Original Article

Evaluation of a disease management program for COPD using propensity matched control group

Pradeep Paul George[1], Bee Hoon Heng[1], Tow Keang Lim[2], John Abisheganaden[3], Alan Wei Keong Ng[3], Akash Verma[3], Fong Seng Lim[4,5]

[1]Health Services & Outcomes Research (HSOR), National Healthcare Group HQ, Singapore; [2]Division of Respiratory and Critical Care Medicine, National University Hospital, Singapore; [3]Department of Respiratory and Critical Care Medicine, Tan Tock Seng Hospital, Singapore; [4]Disease Management, National Healthcare Group, Singapore; [5]National Healthcare Group Polyclinics, Singapore

Contributions: (I) Conception and design: PP George, BH Heng, J Abisheganaden; (II) Administrative support: A Verma, AW Ng; (III) Provision of study materials or patients: PP George, BH Heng, FS Lim, TK Lim; (IV) Collection and assembly of data: PP George, BH Heng, J Abisheganaden; (V) Data analysis and interpretation: PP George, TK Lim, J Abisheganaden, A Verma, FS Lim, AW Ng; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Akash Verma, MRCP. Department of Respiratory and Critical Care Medicine, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng 308433, Singapore. Email: Akash_Verma@ttsh.com.sg.

Background: Disease management programs (DMPs) have proliferated recently as a means of improving the quality and efficiency of care for patients with chronic illness. These programs include education about disease, optimization of evidence-based medications, information and support from case managers, and institution of self-management principles. Chronic obstructive pulmonary disease (COPD) is a major cause of morbidity and mortality in Singapore and worldwide. DMP aims to reduce mortality, hospitalizations, and average length of stay in such patients. This study assesses the outcomes of the DMP, comparing the propensity score matched DMP patients with controls.

Methods: DMP patients were compared with the controls, who were COPD patients fulfilling the DMP's inclusion criteria but not included in the program. Control patients were identified from Operations Data Store (ODS) database. The outcomes of interest were average length of stay, number of days admitted to hospital per 100 person days, readmission, and mortality rates per person year. The risk of death and readmission was estimated using Cox, and competing risk regression respectively. Propensity score was estimated to identify the predictors of DMP enrolment. DMP patients and controls were matched on their propensity score.

Results: There were 170 matched DMP patients and control patients having 287 and 207 hospitalizations respectively. Program patient had lower mortality than the controls (0.12 *vs.* 0.27 per person year); cumulative 1-year survival was 91% among program patient and 76% among the control patients. Readmission, and hospital days per 100 person-days was higher for the program patients (0.36 *vs.* 0.17 per person year), and (2.19 *vs.* 1.88 per person year) respectively.

Conclusions: Participation in "DMP" was associated with lower all-cause mortality when compared to the controls. This survival gain in the program patients was paradoxically associated with an increase in readmission rate and total hospital days.

Keywords: Pulmonary disease; chronic obstructive; disease management program (DMP); case management; mortality; readmission

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Introduction

Chronic obstructive pulmonary disease (COPD) is a growing health concern causing chronic morbidity and mortality worldwide (1). The prevalence of moderate to severe COPD in Singapore is estimated at 2.3% (2), or absolute number of 87,819 patients in the community. These patients have frequent hospital admissions (3), and emergency department attendances (4), costing the country about US$128 million a year (5). In 2010, COPD was ranked as the seventh leading cause of death and hospitalization in Singapore, accounting for 2.5% of total deaths and more than 10,000 admissions (6). These numbers are expected to grow with increasing prevalence of smoking, thus burdening health care services in Singapore (7).

Disease management programs (DMPs) have proliferated recently as a means of improving the quality and efficiency of care for patients with chronic illness (8). These programs include education about disease, optimization of evidence-based medications, information and support from case managers, and institution of self-management principles (9). Evidence exists on successful implementation of DMPs for chronic conditions such as COPD, heart failure and diabetes mellitus (10). However, with the introduction of DMP against a background of resource constraints in the healthcare sector, policymakers, healthcare managers, planners and funders increasingly want to know if implementing such approaches improve the quality and reducing the cost of healthcare, and, ultimately, improving health outcomes for the chronically ill.

Evaluation of healthcare programs and interventions has become an important component of decision making on the (public) funding of new health technologies and wider dissemination of proven health interventions. The randomized controlled trial is considered the gold-standard research and program evaluation design (11,12); however, randomized control trial (RCT) design may not be suitable for many research endeavours unless the study is conducted in a tightly controlled environment. Disease management (DM) by its very nature is population based and, thus cannot be tightly controlled. The most common method currently used in DM evaluation is referred to as a "total population approach" (13), a pre-test/post-test design which is a relatively weak research and evaluation technique (14-16). The most basic limitation of this design is that there is no randomized control group for which comparisons of outcomes can be made, thereby allowing several sources of bias and/or competing extraneous confounding factors to offer plausible alternative explanations from any change from baseline (13-16).

DM programs currently do not use randomized control groups under the belief that: (I) it would be costly and difficult to track behavioural change longitudinally and outcomes for a group not under their purview; (II) the organization may be hesitant to offer services to one subset of the population while withholding that same "value added" benefit to others; and (III) there is a need to treat all members with the disease (if these interventions are indeed clinically effective) because each member receiving the intervention has the potential of adding to the medical cost savings and positive clinical outcomes promised by the program. With these concerns in mind, we have considered an alternative approach, "propensity scoring", which utilizes existing data sources to create randomly matched controls, which are conditional on having an adequate set of observable characteristics for both DMP participants and non-participants (17).

The National Healthcare Group's (NHG) DMP for COPD was started in April 2008 to optimize resources for better management of patients afflicted with COPD and community acquired pneumonia (CAP) based on patient severity. The purpose of this study is to compare the outcomes of COPD patients enrolled in "DMP" with propensity matched controls who are not enrolled in the program.

Methods

Study design

This is a retrospective propensity matched cohort study comparing COPD patients (Diagnosis Related Group, DRG 177) who were enrolled in a DMP with controls who are COPD patients (DRG 177) who fulfilled the DMP enrolment criteria but were not enrolled (*Figure 1*). A control group was identified from Operations Data Store (ODS), they were COPD patients (DRG 177; ICD 490, 491, 492, 496) who fulfilled the DMP's inclusion criteria but were not enrolled in the DMP. DMP patients were identified from Central Clinical Research Database (CCRD). The studies on "Disease management" are exempted from IRB approval (NHG DSRB) in our institutions; hence ethics approval was not obtained for this study.

Hospitalizations and mortality in these patients were tracked from April 2008 to December 2009. Follow up time was from the first admission date to censor date (31 Dec 2009) or date of death and expressed as person years (PY). The outcomes of interest were average length

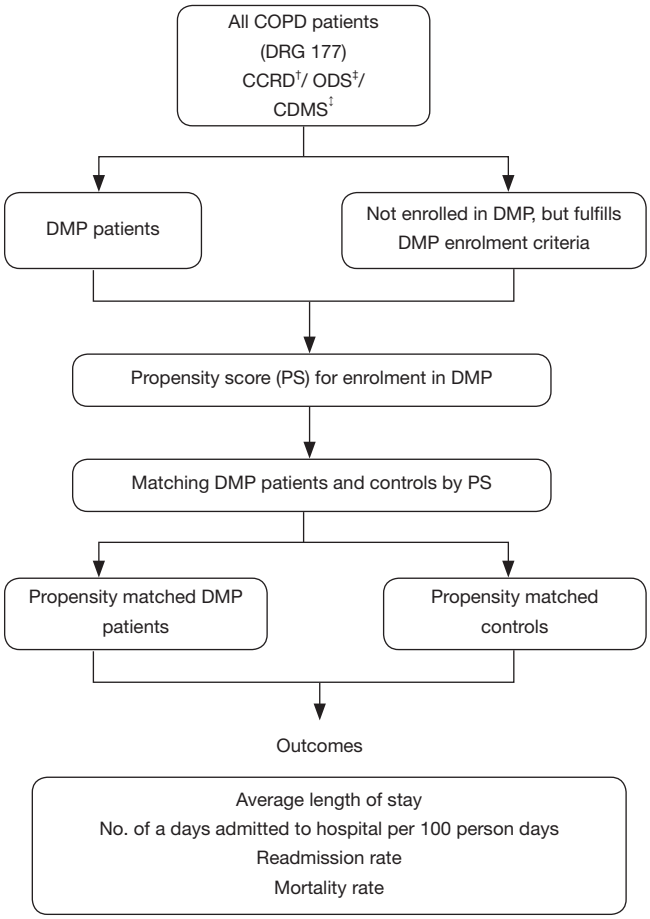

Figure 1 Disease management program for COPD—evaluation schema. †, Central Clinical Research Database; ‡, Operation Data Store; ‡, Chronic Disease Management System.

of stay, number of days admitted to hospital per 100 person days, readmission and mortality rates per person year. Index admissions were the starting point for analysing repeat hospital visits. Readmissions were defined as any admission from the index admission. The 30-day readmissions include any admission within the 30-day window from the date of discharge of index admission.

Primary endpoints and data sources

The primary end points included all-cause mortality, mortality due to respiratory diseases (ICD-9 CM: 460–519), readmissions due to COPD (DRG 177; ICD 490, 491, 492, 496). Death data were obtained from Epidemiology and Disease Control division, Ministry of Health (MOH), Singapore. Hospitalization data for DMP patients and controls were obtained from CCRD and ODS administrative databases, respectively. Co-morbidity data was extracted from the Chronic Disease Management System (CDMS). Patients with hospitalization after enrolment/refusal were analysed.

Disease management program (DMP)

Disease management program (DMP) multi-disciplinary team

DMP consists of a core group of respiratory case managers who coordinate COPD care; they work collaboratively with the respiratory physicians, ED physicians and general practitioners to manage both conditions across the continuum. DMP follows the long accepted principles of chronic DM such as stratification of patients by the acuity of disease, evidence-based algorithms, fast track protocols to specialist outpatient clinics (SOCs), team-based approach, and self-management.

Disease management program (DMP) core components

Besides the conventional COPD care which included pharmacological interventions, a comprehensive, individualized patient education for self-management of COPD is conducted to prevent exacerbations, to reduce unnecessary re-admissions and to improve quality of life. Telephonic case management is done for all patients to ensure compliance to clinic appointments (usually 3–4 months), medications and thereby treatment optimization. The home care plan is provided for selected patients during their post-discharge period. For patients who are stable and are capable of self-management, the case manager will call the patients once every 2 months. Patients who are discharged after an acute exacerbation of COPD were monitored more closely with telephone calls once a week. Smoking cessation, rehabilitation and vaccination programs were enhanced for DMP patients. Control patients had conventional pharmacological interventions.

Disease management program (DMP) inclusion and exclusion criteria

Inclusion criteria for DMP were patients with definite COPD [forced expiratory volume in 1 second (FEV_1)/forced volume capacity (FVC) <70%] or possible COPD based on clinical judgment, patients should be willing to participate in the program, comply with telephonic case management and medical instructions, willing to attend a smoking cessation counselling program and attempt to

quit smoking. Patients who do not fulfill the diagnosis of COPD, patients with complicated medical conditions (e.g., advanced malignancy); patients who are clinically unstable requiring mechanical ventilation, intensive care support, patients with cognitive, psychiatric disorders were excluded from DMP.

Disease management program (DMP) recruitment

At the emergency department all diagnosed COPD patients are evaluated for clinical severity, high risk and intermediate risk patients are hospitalized, while low risk patients are evaluated for home care and given an outpatient appointment in 2 weeks, a telephone contact and a home visit, where appropriate follow. If the home care plan fails, the patient is transferred back to the hospital.

Principles of propensity scoring

In general, DMPs provide high-intensity interventions (such as telephonic nurse/education services) to only a small number of participants out of a much larger population of patients with similar disease. Matched sampling techniques attempt to choose members from the untreated population so that they are similar to the program participants with respect to one or more pre-program variables. Controlling for differences in pre-intervention characteristics is extremely important in DMP because program participants are typically dissimilar to non-participants (as a rule, DM program strives to enrol those individuals at the highest risk for incurring higher costs or higher healthcare utilization during the program term, thereby creating an unbalanced case mix between enrolled and non-enrolled groups. The propensity score, defined as the probability of assignment to the treatment group, conditional on covariates (i.e., independent variables) (18), can control for pre-intervention differences between the enrolled and non-enrolled groups, with the underlying assumption that DMP is associated with observable pre-program variables (e.g., age, sex, utilization, and cost) (19,20). Propensity scores are derived from a logistic regression equation, which reduced each participant's set of covariates into a single score, making it feasible to match on what are essentially multiple variables simultaneously (16).

Estimation of propensity scores and matching

We used propensity score matching to adjust for differences in baseline characteristics between DMP patients and controls (21,22). Propensity scores for DMP enrolment using a non-parsimonious multivariable logistic regression model which included the following variables, age, gender, race, hospital, Socio-economic status, comorbidities: presence of asthma, diabetes mellitus, hypertension, stroke, coronary heart disease, heart failure, dyslipidaemia and obesity. Ward class was used as a surrogate for socio-economic status (SES). Our propensity score model discriminated well between DMP patients and controls. (C-statistic =0.79). We then used the propensity score to match each DMP patient to a control, who had a similar propensity score using nearest neighbour without the replacement matching algorithm, thus matching 171 DMP patients to 171 controls.

Statistical analysis

Demographic, health care utilization characteristics were assessed as counts and percentages for categorical variables, and as standard measures (mean and SD) for continuous variables. We used Chi-square tests, independent sample *t*-tests and paired *t*-tests, as appropriate, for descriptive analysis to compare baseline characteristics between pre-match DMP patients and controls. For descriptive analysis of post-match cohorts, McNemar tests were used. Adequacy of matching was assessed using P values for comparison tests and standardized percentage differences (21,22).

Mortality and readmission rates were calculated by dividing the number of events during follow-up by the corresponding PY at risk. All rates were presented as number of events per PY with corresponding 95% confidence intervals (CI). We used Kaplan-Meier survival analyses, matched Cox proportional hazards model and competing risk regression (23,24), to estimate the associations between mortality, morbidity (hospitalizations and visits), and participation in DMP. We confirmed proportional hazards assumption by a visual examination of the log (minus log) curves. All significance tests were two-tailed and data analyses were performed with the STATA 11.2 software (StataCorp, College Station, TX).

Results

Overall there were 334 DMP and 893 control patients with 488 and 1,227 hospitalizations respectively. Median follow up period was 0.99 & 0.66 years for DMP and control patients respectively. Total PYs of follow-up was higher for controls (739 PY) when compared to DMP

Table 1 Overall demographic characteristics of the patients before and after PS matching

Characteristics	Before PS matching		After PS matching	
	DMP patients (n=309)	Controls (n=893)	DMP patients (n=170)	Controls (n=170)
Age (mean ± SD) (years)	72.9±8.9†	72.3±10.3†	72.6±9.7†	72.7±8.4†
Males (%)	89.0‡	82.1‡	88.2	88.2
Race (%)				
Chinese	76.4	74.4	78.8	78.2
Malay	13.3	16.1	11.8	14.7
Indians	7.1	6.7	6.5	7.1
Hospital (%)				
X	9.1‡	13.3‡	10.6	10.6
Y	43.0‡	19.5‡	62.9	58.8
Z	47.6‡	67.2‡	26.5	30.6
Socio-economic status (%)				
A	1.3‡	1.6‡	1.8	1.8
B	21.4‡	35.6‡	35.3	38.2
C	41.4‡	61.3‡	56.5	53.5
Co-morbidities (%)				
Asthma	36.6	32.9	36.6	31.8
DM	29.4	30.1	29.4	24.1
HT	48.9	56.3	48.9	48.2
Stroke	10.4	11.6	10.4	10.0
CHD	34.0	28.4	34.0	30.0
HF	16.8	20.9	16.8	17.1
Dyslipidemia	59.5	61.4	59.5	61.8
Obesity	33.3	24.6	33.3	27.1

Comparisons were made using *t*-test† and unless noted, Z test for proportions. ‡, significant, unless noted, not significant. Socio-economic status A, B, C represent ward class A, B and C respectively. PS, propensity score.

patients (269 PY).

Demographic and admission characteristics

Table 1 summarizes the demographic characteristics of all patients. There were significant differences between DMP patients and controls in gender, hospitals and SES categories (*Table 1*). DMP patients had significantly shorter length of stay at the hospital, lower percentage of all-cause deaths and deaths due to respiratory system diseases. All-cause mortality rate per person year and mortality rate due to respiratory system diseases was lower for DMP patients. Readmission rate per person year and 30-day readmission rate was significantly higher for DMP patients (*Table 2*).

Propensity score computation and matching

DMP patients were matched to controls by their propensity to be enrolled in the program. Odds for enrolment in DMP was higher for patients from hospital B [odds ratio (OR) =2.5; 95% CI, 1.5–4.3] and patients with obesity (OR =1.7; 95% CI, 1.2–2.3) and lower for

Table 2 Overall admission characteristics before matching

Variables	DMP patients (n=309)	Controls (n=893)	P value
Episodes	488	1,227	–
ALOS (mean ± SD) (days)	4.40±4.70	4.70±5.10	0.0435[†]
Total hospital days	2,122	5,764	–
Average hospital days per patient	6.90	6.50	0.2260[‡]
Total person years of follow up	268.83	738.63	–
No. of days admitted to hospital per 100 person year	2.16	2.14	0.6511[⊣]
No. of deaths (%)	35 (11.3)	173 (19.4)	0.0003[‡]
Deaths due to respiratory system diseases (%)	25 (8.1)	124 (13.9)	0.0001[‡]
Crude all-cause mortality rate[‡] per person year (95% CI)	0.13 (0.09–0.18)	0.24 (0.20–0.27)	0.0008[⊣]
Crude mortality rate[‡] per person year, respiratory system diseases (95% CI)	0.09 (0.06–0.14)	0.17 (0.14–0.20)	0.0034[⊣]
Readmission rate per person year (95% CI)	0.33 (0.26–0.41)	0.23 (0.19–0.27)	0.0094[⊣]
30-day readmission rate per person year, (95% CI)	0.12 (0.08–0.17)	0.05 (0.04–0.07)	0.0013[⊣]
No. of days admitted to hospital per 100 person days	2.16 (2.07–2.25)	2.14 (2.08–2.19)	0.6511[⊣]

[†], Wilcoxon rank sum test; [‡], Student *t*-test; [‡], Z test for proportion; [⊣], IRI, incidence rate comparison, (STATA). ALOS, average length of stay; SD, standard deviation.

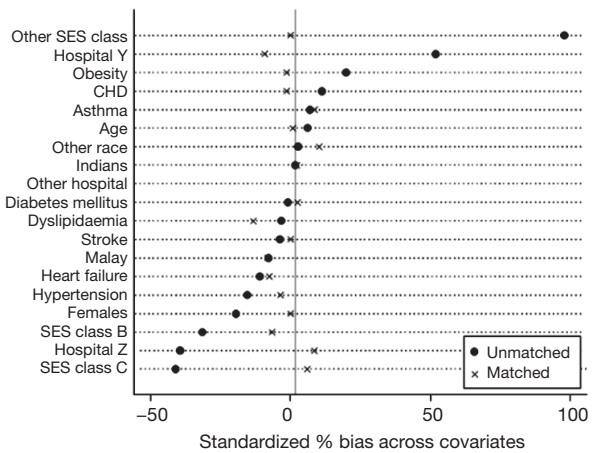

Figure 2 Covariate balance before and after PS matching.

patients with hypertension (OR =0.58; 95% CI, 0.42–0.80). The performance of the prediction model was evaluated by receiver operating characteristic curve (ROC) analysis, C-statistic was 0.79 indicating good predictive power—variables selected in our propensity model were highly predictive of the treatment (in this case, enrolment in the DMP). After matching, the socio-demographic characteristics and comorbidities between the DMP and controls were similar (*Table 1*). *Figure 2* shows the covariate balance before and after PS matching; the standardized bias percentage has reduced considerably across the covariates.

Demographic and admission characteristics after matching

Table 3 shows the matched DMP patients and controls. The 170 matched DMP patients and control patients had 287 and 207 hospitalizations respectively. Median follow up period was 1.1 and 0.62 years for the matched DMP and control patients respectively. DMP patients and controls were similar with regards to age, gender, race, hospital, SES, comorbidities and average hospital length of stay (*Tables 1*,*3*). DMP patients had lower mortality than the controls (0.12 *vs.* 0.27 per person year); cumulative 1-year survival was 91% and 76% between DMP and control patients respectively (*Figure 3*). Hospital days per 100 person-days were higher for DMP patients (2.19 *vs.* 1.88) (*Table 3*).

Risk of death and readmission

The risk of death was lower in DMP patients [hazard ratio (HR) =0.38; 95% CI, 0.21–0.69], patients with asthma

Table 3 Admission characteristics of the patients in both groups after PS matching

Variables	DMP patients (n=170)	Controls (n=170)	P value
Episodes	287	207	–
ALOS (mean ± SD) (days)	4.2±4.7	4.3±4.9	0.8800†
Total hospital days	1,207	891	–
Average hospital days per patient	7.1	5.2	0.0003‡
Total person years of follow up	152.02	129.49	–
Total hospital days per 100 person days¶	2.2	1.9	0.0012┤
Total No. of deaths (%)	18 (10.6)	35 (20.6)	0.0105‡
Deaths due to respiratory system diseases (%)	15 (8.8)	26 (15.3)	0.0664‡
Crude all-cause mortality rate‡ per person year (95% CI)	0.12 (0.07–0.19)	0.27 (0.19–0.38)	0.0036┤
Crude mortality rate‡ per person year for Respiratory system diseases (95% CI)	0.09 (0.06–0.16)	0.20 (0.13–0.29)	0.0282┤
Readmission rate per person year (95% CI)	0.36 (0.27–0.48)	0.17 (0.11–0.26)	0.0032┤
30 day readmission rate per person year (95% CI)	0.14 (0.09–0.22)	0.03 (0.01–0.08)	0.0016┤
No. of days admitted to hospital per100 person days	2.19 (2.07–2.31)	1.88 (1.76–2.01)	0.0007┤

†, Wilcoxon rank sum test; ‡, Student *t*-test; ‡, Z test for proportion; ┤, IRI, incidence rate comparison, (STATA); ¶, person time (days)—program: 55,527 and controls: 47,295. ALOS, average length of stay; SD, standard deviation; CI, confidence interval.

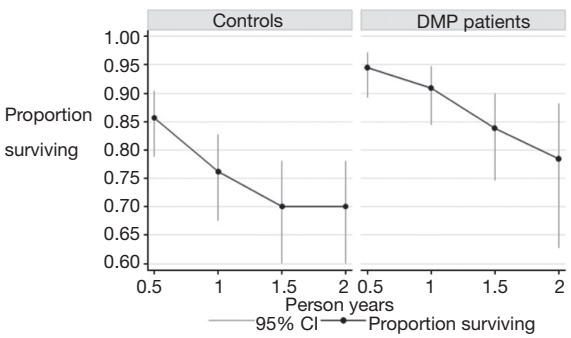

Figure 3 Kaplan–Meier survival curve, DMP patients *vs.* controls.

(HR =0.37; 95% CI, 0.18–0.78), obesity (HR =0.22; 95% CI, 0.08–0.65) and higher for older patients (HR =1.04; 95% CI, 1.00–1.08) and patients with DM (HR =2.3; 95% CI, 1.2–4.3) (*Table 4*). Risk of readmission was higher for DMP patients than control patients (adjusted for competing risk—mortality, SHR =3.4; 95% CI, 1.8–6.4) (*Table 5*).

Discussion

In this retrospective propensity matched cohort study of DMP patients and controls, participation in DMP had reduced 1-year all-cause mortality by 15%. However, DMP patients had higher readmissions and total hospital days, the survival gain may have contributed to this increase. To our knowledge, this is the first comprehensive DMP for COPD to show mortality reduction, other studies of pharmacological interventions showed similar reductions in mortality (25).

Literature shows that smoking cessation has been the single most effective and cost-effective way to reduce the risk of developing COPD and stop its progression (26). In this study, DMP patients were enrolled in a smoking cessation program and counselled on quitting smoking by the case managers, the counselling and advice were sustained through telephonic case management. Studies worldwide have shown that even in severe COPD, smoking cessation slows the accelerated rate of lung function decline and improves survival compared with continued smoking (27,28). A recent study of smoking cessation and COPD mortality among Japanese men and women, shows smoking cessation reverses the excess risk of COPD mortality to a level similar to that observed among never smokers in men (29). These data suggest that the inflammatory changes are reversible rapidly after smoking cessation and could explain the lower risk of death observed

Table 4 Multivariate Cox proportional hazards model for factors associated with mortality

Variables	Hazard ratio	95% confidence interval	P value
Age	1.04	1.00–1.08	0.05
Females	0.50	0.17–1.46	0.21
Hospital			
Y	0.83	0.31–2.22	0.71
Z	0.83	0.35–1.99	0.68
SES			
B	0.62	0.13–2.89	0.54
C	1.15	0.26–5.05	0.86
Readmission	1.99	1.09–3.61	0.03
Asthma	0.37	0.18–0.78	0.01
DM	2.27	1.20–4.30	0.01
HT	1.00	0.50–2.01	1.00
Stroke	0.98	0.38–2.49	0.96
CHD	1.06	0.49–2.29	0.88
HF	1.00	0.44–2.27	1.00
Dyslipidemia	1.18	0.57–2.43	0.66
Obesity	0.22	0.08–0.65	0.01
DMP patients	0.38	0.21–0.69	0.00

Reference category: males, hospital X, SES A; patients with: no readmission, no asthma, no DM, no HT, no stroke, no CHD, no HF, no dyslipidemia, no obesity, and control patients. Socio-economic status (SES) A, B, C represent ward class A, B and C respectively.

Table 5 Completing-risk regression analysis of the association between covariates and the risk of readmission

Variables	Hazard ratio	95% confidence interval	P value
Age	1.01	0.97–1.04	0.65
Females	1.19	0.57–2.51	0.65
Race			
Malay	0.57	0.17–1.84	0.35
Indian	1.49	0.60–3.73	0.39
Hospital			
Y	0.51	0.17–1.58	0.25
Z	1.16	0.51–2.63	0.73
SES			
B	0.86	0.28–2.68	0.80
C	1.12	0.38–3.30	0.84
Asthma	1.55	0.81–2.96	0.19
DM	0.44	0.19–1.02	0.05
HT	0.98	0.53–1.79	0.94
Stroke	0.91	0.30–2.73	0.87
CHD	0.83	0.36–1.92	0.67
HF	0.87	0.32–2.37	0.79
Dyslipidemia	1.09	0.51–2.31	0.83
Obesity	1.37	0.69–2.72	0.36
DMP patients	3.40	1.81–6.39	0.00

*, death was the competing risk. Reference category: males, Chinese, Hospital X, SES A, Patients with: no asthma, no DM, no HT, no stroke, no CHD, no HF, no dyslipidemia, no obesity, and control patients, Socio-economic status (SES) A, B, C represent ward class A, B and C respectively.

among DMP patients. Other components of DMP such as timely follow up with the physicians coordinated by a case manager, telephonic case management, optimization of medications, self-management of the condition and timely treatment for exacerbation at the hospital would have had a synergistic effect on survival.

Previous trials and systematic reviews of DM in COPD were heterogeneous in terms of size, multi-component interventions, duration of follow up and outcomes. These studies have reached differing conclusions (30), majority of the studies had recognized the potential value of this type of intervention for reducing hospital readmissions and ED attendances (31). However, in a RCT, comparing a comprehensive care management program (CCMP) with usual care for COPD, CCMP in patients with severe COPD had not decreased COPD-related hospitalizations (32). In another multicentre RCT, among patients with diabetes, COPD, and congestive heart failure, the intervention designed to improve patients' access to primary care providers, the coordination of outpatient services, and the provision of comprehensive and continuous care (program components similar to DMP) increased the rate of rehospitalisation (33).

Mortality or readmission with 30 days suggests the possibility of inadequate care (34). However growing evidence reveals that mortality and readmissions may in fact be inversely associated with one another (35,36). In our study, DMP patients had lower mortality but higher readmission than controls. The results are different from similar studies elsewhere (37). Our findings suggest that readmissions could be "adversely" affected by a competing

risk of death. A patient who dies during the index episode of care can never be readmitted. Since DMP patients have low mortality, a greater proportion of discharged DMP patients are eligible for readmission. As such, a higher readmission rate may be a consequence of successful care in DMP. Studies show, case management improved access to resources and staff-patient communication (38). Heightened monitoring of discharged patients in a DMP provides a channel for patient to voice their complaints resulting in more readmissions but also saving more lives (39). Six percent of DMP patients had over 4 readmissions (frequent flyers) and accounted for 42% of total readmissions in comparison there were none in the control group who had more than four readmissions. The higher readmissions among DMP patients are partially driven by the frequent flyers.

Hospitalization for exacerbation of COPD represents a very complex, multi-factorial picture and is associated with high risk of mortality (40). Vast majority these readmissions could be attributable to "unavoidable" issues such as disease progression or social factors (8). Furthermore, preventing or mitigating exacerbation in COPD is essential to prolonging life, this would require hospitalization for at least 35% of the patients and may lead to readmission (41). Therefore, DMP planning for COPD should take into account the inverse relationship between readmission and mortality.

This study has several strengths. It has led to a greater understanding of the local COPD population and how a CCMP affects outcomes for patients enrolled in the program. The study had complete mortality follow-up and provides estimates of the adjusted sub-hazard of COPD readmission using Fine and Gray competing risk framework. The estimated risks of mortality and readmission are more reliable and less likely to be biased. Some of the limitations are, first, since the evaluation focuses on patients who had hospitalization (severe patients), the results may not be generalizable to all COPD patients. This analysis has been adjusted for demographics and comorbidities and not adjusted for lung function and disease severity. Second, we did not report spirometry which would be useful as it is the gold standard for COPD classification. However, our study was a real-world experiment conducted using administrative database, and spirometry was not performed for everyone, hence we were not able to report this. Third, readmissions were captured only for the three hospitals, admissions/readmissions that happened outside these three hospitals are not captured. Lastly this evaluation has established associations, not causality.

The DMP has led to improved survival and added years of life to patients with COPD. However readmission rates were higher among DMP patients, this could be due to increased patient contact with the system facilitated by the case managers and could be partially due to frequent flyers (patients with four or more admissions). Increase in readmission may lead to hospital bed crunch, choking up the already scarce healthcare resources at the hospital. This calls for better coordination of COPD services with primary, intermediate and long-term care partners.

In conclusion, the study highlights the usefulness of propensity scoring methodology for identifying appropriate control for evaluation of DMP from administrative data. Our analysis showed that participation in the "DMP" was associated with lower all-cause mortality and increased readmission. Planners have to be aware of the vicious cycle between readmission and death in severe ill COPD patients. Further studies are required to ensure corrections for case mix and time bias and unobserved confounders.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The studies on "Disease management" are exempted from IRB approval (NHG DSRB) in our institutions, hence ethics approval was not obtained for this study.

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