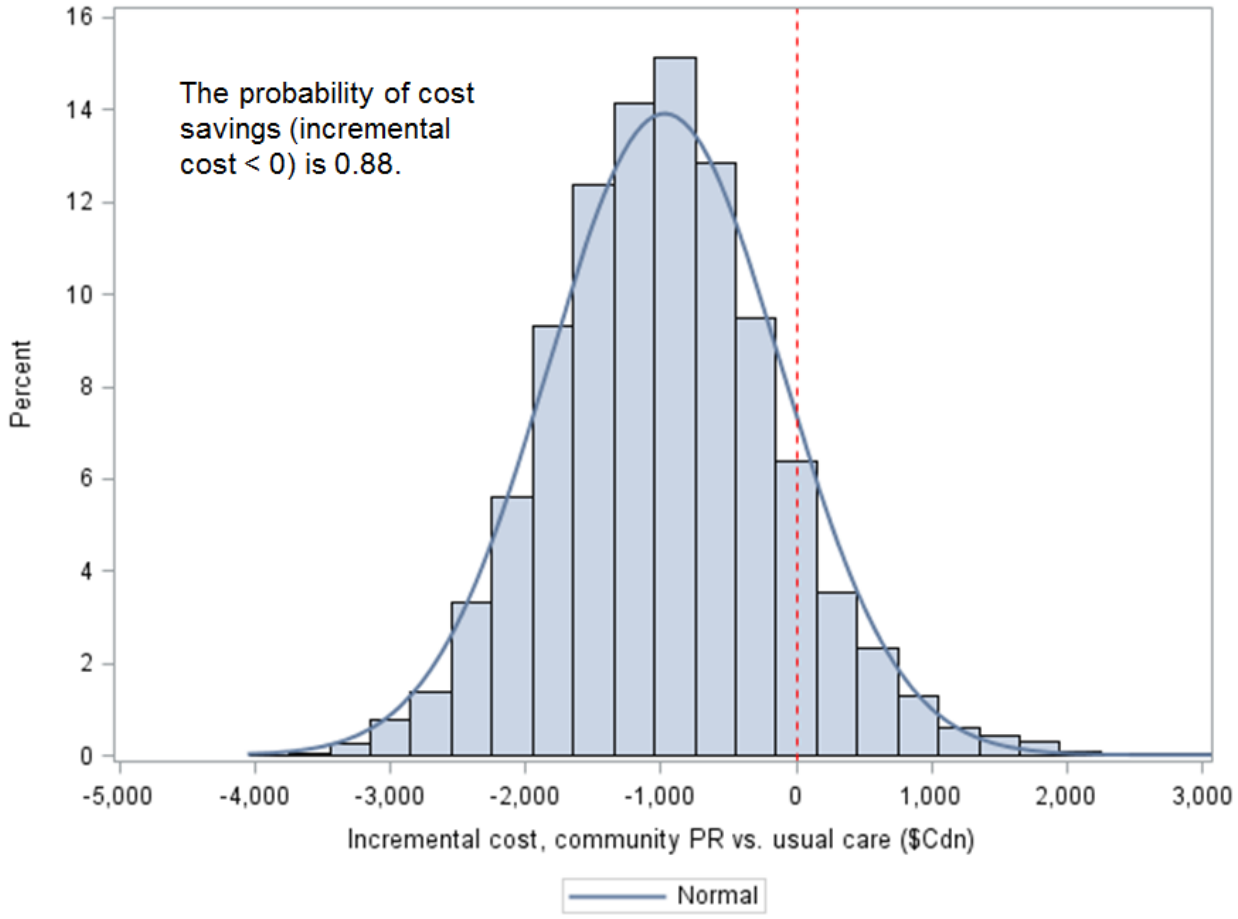
Abbreviation: PR, pulmonary rehabilitation.

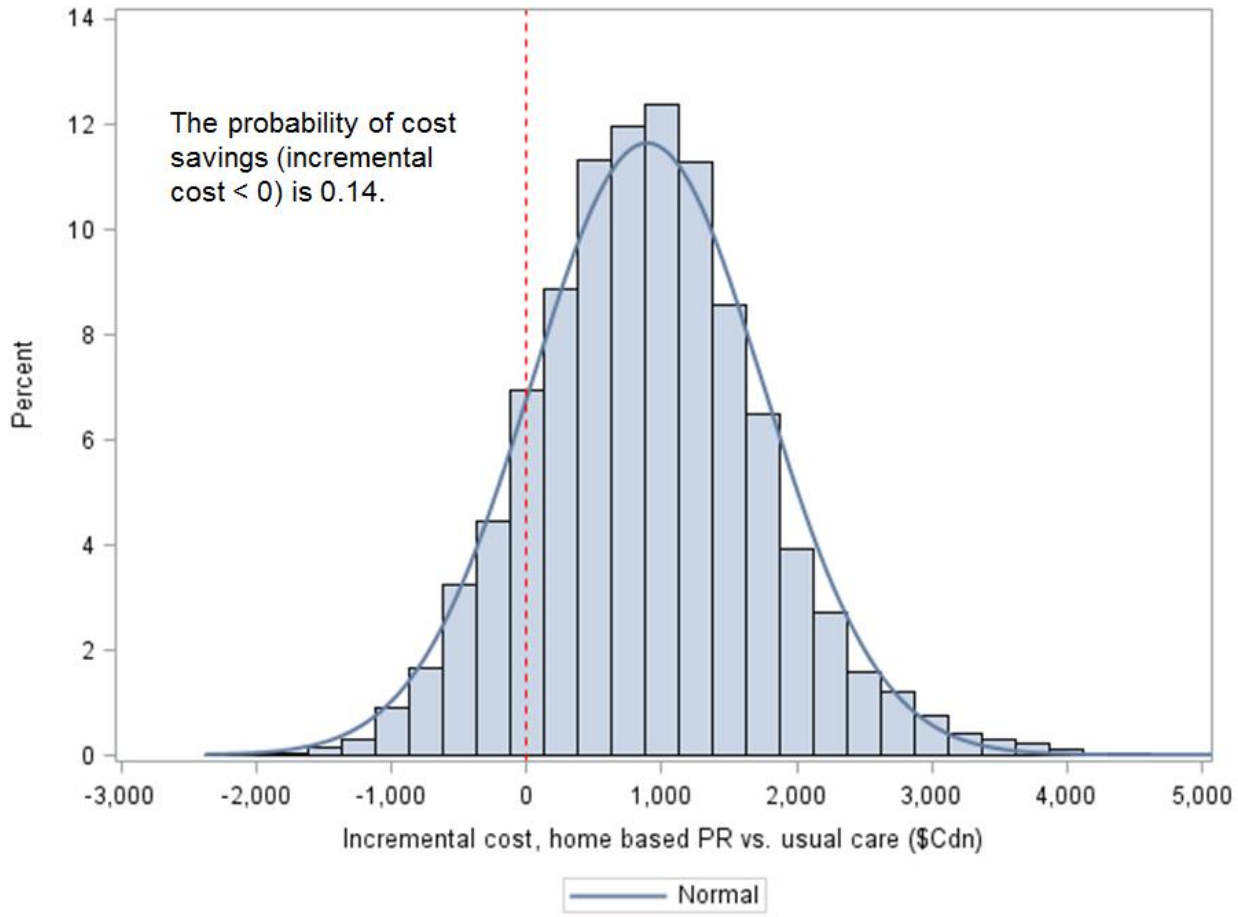
Appendix 4: Incremental Cost for Patients With Previous Hospitalizations for Acute Exacerbations of COPD

Exacerbation Sequence Number	Median Time to Subsequent Exacerbation (Y)[a]	Expected Event (N/Y[b])	Outpatient Hospital- or Community-Based PR ($Cdn)	Home-Based PR ($Cdn)
1	5.4	0.19	370	1,873
2	1.6	0.63	-2,633	-1,130
3	0.9	1.11	-5,952	-4,449
4	0.7	1.43	-8,119	-6,616
5	0.5	2.00	-12,021	-10,517
6	0.4	2.50	-15,434	-13,931
7	0.3	3.33	-21,124	-19,621
8	0.3	3.33	-21,124	-19,621
9	0.3	3.33	-21,124	-19,621
≥10	0.2	5.00	-32,503	-31,000

Abbreviations: N, number; PR, pulmonary rehabilitation; y, year.
[a]Estimates for time to subsequent exacerbation extracted from Suissa et al., 2012 **(33)**
[b]We approximated the rehospitalization rate as 1 divided by the median time to subsequent hospitalization.

Appendix 5: Distribution of Incremental Cost, Outpatient Hospital- or Community-Based PR and Home-Based PR Versus Usual Care




The probability of cost savings (incremental cost < 0) is 0.14.
Percent
14
12
10
8
6
4
2
0
-3,000
-2,000
-1,000
0
1,000
2,000
3,000
4,000
5,000
Incremental cost, home based PR vs. usual care ($Cdn)
Normal

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