Regularity of contact with general practitioners and diabetes-related hospitalisation through a period of policy change: A retrospective cohort study

David Youens¹, David B Preen², Mark Harris³, Cameron Wright¹ and Rachael Moorin¹

Abstract
Background: This study evaluated changes in regularity of general practitioner (GP) contact (the pattern of visits over time) and the impact of regularity on diabetes-related hospitalisation following introduction of care co-ordination incentives.

Methods: Linked primary care, hospital and death records covered West Australian adults from 1991–2004. Different eras were evaluated based on incentive program changes and model fit, to assess changes in regularity. Changes in regularity, derived from the variance in the number of days between GP contacts, were evaluated using ordered logistic regression. The impact of regularity on hospitalisation rates and costs were evaluated.

Results: Two eras prior to program introduction (1991/92–1994/9 and 1995/96–1998/99), and one after (1999/2000–2002/03) were assessed. Among 153,455 at risk of diabetes-related hospitalisation GP contact became slightly less regular in the second era, though there was no change from the second to third era. The most regular decile had 5.5% fewer hospitalisations (95% CI -0.9% to -9.9%) and lower per-patient costs (difference AU$115, CI -$63 to -$167) than the least regular. Associations were similar in each era.

Conclusions: Ongoing relationships between GPs and patients are important to maintaining health. Historical data provide the opportunity to assess the impact of care co-ordination incentives on relationships.

Keywords
general practice, hospital utilisation, incentives

Summary of findings and implications for managers
This analysis of historical data provides a unique opportunity to examine the impact of financial incentives designed to improve the general practice management of complex patients with chronic disease. Findings suggest that through the study period regular GP contact was associated with reductions in diabetes-related hospitalisation. Neither these associations nor GP regularity changed substantially over time nor following the introduction of the program, possibly due to a low initial program uptake. For service managers, this highlights the value of maintaining ongoing relationships with patients, using a different metric to the more commonly used continuity of care measures.

Background
Australian health expenditure over the last 15–20 years has been growing at 5% annually¹ and as a consequence Australia, like developed countries elsewhere, faces challenges in the funding and delivery of health care. One

¹School of Population Health, Faculty of Health Sciences, Curtin University, Perth, Australia
²School of Population and Global Health, The University of Western Australia, Crawley, Australia
³Faculty of Business and Law, Curtin University, Perth, Australia

Corresponding author:
David Youens, Curtin University, GPO Box U1987, Perth, AU-WA
Western Australia 6845, Australia.
Email: david.youens@curtin.edu.au
response to these challenges has been to shift service delivery from the acute to the primary health sector.

**The Australian health system**

In Australia universal health insurance is provided by the Federal Government via Medicare, covering all Australian citizens and permanent residents. General Practitioners (GPs) operate in private practices and are reimbursed for all services rendered on a fee-for-service basis via Medicare, though are free to charge patients additional co-payments. GPs have a gatekeeper role with specialist care only accessible via GP referral, and referral to allied health and hospital also common. Patients are free to visit the GP of their choice and can change providers at any time. Medicare also guarantees access to public hospitals and emergency departments (which are managed and partly funded by State governments) free of charge, and many people additionally hold health insurance providing access to private hospitals. Hospitals are accessed via referral from a GP or specialist, or following presentation at an emergency department. Western Australia covers approximately 1/3rd of the Australian continent with a population of 1.88 million at the time of the study. 80% of this population live in Perth with the majority of the State being sparsely populated.

**Policy context**

Throughout the 1990s evidence developed suggesting that health could be maintained and hospitalisations reduced through sufficient access to physicians or GPs, according to insurance coverage, and by preparation of care plans, while further studies suggested that continuity of care between the patient and physician could reduce hospitalisation and emergency department presentations. Concurrently, the concept of Ambulatory Care Sensitive Conditions (ACSCs) was developed through clinical consensus panels. As a result, the Enhanced Primary Care (EPC) model was introduced in Australia from 1999. Under this model, fee-for-service items aimed at improving the continuity and quality of healthcare provided by GPs to older Australians and those with chronic diseases were made available through the Medicare Benefits Schedule (MBS). These were expanded and repackaged as Chronic Disease Management (CDM) items in 2005. These items did not specify continuity of primary care in terms of continuity of provider.

While the cost of CDM items in the 2007/08 financial year was AUD203.8 million, little is known about their impact on potentially preventable hospitalisations (PPHs). Knowledge about the influence of patterns of GP contact on PPHs is needed to evaluate the effect of shifting the focus from acute to primary care using a mechanism focused on ongoing, regular contact with a GP.

**The role of regular GP contacts**

In this paper continuity of care is assessed as “regularity” of GP contact. This refers to the timing of patients’ GP visits, to distinguish between those having regular and irregular care. We use regular contact as a marker for ongoing proactive care, likely to reflect disease management activities. Conversely irregular contact is a marker for reactive care (i.e. exacerbations of symptoms prompting GP contacts to have “the problem fixed”). We previously found that use of EPC/CDM items by those aged ≥65 years increased regularity of GP contact for the remainder of the year, suggesting that regularity is a good marker of proactive care. Additionally, previous work has demonstrated associations between regularity and hospital/emergency department use which persist after controlling for provider continuity, indicating that regularity may be a meaningful measure distinct from continuity of provider.

Uptake of EPC items in Australia was initially low. A qualitative analysis suggested that GPs were already undertaking activities like those encouraged by the EPC program due to changes in thinking about the management of chronic disease, but not claiming the items due to their administrative complexity. Thus, it is likely that at the same time or prior to the EPC items being implemented there was already a paradigm shift in primary care that may have resulted in more regular contact. Therefore, the additional cost burden to the health system of the new MBS items to encourage a change in practice may not have been warranted.

During a period of change in Australian primary care, this study aimed to evaluate: (i) whether regularity of GP contact changed (which may indicate shifts from reactive to more proactive care), and (ii) the impact of regularity on diabetes-related hospitalisation using a community-level analysis. Findings will be of interest to policy makers and service managers who may benefit from a clearer understanding of the relationship between patterns of GP contact and hospitalisation outcomes, and will also be of interest to researchers interested in assessing continuity of care. Though this analysis uses historical data, the use of incentives in primary care continues to have contemporary relevance in Australia and elsewhere.

**Methods**

This was a whole-population retrospective cohort study using linked administrative data. Reporting follows the RECORD statement.
University of Western Australia and Curtin University Human Research Ethics Committees (reference numbers RD-42-14 and RA/4/1/1239, respectively) which exempted the study from requiring individual patient consent.

**Data sources**

The cohort included adults aged ≥18 enrolled to vote in Western Australia (WA) at any time between 1 July 1991 and 30 June 2004. Person-level linked data covering 1980–2004 included:

1. WA mortality records;
2. WA Hospital Morbidity Data System (HMDS) records, including all private and public inpatient activity;
3. WA Electoral Roll records (1988–2004); and
4. MBS records originating in WA

WA data were linked and extracted via the WA Data Linkage System (WADLS) and MBS data by the Commonwealth Department of Health and Ageing.

**Cohort**

Though programs such as EPC often target specific diagnoses, there may also be potential for benefit among those at risk of developing the condition, and hence being hospitalised. Therefore, this analysis extends beyond those people with diabetes, to include people at high risk of the condition. For each financial year (1 July–30 June) individuals were classified into one of two risk groups: confirmed diabetes or risk of diabetes. Confirmed diabetes was indicated by any of: (i) diagnosis on any hospital record (code 250 using ICD-9-CM and E10-E14 using ICD-10-AM); (ii) diabetes cycle of care consultation in MBS data (a reimbursement to the GP for completing a set of annual diabetes management activities); (iii) quantitation of fructosamine for diabetes management in MBS data; or (iv) quantitation of HbA1c in MBS twice within six months. Risk of diabetes was indicated by: (i) impaired glucose function in hospital data (790.2 in ICD-9-CM or E09, R73 or O24.5 in ICD-10-AM); (ii) an oral glucose tolerance test outside pregnancy in MBS data; (iii) HbA1c quantitation once within six months in MBS data; or (iv) the combination of being Indigenous, aged ≥45 and diagnosed as obese on any hospital record. ICD-9-CM data did not allow differentiation between diabetes types.

Individuals entered either risk group on the day they met the criteria for that group and exited upon permanent outward migration from WA, death or study end.

In Australia the Electoral Roll captures address changes once registered, and hence indicates residence within the study area (WA). Cohort entry was 1 July in the first full year from 1990 in which an individual resided within WA and had entered one of the risk groups. Eligible person-time was restricted to full financial years individuals were in a risk group, alive and resident in WA.

**GP contact**

GP contact was captured via MBS claims for “Attendances by General Practitioners”, as described previously. Briefly, for each GP visit within a financial year the number of days since the previous GP visit was calculated (which for the first visit in a given year, will have taken place in the prior year), and the coefficient of variation in this number of days was calculated. An annual index (R) was constructed using the formula $R = 1/(1 + \text{Coefficient of Variation(Days)})$, resulting in a score between 0 and 1 per person-year, with 1 indicating perfectly regular contact. Deciles were created from least to most regular. Calculation required at least two GP contacts within a financial year, person-years with fewer contacts were excluded.

Contact with GPs was also characterised in terms of frequency (i.e. the annual count of contacts) as this likely reflects health status and health-seeking propensity.

**Outcomes**

Diabetes-related PPHs and hospitalisations where diabetes was identified as a significant risk factor by Davis et al. were classified as diabetes-related hospitalisations using HMDS data. Hospitalisations where diabetes was a significant risk factor included certain circulatory disorders, visual disorders, renal complications, and others. Outcomes were the number and cost of these hospitalisations in each financial year, with inter-hospital transfers counted as a single episode. Costs were based on Australian-refined diagnostic related groups (AR-DRGs) which were first developed in 1992. They were developed by clinical colleges, derived from the DRGs previously developed in the United States with a national costing study run to determine the appropriate cost weights for each AR-DRG. Cost weights are now updated annually based on a representative sample of hospital separations for each AR-DRG. For this sample, bottom-up costs are calculated, and the mean cost across the sample for each AR-DRG is used to reimburse hospitals for episodes of care. New AR-DRG versions are released every 4–5 years. In this study the costs applied to each separation in each year are specific to the AR-DRG version and cost weights which were in use in that year. Although separate cost-weights exist for public and private hospitals, public hospital cost weights have been applied to all separations in
this study so as to prevent health system changes (e.g., private health insurance incentives) influencing results.

**Time periods (eras)**

The study data cover a period of change in primary care practice and policy in Australia. As such, the study period was divided into eras to test for changes in regularity or associations between regularity and hospitalisation. The period from 1999/2000 to 2002/03 was treated as a separate era to the period from 1990/91 to 1998/99, reflecting the introduction of the EPC program. We additionally tested for changes prior to the program’s introduction, following international experience. In the United Kingdom, the Quality Outcomes Framework (QOF) was introduced in 2004. This was a pay-for-performance scheme under which family practices were offered financial incentives to perform and record a range of chronic disease management activities. Evaluations have found that although there was improvement in these activities following the QOF, many of these improvements had begun prior to implementation of the framework. We therefore tested for changes in regularity and associations of interest in the lead-up to the introduction of the EPC.

We considered several approaches with respect to the number and timing of eras, using Akaike and Bayesian Information Criterion (AIC/BIC) values. We considered firstly a two-era variable (the cut-point being the introduction of the EPC program) and then three-level era variables where the earlier cut-point was varied from 1993/94 to 1997/98. Additionally, a MEDLINE search was conducted to understand the development of relevant literature through this period to better understand potential changes in practice and patient management. The search included papers published from 1985 to 2004 assessing the impact of managed (as opposed to ad-hoc) primary care on hospitalisation for ACSCs (search strategy detailed in online Additional file 1, pages 1 to 4). Cut-off values were primarily based on AIC/BIC values, with published literature assessed to guide discussion of the likely ‘face validity’ of these in the context of discussion via published research.

**Covariates**

Sex, age and indigenous status were captured in datasets. Socio-economic status (SES) and service accessibility were based on the Socio-Economic Index for Areas (Index of Relative Socio-economic Disadvantage) and Accessibility/Remoteness Index of Australia applied annually, based on postcode. Comorbidity was ascertained using the Multipurpose Australian Comorbidity Scoring System (MACSS) defined as the count of MACSS conditions, excluding diabetes, on HMDS data in the previous five years, updating annually.

Frequency of GP and specialist physician contacts in each exposure year were included in models. We included measures of past health service use, as these are associated with future hospitalisation including hospitalisations, the count of GP contacts and mean regularity decile in the 3 years prior to the exposure year.

The number of years available for identification of cohort members was captured as a count for each person based on time within the study area. Changes in the availability of tests was controlled for through the use of binary variables for each method of cohort identification, flagging which individuals had recorded each potential method of cohort entry prior to each study year.

**Analysis**

Stata SE Version 14.2 was used. The data formed panels with multiple years per person. Panels were unbalanced and complex as individuals may have exited and re-entered the study area. Analyses related regularity to hospitalisation in the following year, preventing reverse causation. Descriptive statistics were generated for socio-demographics and service use across eras. Changes in regularity across eras was evaluated using multivariable random effects ordered logistic regression. The adjusted percentage change in the probability of being in each regularity decile was determined based on the predicted probabilities of each category and the marginal effects of era using the Stata margins command.

Hospitalisation data are typically characterised by high numbers of zero counts and right-skewed distributions, making Poisson regression models unsuitable. Zero-inflated negative binomial (ZINB) models were therefore used for hospitalisation count outcomes, while Cragg-hurdle models were used for hospitalisation cost outcomes. Descriptions of these models are available in Jones et al. along with equations and discussion of the application of these models to health service use data. In the ZINB model the zero component contained a constant term only. Appropriateness of the ZINB model, in comparison to a zero-inflated Poisson, was assessed based on the significance of the dispersion parameter reported by Stata’s ZINB command, following Cameron and Trivedi. The multivariable Cragg-hurdle model was clustered with robust standard errors, a lower limit of zero and no upper limit. The hurdle model combined (i) a selection model that determined if an individual had a diabetes-related hospitalisation, and (ii) an outcome model determining the cost for these hospitalisations. The covariates for the selection model were determined using logistic regression.
with diabetes-related hospitalisation as the dependent variable. Significant covariates were used in the selection model while the outcome model used all covariates. Models were pooled versions with clustering at the person level, and employed Mundlak variables (i.e. group-means of time-varying variables: age, count of GP contacts, count of specialist contacts, comorbidity history, and regularity) to proxy the fixed effects, reducing potential bias introduced by unobserved heterogeneity. A detailed description of this approach to using Mundlak variables is available in Schunck et al.

Analysis included interactions of regularity and the era variable to understand how associations between regularity and hospitalisation outcomes may have changed across eras.

Associations between regularity of GP contact and hospitalisation were ascertained using the –margins– command, with marginal effects produced at each level of the era variable.

Robustness check

A robustness check was performed to assess the potential influence of migration to or from the study area. Analysis examining the count and costs of hospitalisations were repeated, limited to those cohort members who did not migrate to or from the study area (though could exit the study due to death).

Results

Eras

In comparison to an era variable with one cut-point (in 1999/00, reflecting the introduction of EPC), AIC/BIC values were lowest for the count model with three eras, the second of which started in 1994/95 (Figure 1(a)). The cost model had the lowest AIC score when the second era began in 1995/96 and the lowest BIC score for the two era model, followed by a three era model with the second era starting in 1995/96. All remaining analyses are based on three eras, with the second era starting in 1994/95, for consistency.

Care co-ordination literature

Results of the literature search on the topic of managed/co-ordinated primary care and hospital use are displayed in Figure 1. The search identified few publications on this topic appearing in the literature from 1993, with a substantial increase in the literature in the late 1990’s and further increases in the early 2000’s. More detailed search results are presented in online Additional file 1, pages 5 to 8.

Cohort characteristics

The cohort included 153,455 individuals and increased with successive eras (Table 1). Compared to the first era, cohort members in the last era were slightly younger, more likely to be male, less likely to be non-Indigenous (the remainder including Indigenous and unknowns), less likely to have diabetes (as opposed to high risk), less likely to have died during the study period, lived in areas of less disadvantage and which were more accessible. The median annual number of GP visits declined slightly across eras as did the likelihood of diabetes-related hospitalisation.
When changes in regularity across eras were evaluated, adjusting for confounders (Figure 2), there was a significant though small reduction in the probability of higher regularity categories and a similar increase in the probability of the lower regularity categories from era 1 to era 2. These changes were minor, with the proportion in deciles 5 or above decreasing by only about two percent. From era 2 to era 3 there was no change in the probability of each category.

**Associations between regularity and hospital use**

Only relationships between regularity and hospitalisation are presented here; for detailed outputs of the hospitalisation count model see Table 1 in online Additional file 2, for the cost model see Table 3 in online Additional file 3.

Table 2 presents marginal effects of regularity of GP contact on (A) the rate and (B) the annual cost of diabetes-related hospitalisations. There were differences in the baseline annual costs over time, due to changes in funding algorithms and policies to reduce length of stay. Therefore, in Figure 4 outcomes are presented as proportional changes in hospitalisation costs (i.e. the marginal change relative to the predicted mean for the baseline group). Table 2 and Figures 3 and 4 display that overall there was a pattern of decreasing hospital use with increasing regularity, though there were some differences between count and cost outcomes.

### Table 1. Cohort characteristics at first year in each era (A) and health service use across eras (B).

| (A) Status of individuals at entry into era | Era 1 (1991/2–1993/4) Mean (95% CI) | Era 2 (1994/5–1998/9) Mean (95% CI) | Era 3 (1999/0–2002/3) Mean (95% CI) | Significance3 p-value |
| --- | --- | --- | --- | --- |
| Age4 | 58.72 (58.55–58.90) | 57.02 (56.91–57.12) | 57.24 (57.17–57.32) | <0.001 |
| Gender | | | | |
| Female | 14,620 (51.59%) | 39,602 (50.39%) | 70,080 (50.28%) | <0.001 |
| Male | 13,717 (48.41%) | 38,990 (49.61%) | 69,308 (49.72%) | |
| Indigenous | 26,123 (92.19%) | 78,592 (90.88%) | 124,016 (88.97%) | <0.001 |
| Risk status | | | | |
| High risk | 9,663 (34.10%) | 44,921 (57.16%) | 89,258 (64.04%) | <0.001 |
| Confirmed diabetic | 18,671 (65.90%) | 33,671 (42.84%) | 50,130 (35.96%) | |
| Died during study | 9,830 (34.69%) | 12,470 (15.87%) | 6,934 (4.97%) | <0.001 |
| SEIFA IRSD1 quintile* | | | | |
| Highest disadvantage | 5,844 (20.62%) | 14,857 (18.90%) | 25,103 (18.01%) | <0.001 |
| High disadvantage | 8,996 (31.75%) | 21,517 (27.38%) | 34,965 (25.08%) | |
| Moderate disadvantage | 4,260 (15.03%) | 11,148 (14.18%) | 19,966 (14.35%) | <0.001 |
| Less disadvantage | 3,504 (12.37%) | 11,565 (14.72%) | 22,792 (16.35%) | |
| Least disadvantage | 5,632 (19.88%) | 18,819 (23.95%) | 34,966 (25.09%) | |
| Accessibility to services (ARIA2)* | | | | |
| Very remote | 826 (2.91%) | 2,043 (2.60%) | 3,781 (2.71%) | <0.001 |
| Remote | 591 (2.09%) | 1,347 (1.71%) | 2,114 (1.52%) | |
| Moderately accessible | 1,679 (5.93%) | 3,461 (4.40%) | 6,456 (4.63%) | |
| Accessible | 1,586 (5.60%) | 3,694 (4.70%) | 7,462 (5.35%) | |
| Highly accessible | 23,572 (83.18%) | 67,381 (85.74%) | 118,013 (84.67%) | |
| Total number of individuals in the cohort | 28,337 | 78,582 | 139,388 | |

| Use of health services | Era 1 (1990/1–1994/5) Median (IQR) | Era 2 (1995/6–1998/9) Median (IQR) | Era 3 (1999/0–2002/3) Median (IQR) | Significance P-value |
| --- | --- | --- | --- | --- |
| Annual number of GP visits5 | 9 (5–14) | 8 (5–14) | 7 (4–12) | <0.001 |
| Probability of diabetes related hospitalisation | 11.87% | 8.32% | 7.29% | <0.001 |

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4Numbers in categories do not sum to the total cohort due to unknown (missing) information.
5Socioeconomic Index for Areas, Index of Relative Socio-economic Disadvantage.
6Accessibility and Remoteness Index for Australia.
7Significance testing based on Chi-squared test unless otherwise stated.
8Significance testing based on ANOVA test.
9Significance based on Kruskal-Wallis test.

**Changes in regularity**

When changes in regularity across eras were evaluated, adjusting for confounders (Figure 2), there was a significant though small reduction in the probability of higher regularity categories and a similar increase in the probability of the lower regularity categories from era 1 to era 2. These changes were minor, with the proportion in deciles 5 or above decreasing by only about two percent. From era 2 to era 3 there was no change in the probability of each category.
Results show that compared to the baseline (least regular) decile, increasingly regular GP contact was associated with significant reductions in hospitalisation. Compared to the least regular group, the second most regular and most regular groups had 6.9% (95% CI 2.8% to 10.7%) and 5.5% (95% CI 0.9% to 9.9%) fewer hospitalisations, respectively. In the first era there was no significant association between regularity and the hospitalisation rate due in part to a smaller group size and larger standard errors, though point estimates showed similar patterns. In the second era the second most regular and most regular deciles were associated with reductions of 9.8% (95% CI 3.0% to 16.2%) and 8.4% (1.3% to 15.0%) respectively. In the final era the second most regular decile was associated with a 5.5% lower (95% CI 0.1% to 10.7%) hospitalisation rate though the most regular decile did not differ significantly from baseline. The dispersion parameter, \( \alpha \), was significant (see Table 1 in online Additional file 2), indicating that the negative binomial regression adopted was more appropriate than a Poisson model.

Results for the cost outcome were similar to those for the hospitalisation rate (Table 2 and Figure 4), although in this case significant associations were observed at lower levels of regularity rather than only at the highest levels. Across the entire study period the most regular decile had lower costs by $115 (95% CI $63 to $167). In the first era the most regular category was associated with a $264 reduction in inpatient costs (95% CI $96 to $431). In the second era significant reductions were observed from the sixth decile onwards, and these reductions were similar in scale from the sixth to the most regular decile, where a reduction of $108 (95% CI $22 to $194) was observed. In the final era significant reductions were observed across all deciles except the second and fourth least regular; in the most regular decile a reduction of $96 (95% CI $33 to $159) compared to baseline was reported. Figure 4 presents the same information, with costs at each decile instead presented as a percentage change from the adjusted baseline cost in each era, to allow a comparison in effects accounting for different baseline costs.

**Robustness check**

In the robustness check limited to those who did not migrate to or from the study area, the cohort size was reduced by approximately 25%. Incidence rate ratios for the hospitalisation count outcome did not change dramatically in comparison to the main analysis. Overall, the two highest regularity deciles had significantly reduced hospitalisations in comparison to the least regular, as was the case in the main analysis. These relationships attenuated across eras.

Negative associations between regularity and hospitalisation cost remained, though were slightly diminished. Overall, these negative associations were significant from the 5th most regular decile and above, compared to the main analysis where all deciles had significantly lower hospitalisation costs than the least regular reference group. The effect attenuated across eras, as with the main analysis. Results from the robustness check relating to the count model are in Table 2 in online...
Table 2. (A) IRR\(^1\) for hospitalisation count and (B) change in annual cost\(^2\) ($AUD2017\(^3\)) by regularity category.

| Regularity                        | A: Hospitalisation rate | B: Hospitalisation costs |
|-----------------------------------|-------------------------|--------------------------|
|                                   | N\(^4\)                 | IRR  | 95% CI | Change  | 95% CI |
|-----------------------------------|-------------------------|------|--------|---------|--------|
| **Full study period (1990/91–2002/03)** |                         |      |        |         |        |
| Least regular                     | 68,563                  |      |        |         |        |
| 2                                 | 68,564                  | 0.981| 0.936, 1.029 | −60.42 | −108.22, −12.62 |
| 3                                 | 68,563                  | 0.993| 0.948, 1.040 | −64.88 | −112.10, −17.65 |
| 4                                 | 68,564                  | 0.978| 0.935, 1.023 | −52.32 | −100.17, −4.48 |
| 5                                 | 68,563                  | 0.979| 0.932, 1.028 | −92.30 | −139.34, −45.26 |
| 6                                 | 68,564                  | 0.975| 0.931, 1.021 | −96.45 | −144.12, −47.89 |
| 7                                 | 68,563                  | 0.989| 0.942, 1.037 | −82.23 | −129.96, −34.51 |
| 8                                 | 68,564                  | 0.960| 0.915, 1.007 | −97.08 | −145.71, −48.44 |
| 9                                 | 68,563                  | 0.931| 0.893, 0.972 | −125.10| −174.53, −75.68 |
| Most regular                      | 68,564                  | 0.945| 0.901, 0.991 | −114.91| −167.31, −62.52 |
| **Era 1 (1991/2–1993/4)**        |                         |      |        |         |        |
| Least regular                     | 7,023                   |      |        |         |        |
| 2                                 | 6,012                   | 1.005| 0.870, 1.160 | −101.66| −281.54, 78.21 |
| 3                                 | 5,980                   | 0.972| 0.866, 1.091 | −60.65 | −236.82, 115.53 |
| 4                                 | 5,787                   | 0.970| 0.817, 1.150 | −58.94 | −239.11, 121.22 |
| 5                                 | 5,915                   | 1.029| 0.834, 1.270 | −158.50| −329.34, 12.33 |
| 6                                 | 5,933                   | 0.965| 0.851, 1.093 | −71.59 | −248.22, 105.04 |
| 7                                 | 5,778                   | 1.018| 0.872, 1.189 | −108.64| −281.20, 63.91 |
| 8                                 | 6,016                   | 0.906| 0.811, 1.012 | −182.81| −348.09, −17.53 |
| 9                                 | 6,127                   | 0.959| 0.848, 1.086 | −101.84| −275.16, 71.48 |
| Most regular                      | 6,477                   | 0.900| 0.802, 1.010 | −263.54| −431.18, −95.90 |
| **Era 2 (1994/5–1998/99)**       |                         |      |        |         |        |
| Least regular                     | 25,245                  |      |        |         |        |
| 2                                 | 24,115                  | 0.933| 0.864, 1.007 | −61.72 | −145.30, 21.85 |
| 3                                 | 24,135                  | 1.031| 0.934, 1.138 | −21.98 | −105.64, 61.68 |
| 4                                 | 23,896                  | 0.950| 0.879, 1.027 | −49.19 | −130.83, 32.46 |
| 5                                 | 23,531                  | 0.965| 0.891, 1.050 | −70.07 | −151.10, 10.97 |
| 6                                 | 23,111                  | 0.959| 0.880, 1.046 | −111.66| −193.57, −29.75 |
| 7                                 | 22,823                  | 0.965| 0.880, 1.060 | −98.64 | −179.16, −18.13 |
| 8                                 | 22,462                  | 0.964| 0.882, 1.053 | −87.39 | −169.21, −5.58 |
| 9                                 | 22,345                  | 0.902| 0.838, 0.970 | −115.66| −197.67, −33.65 |
| Most regular                      | 21,832                  | 0.916| 0.850, 0.987 | −107.85| −193.94, −21.73 |
| **Era 3 (1999/00–2002/03)**      |                         |      |        |         |        |
| Least regular                     | 36,295                  |      |        |         |        |
| 2                                 | 38,437                  | 1.008| 0.941, 1.079 | −53.74 | −114.63, 7.16 |
| 3                                 | 38,448                  | 0.974| 0.922, 1.030 | −91.78 | −150.80, −32.75 |
| 4                                 | 38,881                  | 0.999| 0.942, 1.059 | −54.66 | −114.70, 5.38 |
| 5                                 | 39,117                  | 0.976| 0.922, 1.034 | −95.50 | −153.87, −37.14 |
| 6                                 | 39,520                  | 0.987| 0.929, 1.050 | −93.67 | −152.31, −35.03 |
| 7                                 | 39,952                  | 0.997| 0.939, 1.059 | −69.37 | −128.34, −10.40 |
| 8                                 | 40,086                  | 0.970| 0.912, 1.031 | −90.12 | −149.63, −30.61 |
| 9                                 | 40,091                  | 0.945| 0.893, 0.999 | −136.44| −195.61, −77.27 |
| Most regular                      | 40,225                  | 0.975| 0.909, 1.045 | −95.78 | −158.64, −32.92 |

Note: Models adjusted for age\(^5\), gender, indigenous status, socioeconomic status (Socio-Economic Indexes for Areas - Index of Relative Socio-economic Disadvantage), remoteness (Accessibility/Remoteness Index of Australia), number of GP\(^6\) and specialist physician contacts\(^6\), comorbid history\(^4\), diabetes risk level, history of diabetes-related hospitalisations, history of primary care contacts, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity\(^6\), era, era-regularity interaction and group-means of time-varying variables (denoted by \(^6\)).

\(^1\)Incidence Rate Ratio indicating change in the predicted rate per person-year from reference group, derived from negative binomial regression.

\(^2\)Change in the predicted annual mean cost per person from reference group, derived from Cragg Hurdle regression.

\(^3\)As updated inflation multipliers were released during the study, models were applied to data in $AUD2014 and results later inflated to $AUD2017.

\(^4\)Crude count in category in each era.
Additional file 2, and for the cost outcome are presented in Table 4 in online Additional file 3.

**Discussion**

Where a patient has regular GP contact, this may impact health by facilitating the detection of changes in health and treatment modification. Results here indicated that regular GP contact was associated with a reduction in the number and cost of diabetes-related hospital admissions, and this association was fairly similar across the periods prior to and following the EPC program introduction. While effect sizes were small at the individual level, they are significant from a practice perspective when considering the high prevalence of diabetes. There were slight differences in associations observed for hospitalisation count and cost outcomes. Reduced hospitalisation rates were observed only at the highest levels of regularity whereas with regards to costs, significant associations were observed from lower levels of regularity, compared to baseline. The different modelling techniques might account for this, though it is also plausible that contact with the GP might mean that a change in condition is detected early which results in hospitalisation for management of the acute problem, preventing further deterioration which might otherwise have resulted in a more complex and costly admission. Similar findings have been observed in chronic care models previously.\(^30\)

Previous work has demonstrated that where GPs claim EPC items, regularity increased in the following year,\(^11\) contrasting with the lack of change observed here following the introduction of EPC. It may be the case that the initial low uptake of the program meant that these individual level changes were outweighed in the current analysis by broader population trends. Practice sizes in Australia were increasing through the study period\(^31\) which is associated with lower interpersonal continuity (i.e. patients less likely to see the same provider).\(^32\) This could result in irregular contact if patients and doctors are less likely to schedule follow-up appointments, for example. Additionally, although the literature search in this paper identified only a few publications on the topic of managed care prior to the EPC program.
introduction, through the 1990s various guidelines for diabetes management were developed. It is possible therefore that the introduction of the EPC program represented policy catching up with changes in practice, rather than policy driving practice change.

In 2004 the EPC program was replaced by the CDM program and uptake increased. This may have resulted in shifts towards more regular contact, though the current study does not capture this period. The historical data used here provide a unique opportunity to inform about the utility of regularity of contact as a distinct domain (and potential policy lever) which may not be possible today due to the proliferation of policies encouraging ongoing contact. In recent years primary care policies have been proposed and introduced with the potential to influence preventive contacts and therefore regularity of GP care, hence evidence regarding associations with hospitalisation outcomes remains relevant.

Similar efforts to promote the primary care management of diseases have been made internationally. In the United Kingdom the QOF was introduced in 2004. Though this is much broader in scope than any program attempted in Australia, the QOF has similarities to the EPC/CDM in that it provides financial incentives for practices and providers to perform and document a range of activities aimed at the prevention and management of chronic disease. Improvements in the achievement rates of many QOF indicators were occurring leading up to introduction of the framework. Any similar trend in Australia might partially explain the lack of change in associations observed here following introduction of EPC. In the USA financial incentives for disease prevention and management activities have been implemented via collaborations between health plans, physician organisations and purchasers, though the incentives are inevitably different, reflecting different purchasing arrangements.

Strengths and limitations

The use of longitudinal, whole-population data and variety of datasets available have several major strengths. The use of administrative data prevents sampling or non-response bias. It also enabled a look-back prior to the study start date capturing potential heterogeneity on a range of factors. Address data allowed us to capture migration to/from the study area and correct person-time at risk of hospitalisation. The fact that the data were panel allowed for the group means of time-varying variables to be added to models as a means to control for unobserved time-invariant individual level factors. Information on comorbidities, previous hospitalisation and frequency of GP contacts were included to control for health status and remove potential bias from effects of regularity.

Figure 4. Associations between regularity of GP contact and diabetes-related hospitalisation costs. Associations are presented separately for the entire study period (a) and for eras 1, 2 and 3 (b to d). Covariates included age, gender, indigenous status, socioeconomic status (Socioeconomic Index for Areas), remoteness (Accessibility/Remoteness Index of Australia), number of GP and specialist physician contacts, comorbid history, history of diabetes-related hospitalisations, diabetes risk level, years available for ascertainment of diabetes status, presence of individual diabetes status/risk indicators, regularity, era regularity interaction and group-means of time-varying variables (denoted by *). Error bars represent 95% confidence intervals.
A common issue in administrative data is the lack of clinical information available. Although we identified separate cohorts of people with and at risk of diabetes, detailed clinical data may improve adjustment for confounding. Similarly, MBS data provides little contextual information on services provided. We had no information on health service use outside of WA, so people diagnosed with diabetes elsewhere will not have entered the cohort until they used services within WA. As this study is observational we cannot make inferences regarding causation. A particular concern is unobserved variables which may influence associations. There are some differences in the cohort demographics between eras. To reduce the potential for changes in diagnostic practices to cause differences in associations between eras we included as covariates the length of time in the study population (i.e. available for entry in to the cohort) and variables for each method of cohort entry, flagging which indicators each person had recorded. Variables such as the comorbidity indicators should additionally control for potential changes in the overall health of the cohort between eras. The use of eras, though informative in understanding changes in relationships over time, should be interpreted with caution. In particular, the division between eras 1 and 2 was selected based on AIC/BIC values rather than reflecting a discrete practice change; the differences between these eras in reality reflects more gradual trends across this decade. Finally, findings may differ substantially for conditions other than diabetes.

Conclusion
Among a cohort at risk of diabetic related hospitalisation, more regular GP contact was associated with a small reduction in diabetes-related hospitalisation, and this association was fairly consistent in the periods prior to and following the introduction of policies aimed at improving the primary care management of chronic disease. The apparent protective effect of regular contacts is relevant to health service managers, and poses the question as to which component of continuity of primary care is the most important in further reducing potentially preventable hospitalisations. Given the significant financial investment in programs to improve the quality of chronic disease management in Australia and other developed countries, further investigation of this with contemporary data is warranted.

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ORCID iD
David Youens https://orcid.org/0000-0002-4296-4161

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