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Time protective effect of contact with a general practitioner and its association with diabetes-related hospitalisations: a cohort study using the 45 and Up Study data in Australia

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ABSTRACT

Objectives To evaluate the relationship between the proportion of time under the potentially protective effect of a general practitioner (GP) captured using the Cover Index and diabetes-related hospitalisation and length of stay (LOS).

Design An observational cohort study over two 3-year time periods (2009/2010–2011/2012 as the baseline and 2012/2013–2014/2015 as the follow-up).

Setting Linked self-report and administrative health service data at individual level from the 45 and Up Study in New South Wales, Australia.

Participants A total of 21 965 individuals aged 45 years and older identified with diabetes before July 2009 were included in this study.

Main outcome measures Diabetes-related hospitalisation, unplanned diabetes-related hospitalisation and LOS of diabetes-related hospitalisation and unplanned diabetes-related hospitalisation.

Methods The average annual GP cover index over a 3-year period was calculated using information obtained from Australian Medicare and hospitalisation. The effect of exposure to different levels of the cover on the main outcomes was estimated using negative binomial models weighted for inverse probability of treatment weight to control for observed covariate imbalance at the baseline period.

Results Perfect GP cover was observed among 53% of people with diabetes in the study cohort. Compared with perfect level of GP cover, having lower levels of GP cover including high (incidence rate ratio (IRR) 2.8, 95% CI 2.6 to 3.0), medium (IRR 3.2, 95% CI 2.7 to 3.8) and low (IRR 3.1, 95% CI 2.0 to 4.9) were significantly associated with higher number of diabetes-related hospitalisation. Similar association was observed between the different levels of GP cover and other outcomes including LOS for diabetes-related hospitalisation, unplanned diabetes-related hospitalisation and LOS for unplanned diabetes-related hospitalisation.

Conclusions Measuring longitudinal continuity in terms of time under cover of GP care may offer opportunities to optimise the performance of primary healthcare and reduce secondary care costs in the management of diabetes.

Strengths and limitations of this study

- In this study, we used a large contemporary population-based cohort linked with individuals' healthcare service records that enabled us to account for differences across time periods and a wide range of demographic, socioeconomic and clinical characteristics.
- Using empirical analytical approaches to construct the general practitioner (GP) cover index, the study was able to explore latent patterns of GP utilisation relative to demographic and clinical characteristics that unpack further dimensions of longitudinal continuity of primary care.
- The cover index expresses the proportion of time under cover of GP care and therefore can quantify the extent of sufficiency of primary care utilisation and can be applied at the individual, subpopulation or whole population level.
- Since both GP cover and hospitalisations were measured over the same period, caution is required when interpreting any causal relationship between the cover of GP care and diabetes-related hospitalisation although imbalance in the observed demographic and clinical characteristics between GP cover levels was controlled using inverse probability of treatment weight.
- Hospitalisations classified as diabetes-related hospitalisation in this study may not be all truly avoidable by effective GP care; however, further analysis using unplanned diabetes-related hospitalisation outcome confirmed that increasing GP cover reduces unplanned hospitalisation, likely via better management of the condition.

INTRODUCTION

Diabetes causes major burden for healthcare systems worldwide with 425 million people living with diabetes in 2017.[1] About 1.1 million people in 2017 are living with diabetes in Australia.[2] Diabetes and its related complications are associated with poor health

outcomes, low quality of life and substantially high burden of healthcare expenditure.[2 3]

To address burden of complex chronic conditions such as diabetes, many healthcare systems have been oriented toward strengthening the roles of primary healthcare.[4 5] In Australia, the government has set a focus on strengthening the primary healthcare system through providing financial incentive for aspects of primary care such as services/practice incentive payment.[6] The practice incentive payment was introduced in 1998 and went through many changes but has remained stable since 2006.[7] General practitioners (GPs) play a central role of primary care providing care for approximately 85% of the general population.[5] The GPs are responsible for first contact of care, gatekeeping access to healthcare system, coordinating and integrating with other health professionals in secondary care settings including specialty, allied health and hospital care.[5] The GPs' roles have been vital for efficient use of healthcare resources, management of chronic conditions[8] and improving population health outcomes.[4 9]

Literature highlights the importance of continuity of care in which GPs play a central role, to ensure a sufficient provision of care, to minimise unnecessary or harmful care and to promote self-management for people with the chronic complex conditions.[10–14] A modern concept of continuity comprises three main aspects including interpersonal continuity, management continuity and information continuity.[15] Previous studies found that more continuity of care in terms of interpersonal continuity captured by higher continuity of provider,[12 16] and management continuity captured by greater regularity of GP visits[17–19] is associated with better patient satisfaction and fewer avoidable hospitalisations.

For people with ambulatory care sensitive conditions such as diabetes, proactive care offers an opportunity for early and sufficient action to be taken to prevent the onset and delay progression of degenerative diseases.[20] Recent evidence examining patterns of GP utilisation has demonstrated that the time interval between GP visits was associated with lower number of hospitalisation.[21 22] The time interval between GP services is integrated into a new continuity of care metric named the 'cover index' capturing the proportion of time people are under the potentially protective effect of GP care.[21] The cover index offers a new measure of continuity of care accounting for management aspect of care to support comprehensive evaluation of continuity of care in the context of a high burden of complex and multiple chronic conditions.[21]

Knowledge about how differing amounts of time people are under the protective effect of contact with GP (as measured by the cover index) on diabetes-related hospitalisations would provide useful information to aid in the development of policies that support proactive care by GPs for people with chronic conditions such as diabetes and improve health outcomes for the population. Building on the previous study[21] using historical data, this study aimed to apply the cover index to evaluate the GP cover of people with diabetes in the contemporary setting and its association with diabetes-related hospitalisation and length of stay (LOS).

METHODS

This was a retrospective observational cohort study using self-reported survey data linked with routinely collected unit record administrative health data. Reporting follows the REporting of studies Conducted using Observational Routinely-collected health Data guidelines.[23]

Data sources

This was a retrospective observational study using data from the Sax Institute's 45 and Up Study in New South Wales (NSW); details of the cohort profile have been previously reported.[24] The Sax Institute's 45 and Up Study was sampled from the Department of Humans Services (formerly Medicare Australia) enrolment data base. The study comprises over 267 000 people aged 45 years and over with individual information on demographics, socioeconomic status, lifestyle factors, health status and well-being collected from the survey between 2006 and 2009. Survey data were linked with administrative health records from (1) the NSW Admitted Patient Data Collection (APDC) (2005 to 2015), (2) the Medicare Benefits Schedule (MBS) (2005 to 2015), (3) the Pharmaceutical Benefit Scheme (PBS) (2005 to 2015) and (4) the NSW Register of Births Deaths and Marriages (RBDM) (2006 to 2015). The NSW Centre for Health Record Linkage (CHeReL) conducted the linkage for APDC and RBDM. CHeReL linkages are probabilistic. The MBS and PBS data are linked deterministically by the Sax Institute using a unique identifier provided by the Australian Government Department of Human Services. The privacy of individual patients is conserved using probabilistically linked technique with very low false-positive and false-negative rates of <0.5 and <0.1%, respectively.[25] All individual data were deidentified and assigned a unique project person number.

The APDC data comprised dates of admission and discharge, diagnoses (primary and secondary), procedures performed and other details of individual episodes of hospitalisation, such as type of admission, transfer and discharged status from all private and public hospitals in NSW. Details of diagnoses were recorded using International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM) codes in the principal diagnosis and up to 54 additional diagnoses.[26] The MBS records consisted of claim items, date of services and deidentified provider codes for medical and diagnostic services provided out of hospital under Australia's universal health insurance scheme. The PBS records comprised claims for subsidised prescription medicines and included item code, Anatomical Therapeutic Chemical (ATC) code, quantity and date supplied. The death registry had information on the date

and cause of death and was used to identify participants in the study population who died during the study period.

Study population and study design

The study population included people aged 45 years and older identified with diabetes any time prior to 1 July 2009 using information from self-report, APDC and PBS data. People were identified as having diabetes if they answered yes to the question 'has the doctor ever told you that you have diabetes?; or they had an APDC record with ICD-10-AM codes for diabetes (E10, E11, E13, E14) in any field of diagnoses and/or a PBS claim indicating a dispensing between 2005 and 2009 using ATC code of A10A (insulins and analogues) or A10B (blood glucose lowering drugs excluding insulins).[27]

The study cohort was structured into a cohort with two observed time periods (based on financial years: 1 July to 30 June): the baseline period from 1 July 2009 to 30 June 2012 for evaluating pre-exposure characteristics and the follow-up period from 2012/2013 to 2014/2015 for evaluating the effect of GP cover on hospitalisation. A total of 21 965 individuals who were still alive on 1 July 2015 and had no missing basic demographic characteristics or potential linkage errors were included for the study.

Ethics approval

Ethics approval was obtained from Curtin University Human Research Ethics Committee (RD-42–14) and the NSW Population and Health Services Research Ethics Committee (HREC/17/CIPHS/37). Consent was given by all participants in the Sax Institute's 45 and Up Study for their information to be used in approved studies, and for follow-up and data linkage. The conduct of the Sax Institute's 45 and Up Study was approved by the University of NSW Human Research Ethics Committee.

Patient and public involvement

A consumer representative was involved in the design of the grant used to fund this research. The 45 and Up Study, which provided data for this project, maintains a repository of published research using this cohort online.

Outcome measures

Diabetes-related hospitalisations were defined as hospitalisations for conditions where diabetes has been previously identified as a significant risk factor, captured using the principal diagnosis code.[28] We used the conditions suggested by an Australian study[28] which collated evidence from literature on conditions that is attributable to diabetes. This comprehensive list allowed us to fully capture the burden of hospitalisation related to diabetes (online supplementary appendix 1) rather than limit the analysis to diabetic potentially preventable hospitalisation, which also do not have consensus in their definition.[28–32] We excluded routine hospitalisations for kidney dialysis and interhospital transfers were counted as a single episode of care. We also measured unplanned diabetes-related hospitalisations which restricted diabetes-related hospitalisations into those admitted hospitalisation through emergency departments. Three-year accumulated LOS were also calculated for diabetes-related hospitalisations and unplanned diabetes-related hospitalisations with same day episodes counted as 1 day.

Independent measures

Cover index of GP contacts

The cover index of GP contacts was the main predictor used in this study. The index is defined as the proportion of time in a prespecified ascertainment period that people with diabetes are under the potentially protective effect of care from their GP (cover), range from 0 to 1, where 1 is the perfect cover (see figure 1). In this study, the cover index was calculated annually to facilitate interpretation by policy-makers since financial incentives and clinical guidelines usually use 1 year to determine eligibility/compliance (eg, annual diabetes cycle of care payments in Australia).[33 34] In addition, this allows for comparability with most other continuity of care indices such as regularity and usual provider care, which are often evaluated annually. The average of the annual cover index over the 3 years was then calculated and classified as low cover (0–0.5), medium cover (>0.5–0.85), high cover (>0.85–0.99) and perfect cover (>0.99–1). The methods to calculate cover have been previously reported.[21]

In this study, for the main analysis the cover index was calculated using the maximum optimal time interval under GP cover suggested by the previous study conducted in Western Australia.[21] The study suggested that the maximum optimal time interval under potentially protective effect of GP care for people with diabetes was 13 months for diabetes with no complications, 11 months for people with one or two complications and 9 months for people with three or more complications.[21]

For the sensitive analyses, the cover index was also calculated using (1) the maximum optimal time interval under GP cover estimated from the current study cohort with similar model specification from the previous publication and (2) using expert opinion derived from a survey of GPs with expertise in managing chronic conditions. Details of the GP survey are presented in online supplementary appendix 2. The maximum optimal time interval suggested by the NSW cohort was 13, 8 and 6 months for diabetes with none, one or two and three complications, respectively. The details of the estimation using the NSW cohort is presented in online supplementary appendix 3. The maximum optimal time interval suggested by the GP survey was 10–12 months, 6–9 months and 1 month for diabetes with none, one or two complications and three or more complications, respectively (see online supplementary appendix 2).

Other indices of continuity of care by a GP

Frequency of GP contact was calculated as the accumulated number of GP contacts of each financial year and 3-year period, excluding visits within 14 days of the previous visit to avoid overcounting GP episodes of care.[35]

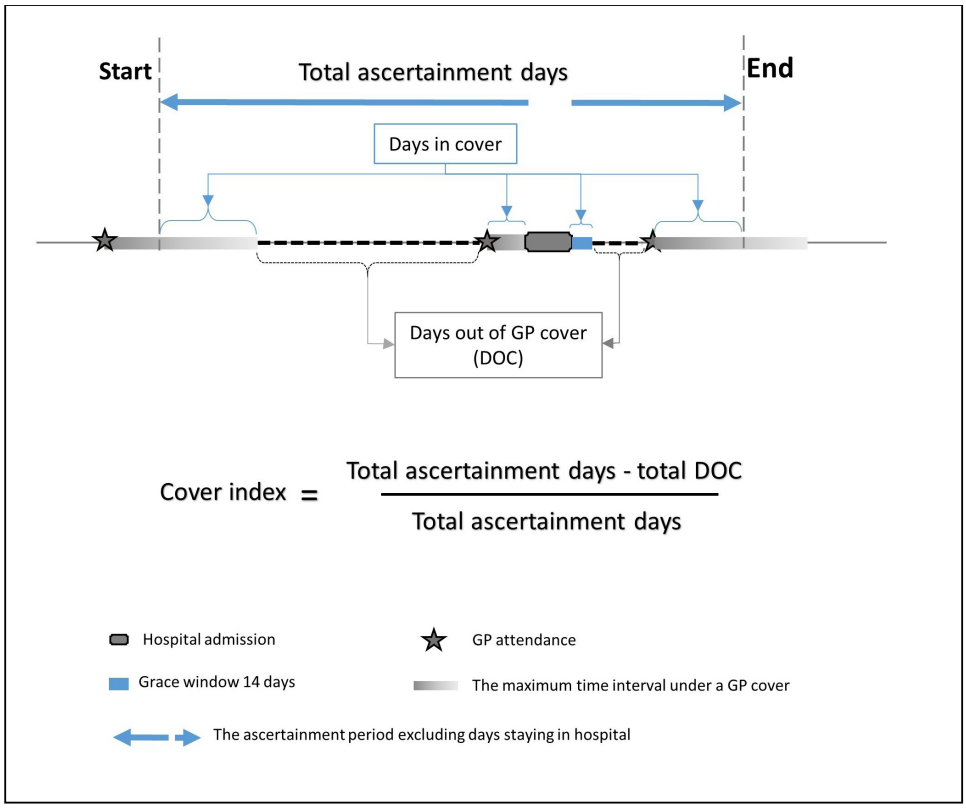

Figure 1 Calculation of the cover index. Following a hospital admission, a 14 day-period of grace was given before requiring a post-discharge general practitioner (GP) visit. Calculation of days out of cover was restarted either at day 15 (if no GP contact was observed) or on the date of the GP visit (if a GP visit was observed prior to day 15).

The regularity index was used to measure the distribution of GP visits over each year and was calculated annually as [1/ (1+SD of the days between visits)], described in detail elsewhere.[18 19 36] The regularity index was categorised into quintiles for each 3-year period.

Usual provider continuity was measured using the usual provider of care index, which measures the proportion of GP contacts within a financial year that were provided by the same GP[12] and were aggregated into the 3-year period.

Other covariates

This study also measured demographic and socioeconomic characteristics including age classified as 45–54, 55–64, 65–74, 75-84 or 85+ years; sex, indigenous status, education, residential remoteness classified according to Accessibility/Remoteness Index of Australia (ARIA)[37] and quintiles of the Census-specific Socio-economic Indexes for Areas index of relative socioeconomic disadvantage.[38] Duration of diabetes was counted from self-reported age at diagnosis with diabetes, first date of diagnosis recorded in APDC or incident diabetes-related PBS record, whichever came first, and classified as 1–5 years, 6–10 years and 11+ years. The number of self-reported comorbidities was the sum of all self-reported conditions including cancers, heart disease, high blood pressure, stroke, blood clot, asthma or hay fever, depression and anxiety, and Parkinson's disease. Levels of limitation in terms of the ability to perform daily activities such as walking, bending, dressing and bathing were measured using the Medical Outcome Study Physical Function Scale[39] and classified into four groups: no limitation, minor limitation, mild limitation and severe limitation. The number of comorbidities up to time period 1 was also counted in the APDC using the Multipurpose Australian Comorbidity Scoring System with a 5-year lookback period.[40 41] Diabetes complications up to time period 1 were identified using ICD-10-AM codes in the APDC data and classified into three severity level groups: no complication, 1–2 complications and 3+ complications as used elsewhere.[42 43] The number of out-of-hospital specialist visits were identified using MBS claims data, counted for each financial year and then aggregated over a 3-year period for time period 1 and time period 2.

Statistical methods

Descriptive observed characteristics was conducted across the cover levels. A generalised propensity score (GPS) for multiple treatment approach was used to control for any imbalance in distribution of the observed covariates in estimating the effect of the cover on the hospitalisation outcomes.[44] The twang package in R[45] was used to perform the generalised boosted models (GBMs) in estimating GPS and evaluating covariate balance after adjusting for inverse probability of treatment weight (IPTW). Both the mean of absolute standardised bias and the Kolmogorow-Simirnov statistic were used as the stopping rules for selecting the optimal iteration of the

GBM.[44 45] The population standardised bias which is less than 0.2 is considered as balance achieved for the given covariate.[44] A similar effective sample size yielded for both balance stopping rules, hence the GPS from the model fit with the mean of absolute standardised bias stopping rule was presented for the results. Online supplementary appendix 4 provides the details of assessing the balance in distribution of the observed characteristics across the GP cover levels, for all the cover index calculating using Western Australia, NSW and survey referenced intervals.

The effects of levels of cover on diabetes-related hospitalisations, unplanned diabetes-related hospitalisations and LOS (for both all and unplanned hospitalisations) were examined using negative binomial models adjusting for all healthcare service use at time period 2 including frequency of GP contacts, regularity of GP contacts and number of specialist visits. The negative binomial models were used to account for overdispersion of the outcome variables as suggested by a likelihood ratio test. In addition, as a high proportion of zeros was observed in the outcome variables, zero-inflated negative binomial model for modelling the number of hospitalisation outcomes and hurdle model for modelling the LOS outcomes were also performed to check the robustness of the results. The models were performed using three different specifications: multivariate models without IPTW, with IPTW and doubly robust estimation which included both IPTW and all observed covariates.

Sensitivity analyses was conducted for the cover index calculated using referenced time intervals estimated from the NSW cohort and the GP survey. The sensitivity analysis was also conducted in the subpopulation which excluded cases identified with diabetes using information from oral medication only. The 14-day grace period after hospital discharge was imposed in the cover calculation based on evidence in literature[46–50]; however, a sensitive analysis with the wider grace period (28 and 45 days) and no imposed grace period was also performed.

All analyses were conducted using STATA[51] for Windows V.MP14 and twang package in R V.3.5.2.[45]

RESULTS

A total of 21 965 individuals aged 45 years and older identified with diabetes in the 45 and Up Study population were eligible for this study. The baseline social demographic and clinical characteristics across the levels of GP cover were shown in table 1. At the time period 2, 53.4% of the study population had a perfect level of cover with GPs, following by 39.0% of a high level, 3.9% of medium level and 3.6% of low level of cover. More than half of all cover groups were living in highly accessible areas, had at least higher school/university/tafe and roughly 40% had less than 5 years duration of diabetes. However, the distribution of some demographic and clinical characteristics varied across the levels of GP cover. The low level of GP cover was dominated by males (64%), aged 75+ years (43%), severe level of limitation (33%) and 3+ complications (34%). In contrast, the perfect level of GP cover was characterised with equal gender distribution (52.0% of males) and lower proportion of people aged 75+ years (22%), severe level of limitation (27%) and 3+ complications (21%).

Results of the effect of GP cover on diabetes-related hospitalisation, unplanned diabetes-related hospitalisation and LOS for the hospitalisation using negative binomial models are presented in table 2. A similar result was found in the robustness check analysis that suggested the effect of excess zero was minimal, presented in online supplementary appendix 5 table 1A,B. The results of doubly robust estimation show that compared with the perfect level of GP cover, having less GP cover including high, medium and low level was significantly associated with 2.8 times (95% CI 2.6 to 3.0), 3.2 times (95% CI 2.7 to 3.8) and 3.1 time (95% CI 2.0 to 4.9) higher number of diabetes-related hospitalisation, respectively. Similar effect was observed in LOS of diabetes-related hospitalisation with higher in LOS for the high level of cover (IRR 1.9, 95% CI 1.6 to 2.3), medium level of cover (IRR 1.7, 95% CI 1.3 to 2.3), compared with the perfect level of GP cover, except for low level of cover with no significant association (IRR 0.8, 95% CI 0.4 to 1.5).

The doubly robust models indicated a higher effect of GP cover on unplanned diabetes-related hospitalisation and its LOS. The medium cover (IRR 1.7, 95% CI 1.5 to 1.9) and high cover (IRR 1.7, 95% CI 1.3 to 2.3) have a significant higher number of unplanned diabetes-related hospitalisation compared with the perfect level of GP cover. For LOS of unplanned diabetes-related hospitalisation, the significant association was observed in only a high level of cover with IRR 1.6, 95% CI 1.3 to 1.9 (table 2).

Sensitivity analysis for the cover index derived from the NSW cohort and GP opinion on the optimal time interval also provided similar effects, although the results from the cover levels derived from GP opinion show larger effect and significantly associated across all levels of cover. When examined the effect of cover in the subpopulation which excluded cases identified using information from the oral medication only, we also found a significant association between the cover levels and diabetes-related and unplanned diabetes-related hospitalisations. The details of the results presented in the online appendix 6 table 1A-1C for both diabetes-related and unplanned diabetes-related hospitalisation and their LOS.

Results of another sensitivity analyses for different scenarios in calculating the cover index related to (1) extending the 14-day grace period following hospital discharge to 28 and 45 days and (2) removing the 14-day grace period are presented in online supplementary appendix 7 table 1A-1C. Extending the grace period to 28 and 45 days resulted in lesser effect of the GP cover on diabetes-related hospitalisation and unplanned hospitalisation, although a similar pattern was observed compared with the result of the 14-day period used in calculating the cover. If the 14-day period was not imposed and

Table 1 Characteristics by cover levels measured at the time period 2

	Low cover (N=786)		Medium cover (N=857)		High cover (N=8576)		Perfect cover (N=11 764)	
	n	%	n	%	n	%	n	%
Sex								
Male	503	64.0	532	62.1	4670	54.5	6108	52.0
Female	283	36.0	325	37.9	3906	45.5	5638	48.0
Age groups, years								
45/54	90	11.5	220	25.7	1106	12.9	1878	16.0
55–64	181	23.0	275	32.1	2384	27.8	3390	28.9
65–74	174	22.1	218	25.4	3108	36.2	3904	33.2
75–84	212	27.0	111	13.0	1777	20.7	2223	18.9
85+	129	16.4	33	3.9	201	2.3	351	3.0
Indigenous								
Yes	774	98.5	834	97.3	8463	98.7	11 590	98.7
No	12	1.5	23	2.7	113	1.3	156	1.3
Accessibility								
Highly accessible	80	10.2	76	8.9	931	10.9	1258	10.7
Accessible	13	1.7	8	0.9	66	0.8	132	1.1
Moderate	258	32.8	288	33.6	3103	36.2	3937	33.5
Very remote/remote	435	55.3	485	56.6	4476	52.2	6419	54.6
SEIFA								
Highest disadvantage	193	24.6	164	19.1	1993	23.2	2829	24.1
High disadvantage	241	30.7	219	25.6	2202	25.7	3481	29.6
Moderate	115	14.6	193	22.5	1382	16.1	1536	13.1
Less disadvantage	114	14.5	142	16.6	1396	16.3	1679	14.3
Least disadvantage	123	15.6	139	16.2	1603	18.7	2221	18.9
Education								
Below secondary school	114	14.5	113	13.2	1458	17.0	2288	19.5
Secondary school	464	59.0	588	68.6	4947	57.7	6571	55.9
Higher school/university/ tafe	208	26.5	156	18.2	2171	25.3	2887	24.6
Levels of limitation								
No	263	33.5	214	25.0	2674	31.2	3482	29.6
Minor	97	12.3	185	21.6	1214	14.2	1930	16.4
Moderate	163	20.7	273	31.9	2435	28.4	3189	27.1
Severe	263	33.5	185	21.6	2253	26.3	3145	26.8
Duration of diabetes, years								
1–5	326	41.5	378	44.1	3587	41.8	5118	43.6
6–10	260	33.1	254	29.6	2698	31.5	3508	29.9
10+	200	25.4	225	26.3	2291	26.7	3120	26.6
Number of self-report comorbidity	2	1–3	1	1–2	2	1–3	2	1–3)
Quintiles of regularity TP1								
No GP contacts	188	23.9	23	2.7	19	0.2	6	0.1
1	337	42.9	450	52.5	2076	24.2	2926	24.9
2	78	9.9	169	19.7	2367	27.6	3102	26.4
3	66	8.4	119	13.9	2328	27.1	2913	24.8

Continued

Table 1 Continued

	Low cover (N=786)		Medium cover (N=857)		High cover (N=8576)		Perfect cover (N=11 764)	
	n	%	n	%	n	%	n	%
4	117	14.9	96	11.2	1786	20.8	2799	23.8
UPC index TP1	0.33	0–0.67	0.8	0.65–0.91	0.82	0.69–0.92	0.82	0.68–0.92
Number of specialist visits TP1	0	0–6	7	1–16	9	4–18	7	2–14
Number of GP contacts TP1	2	0–8	11	6–16	18	14–22	18	14–23
Levels of complications prior to TP1								
0—no complication	337	42.9	449	52.4	3898	45.5	6459	55.0
1/2 complications	185	23.5	208	24.3	2469	28.8	2820	24.0
3+ complications	264	33.6	200	23.3	2209	25.8	2467	21.0
Number of comorbidity (MACSS) prior TP1	4	1–7	3	1–6	4	2–6	3	0–5
Number of diabetes-related hospitalisation TP1	0	0–1	0	0–0	0	0–1	0	0–0
Number of unplanned diabetes-related hospitalisation TP1	0	0–0	0	0–0	0	0–0	0	0–0

n and % for categorical variables and median (IQR) for continuous variables.
Low level of cover: the cover score from 0 to 0.5; medium level of cover: the cover score above 0.5 to 0.85; high level of cover if the cover score above 0.85 to 0.99; perfect level of cover: above 0.99 to 1.0.
GP, general practitioner; MACSS, Multipurpose Australian Comorbidity Scoring System; SEIFA, Census-specific Socio-economic Indexes for areas; TP1, time period 1 between 2009/2010 and 2011/2012; UPC, usual provider continuity.

in-hospital time was excluded in calculation of the cover, no significant association was observed between different levels of cover and diabetes-related hospitalisations and LOS. For unplanned diabetes-related hospitalisation, an association was observed for the high cover level and inverse association was observed in medium cover.

DISCUSSION

This study provided compressive evaluation of the relationship between GP cover and diabetes-related hospitalisation and LOS for the hospitalisation among people with diabetes. The results showed that only 48% of people with diabetes had the perfect level of cover by GP care over a 3-year period. After adjusting for imbalance in distribution of observed covariates at the baseline, having the perfect level of GP cover was significantly associated with lower number of diabetes-related hospitalisation and shorter LOS of the hospitalisation.

Our study used a large population-based cohort linked with individuals' healthcare service records that enabled us to account for differences across a wide range of demographic, socioeconomic and clinical characteristics.[52] The self-report data provided an opportunity to include individuals at the early stage of diabetes prior to any hospitalisation for the condition which makes our study population more likely to be representative of the general population living with diabetes. The data were linked with historical administrative data from 2005, which allowed us to capture the history of complications and comorbidities to better adjust for the effect of disease severity on health service utilisation. By using empirical analytical approaches to construct the GP cover index, the study was able to explore latent patterns of GP utilisation relative to demographic and clinical characteristics that unpack further dimensions of longitudinal continuity of primary care. In addition, the study used doubly robust methods that can correct for any miss-specification of the propensity score models used in calculating IPTW.[53]

The cover index appears to be easier to interpret than indices such as regularity, which has no natural units, as it expresses the proportion of time under cover of GP care and therefore can indicate absolute levels of insufficiency of primary care utilisation. The metric can be applied at the individual, subpopulation or whole population level and therefore is suitable for both development of financial levers via payment incentives (eg, an MBS item) and monitoring utilisation of primary care. The index can also be calculated for individuals with single or no GP visits, which is better than other continuity care metrics such as regularity and usual provider index which can be only calculated when at least two GP visits were observed within a time frame[12 19]; thus unlike these two metrics, the cover index can comprehensively capture the whole population.

Table 2 Effect of cover levels on diabetes-related hospitalisations and LOS

	Diabetes-related hospitalisation			LOS diabetes-related hospitalisation			Unplanned diabetes-related hospitalisation			LOS unplanned diabetes-related hospitalisation		
	IRR	95% CI	P value	IRR	95% CI	P value	IRR	95% CI	P value	IRR	95% CI	P value
Unweighted*												
Low cover	3.2	2.6 to 4.1	<0.001	3.3	2.2 to 4.8	<0.001	1.4	1.0 to 2.1	0.06	2.8	1.4 to 5.3	0.002
Medium cover	2.9	2.6 to 3.4	<0.001	3.3	2.6 to 4.2	<0.001	1.8	1.5 to 2.3	<0.001	1.8	1.2 to 2.7	<0.001
High cover	2.8	2.7 to 3.0	<0.001	1.9	1.8 to 2.1	<0.001	1.7	1.5 to 1.8	<0.001	1.5	1.3 to 1.8	<0.001
Perfect cover	Ref			Ref			Ref			Ref		
Weighted†												
Low cover	3.2	2.0 to 5.3	<0.001	1.2	0.4 to 3.3	0.7	1.8	0.9 to 3.5	0.1	1.6	0.4 to 6.5	0.4
Medium cover	3.3	2.8 to 4.0	<0.001	1.7	1.1 to 2.8	0.02	2.0	1.4 to 2.8	<0.001	1.0	0.5 to 1.8	0.9
High cover	2.7	2.6 to 2.9	<0.001	1.7	1.3 to 2.1	<0.001	1.7	1.5 to 1.9	<0.001	1.2	0.9 to 1.6	0.1
Perfect cover	Ref			Ref			Ref			Ref		
Doubly robust estimation‡												
Low cover	3.1	2.0 to 4.9	<0.001	0.8	0.4 to 1.5	0.4	1.7	0.9 to 3.2	0.07	0.8	0.4 to 1.9	0.6
Medium cover	3.2	2.7 to 3.8	<0.001	1.7	1.3 to 2.3	<0.001	1.7	1.3 to 2.3	<0.001	0.8	0.6 to 1.3	0.4
High cover	2.8	2.6 to 3.0	<0.001	1.9	1.6 to 2.3	<0.001	1.7	1.5 to 1.9	<0.001	1.6	1.3 to 1.9	<0.001
Perfect cover	Ref			Ref			Ref			Ref		

*The negative binomial model adjusted for current health service use (frequency of GP contacts, regularity of GP contact, UPC of GP contacts and number of specialist contacts), and pretreatment covariates (age, gender, indigenous, education, level of limitation, self-report comorbidity, comorbidity, complication, duration of diabetes, history of diabetes-related hospitalisation, cover, frequency of GP contacts, regularity, UPC, number of specialist visits).
†The negative binomial model adjusted for current health service use and weighted with IPTW of observed covariates.
‡ The negative binomial model adjusted for current health service use and pretreatment covariates and weighted with IPTW of observed covariates.
GP, general practitioner; IPTW, inverse probability treatment weight; LOS, length of stay; UPC, usual provider continuity.

This study has some limitations. Whereas efforts were made to facilitate a reasonable interpretation of GP cover, the classification of cover index into different levels may not be an optimal approach. As both cover index and the main interest outcome were measured simultaneously, caution is required when interpreting any causal relationship between the cover of GP care and diabetes-related hospitalisations since both were measured over the same period. To partially counteract this, the study controlled for imbalance in the observed demographic and clinical characteristics using IPTW calculated from GPS. Hospitalisations classified as diabetes-related hospitalisation in this study may not be all truly avoidable by effective GP care as discussed in literature.[54–56] To further explore this, we evaluated a second outcome, unplanned diabetes-related hospitalisations which, because of their emergency admissions status are more likely to represent hospitalisations that are unexpected and result from uncontrolled clinical events. We found that the association of the perfect level of GP cover remained significant when we limited the outcome to unplanned diabetes-related hospitalisations confirming that increasing GP cover reduces unplanned hospitalisation, likely via better management of the condition. This study included individuals with diabetes identified using only history of diabetes oral medications such as metformin and liraglutide. As the medications can be used for other conditions such as polycystic ovary syndrome or weight lost, the study population may include small number of people without diabetes who may introduce bias in the results. However, a similar result was observed among subpopulation which excluded the individuals identified with diabetes using only history of oral medication that indicates the potential bias due to including the individuals was minimal. This study used self-reported information to identify diabetes that may cause recall bias though the effect may be negligible as diagnosis with diabetes is a significant life event. Endogeneity may arise in this study due to failing to include all explanatory variables in the model; however, it has been mitigated by including both diabetes-related hospitalisation and cover observed in the baseline period as instrument to correct for endogeneity.[57 58]The cover index was calculated using an imposed 14-day grace period following discharge that may introduce inverse causality in the association between the cover index and hospitalisation. Sensitivity analyses of different scenarios with longer grace period and without the grace period indicated a variation in the effect of GP cover on the hospitalisation outcome. Although the 14-day grace period appears to be in line with evidence in literature,[46–50 59] a study to provide further validation of this grace period should be considered to improve performance of the cover index.

Our findings suggest that there is an opportunity for avoiding hospital admissions for people with diabetes through proactively providing GP care within an optimal time period. This result is in line with the previous studies which looked at primary care MBS reimbursement items containing time components.[26 60] The items such as the annual cycle of care item, annual review of GP management plan item and team care arrangement item were found significantly associated with lower risk of hospitalisation among people with diabetes.[26 60]

Our finding is supported by numerous literature which implies timeliness support is an important factor to improve patients' health outcomes. Building on the philosophy of the chronic care models, a systematic review emphasised that supporting self-management is the most frequent element that is consistently associated with improving patients' outcomes.[61] The most effective strategies to support self-management of diabetes require timely provision of information and advice, often repeatedly that tailored to current needs of patients with diabetes.[62] The timeliness support can offer opportunities for re-engagement with health professionals and reinforcement knowledge of diabetes that enable people with diabetes to re-evaluate their perception of diabetes and empowers them in making treatment decision.[62] The lack of timeliness support often leads to a cumulative deficit for people with diabetes in enduring effective self-management of their condition.[62] This is in line with a qualitative study which found that the perception and knowledge of diabetes controllability often diminished over time due to nature progress of disease regardless of compliance with recommended self-care activities.[63] Thus, self-diabetes care activities are not always done effectively due to complexity of their own realities.[62 64] Regular contacts their GP for check-ups facilitate a chance of not only receiving preventive advice but also adapting care regimens to be suitable with patients' circumstances.[64–66] However, the time between GP contacts has not been fully integrated in most current indices such as frequency of visits, regularity of contact and usual provider of care indices. The cover index integrates with the potentially protective effect that provides useful indicator to evaluating performance of primary healthcare in managing chronic conditions.

In term of GP-led model of care, GPs are in the best position to manage care, coordinate with appropriate specialists and continuously reviewing and updating care plans because of their deep knowledge and close relationship with the patient.[67] In addition, GPs rather than other specialists can offer a superior care by not primarily focusing on the condition but on the condition in the context of the patients' other health problems.[4] Regular having GP care is therefore necessary to maintain high-quality care for people with complex condition like diabetes.[65] Burridge and Foster[64] valued the established routines of the GP-led model of care as it creates a positive environment and sense of an alliance with healthcare professionals which was conducive to diabetes management.[64] Thus, although GP visit can be for other than diabetes care, it still has potentially protective effect on overall diabetes-related health outcomes. A significant association GP cover and hospitalisation found in our study again confirmed the central role of GP in effective management of diabetes. Thus, facilitate the perfect level

of cover of GP care for people with diabetes would be a possible strategy to improve health outcomes for people with diabetes and effectively reduce avoidable hospitalisation and LOS.

CONCLUSION

Our study found that longitudinal continuity of care in terms of a time under cover of the protective effect of GP contact is associated with reduction in admissions and LOS of both diabetes-related hospitalisation and unplanned diabetes-related hospitalisation. These results provide a more comprehensive view of continuity of primary care and information valuable for the design interventions and policy levers aimed at optimising disease management for people with diabetes, allocating health resources and improving quality and effectiveness of healthcare.

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Patient and public involvement Patients and/or the public were involved in the design, conduct, reporting or dissemination plans of this research. Refer to the Methods section for further details.

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