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Diabetes mellitus monitoring and control among adults in Australian general practice: a national study

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Abstract

Objectives: Regular monitoring of clinical parameters among patients with diabetes mellitus is essential for diabetes control and early detection of complications, especially among those with a recent diagnosis. This study investigated whether the monitoring and control of clinical parameters in patients with past or newly recorded diabetes diagnosis differed by sociodemographic or clinical characteristics.

Design: Retrospective cohort study.

Setting: MedicineInsight, a national general practice database in Australia.

Participants: This study included 101,875 regular adults with past (2015-2016) and 9,236 with newly recorded (2017) diabetes diagnosis who visited their doctor in 2018.

Main outcome measures: 'Well-controlled' diabetes was defined as HbA1c ≤7.0%, blood pressure (BP) ≤140/90mmHg, and total cholesterol <4.0mmol/L. Adjusted odds ratio (OR) and adjusted probabilities (%) were obtained based on logistic regression models adjusted for practice variables and patients' sociodemographic and clinical characteristics.

Results: HbA1c was monitored in 45.2% (95% CI, 42.6-47.7) of patients with past and 39.4% (95% CI, 37.1-41.7) with newly recorded diabetes. The monitoring of HbA1c, BP, or total cholesterol levels was no better among smokers, patients with hypertension or cardiovascular disease compared to patients without these risk factors. HbA1c control was achieved by 54.4% (95% CI, 53.4-55.4) and 78.5% (95% CI, 76.8-80.1) of monitored patients with past or newly recorded diabetes, respectively. Less than 20% of patients had their HbA1c, BP, and total cholesterol levels controlled. Patients with a history of CVD were more likely to have the three clinical parameters controlled than those without a history of CVD, especially among those with newly (adjusted OR=2.43, 95%CI 1.85-3.19) than past recorded diabetes (adjusted OR=1.39, 95%CI 1.30-1.49).

Conclusions: The monitoring of clinical parameters among patients with diabetes attending Australian general practices was suboptimal, and only one in five of these patients achieved control of all clinical parameters.

Keywords: Epidemiological Monitoring, Evidence-Based Practice, Population Health

Strengths and limitations of this study

- This is the first national study to investigate diabetes monitoring and control based on electronic medical records, using a large sample of patients attending primary healthcare services across all Australian states and territories.
- This study explored socioeconomic and clinical variables related to diabetes monitoring and control that were not included in the most recent Australian studies on the same topic.
- Some other relevant covariates (e.g., diet and exercise) were not explored, as they are not consistently recorded in the electronic medical records, or are recorded in the progress notes which cannot be extracted because of confidentiality issues.
- Patients may have had their diabetes parameters monitored somewhere else (e.g., different practices or specialists). To minimize it, we used different fields to identify laboratory results that were not requested and automatically reported to the practice by the laboratories.

Introduction

Diabetes mellitus is a lifelong disease that requires regular monitoring and control to reduce the risk of diabetes-related complications.[1-5] Micro- and macrovascular complications of uncontrolled diabetes (e.g., hypertension, dyslipidaemia, chronic kidney disease-CKD, cardiovascular disease-CVD) increase the health burden worldwide.[6] Blood glucose control is the most critical clinical goal of diabetes management, but other clinical variables also require regular monitoring.[3] The Royal Australian College of General Practitioners (RACGP) guideline recommends patients with diabetes should have their HbA1c, blood pressure (BP), and lipid levels evaluated annually to improve management and control of these clinical parameters.[7] However, different stages of diabetes, such as recent or past diagnosis, may require different management strategies. In the early stages, diabetes treatment includes lifestyle modification and usually, metformin. However, depending on individual factors, such as the presence of co-morbidities, the treatment may include other options.[7] Since diabetes is a progressive disease, maintaining controlled target levels with monotherapy is often possible for several years, after which combination therapy may be necessary. Monitoring clinical parameters is essential to evaluate and modify management accordingly.[8] However, gaps between real-world practice and guideline recommendations for diabetes management have been reported worldwide.[4,9-11] For instance, a survey of 305 primary care physicians in the US showed that 38% of them reported using guidelines for diabetes management.[9]

A systematic review including 123 Australian studies found that approximately 50% of patients with diabetes received 'standard care' (i.e., assessment of HbA1c, BP, lipids, weight, eye, foot health). Among those assessed, 40-60% met management targets for HbA1c, BP, or lipid levels, but the study did not report the proportion that had all three parameters under control.[11] Most studies included in that review used EMRs to investigate diabetes control. However, most studies also sourced data from specialized centres rather than primary healthcare settings, or

used non-representative samples, hindering the generalizability of the results at a national level. Additionally, other potential determinants of diabetes management and control (e.g., sociodemographic and clinical variables) were not widely investigated. Despite these limitations, figures in that review are consistent with measured data from Australian Health Survey (AHS) (2011-2012), which reported that 54.7% of adults with known diabetes met the HbA1c target (≤7.0%), 39% the recommended BP target, and 38% the total cholesterol (TC) target.[12]

Although EMR-based primary care databases have not been widely used, they can provide accurate information on diabetes prevalence,[13-15] management and control.[11,16] EMR-based research can improve diabetes management without increasing overall treatment costs.[17,18] Moreover, EMR databases minimize self-report bias by providing information on doctor-reported diagnoses, objective laboratory results, and prescribed medications.[13,14,19]

Thus, this study used a national general practice database to investigate 1) the proportion of patients with diabetes who had their clinical parameters for diabetes management monitored in 2018; 2) the proportion of those monitored who achieved diabetes control (i.e., HbA1c, BP, TC); and 3) whether diabetes monitoring or control was influenced by sociodemographic, cardiovascular risk factors or co-morbidities. These aims were assessed according to whether patients had past or newly recorded diabetes in the EMRs.

Methods

Data Source

We used retrospective data from an open cohort database (MedicineInsight) that includes de-identified EMRs from approximately 662 general practices (8.2% of all Australian practices) and over 2,700 general practitioners (GP) across Australia.[19] Details of data extraction and database characteristics have been published elsewhere.[19] Although practices in

MedicineInsight were selected using a non-random process, all Australian states and territories, urban and rural settings and socioeconomic settings are represented in the database. Diagnostic algorithms used for identifying patients with chronic disease using MedicineInsight have been validated, showing sensitivity of 89% against the recording of diabetes in the original EMR.[14]

Study Sample

This study was reported according to the REporting of studies Conducted using Observational Routinely collected health Data Statement.[20] Only data from practices with regular data provision (i.e., no gap of more than 6-weeks in data provision in the previous two years) was included. The sample was adults (18+ years) who regularly attended the practice (i.e., those with at least one consultation per year between 2015-2018 and had a diagnosis of diabetes (either type 1 or type 2). Using 4-years of data to define the cohort was necessary to differentiate patients with past or newly recorded diabetes diagnosis (2015-2017), and to ensure all patients had at least one visit in the last 12 months (2018) that the GP could have used to monitor their clinical parameters.[7]

Three fields ('diagnosis', 'reason for encounter', 'reason for prescription') were initially searched to identify patients with recorded diabetes diagnoses. The original search was based on the methods for data extraction used by MedicineInsight.[14,19] It included standard clinical terminology, misspellings, and abbreviations, and then expanded to include prescribed medications and laboratory results. Using as much information as possible from EMRs (i.e., observations, medications, diagnostic information) can provide a more accurate picture for identifying diabetes.[21] Besides, including laboratory results from EMRs are associated with higher rates of diabetes ascertainment.[22,23]

Patients were classified as having past recorded diabetes (i.e. past diabetes) if between Jan/2015-Dec/2016: 1) 'diabetes' was recorded in two different fields; OR 2) antidiabetic

medications were prescribed [Anatomical Therapeutic Chemical A10A or A10B;[24] metformin was considered only in the absence of polycystic ovary syndrome diagnosis]; OR 3) a diabetes diagnosis was recorded only once BUT there was at least one recorded laboratory result (fasting blood glucose, HbA1c or 2-hour oral glucose tolerance test) above the diabetes diagnosis threshold within the same timeframe.[7] Patients were classified as having newly recorded diabetes (i.e. recent diabetes) if: 1) they did not meet the criteria for past recorded diabetes AND 2) between Jan-Dec 2017 they presented any of the three criteria mentioned above for diabetes diagnosis (i.e., 'diabetes' recorded in two fields, antidiabetic medications were prescribed OR 'diabetes' was recorded once only but there was at least one abnormal glycaemic result recorded in 2017).

Outcomes

The first group of outcomes was the proportion of patients with diabetes who had their clinical parameters for diabetes management checked in 2018 (i.e., HbA1c, BP, TC, low-density lipoprotein-LDL, high-density lipoprotein-HDL, triglycerides, estimated glomerular filtration rate-eGFR, or albumin to creatinine ratio-ACR).[7] These clinical parameters were obtained from the fields 'observations' and 'laboratory results' using Logical Observation Identifiers Names and Codes.[25]

According to the guideline, patients with diabetes should achieve recommended targets for all clinical parameters (i.e. HbA1c, lipids [TC, HDL, LDL, non-HDL, triglycerides], BP, and urine albumin excretion).[7] However, three key parameters (HbA1c, BP and TC) can be used to define 'well-controlled' diabetes, since they indicate that patients can comprehensively manage their diabetes and reduce the risk of complications.[10,11] Therefore, the second group of outcomes was the proportion of patients, among those checked, that achieved recommended targets in 2018 [HbA1c≤7.0%, BP≤140/90mmHg, TC<4.0mmol/L]. When multiple results were

reported in 2018 for the same parameter and patient, the mean of these results was estimated and used for analysis.

'Well-controlled' diabetes was then explored using three different approaches. First, we analysed each clinical parameter as a different outcome: i) controlled HbA1c, ii) controlled BP, or iii) controlled TC. Second, based on whether each of these three parameters was controlled or not, we created an outcome variable with eight categories to explore the most frequent combination of parameters that were under control: 1) none controlled, 2) HbA1c only, 3) BP only, 4) TC only, 5) HbA1c and BP controlled, 6) HbA1c and TC controlled, 7) BP and TC controlled, or 8) all controlled. Finally, a binary variable examining the proportion of patients who had all three key parameters controlled. All the outcomes were explored separately for patients with past or newly recorded diabetes.

Covariates

Covariates included a group of sociodemographic and cardiovascular risk factors/history of CVD that may affect diabetes control.[5,26] Practice data included practice remoteness [major cities, inner regional, or outer/remote/very remote] and practice Index of Relative Socioeconomic Advantage and Disadvantage [IRSAD quintiles]. Remoteness and IRSAD were defined based on postcodes. Remoteness is determined according to the population size and average distance to services, while IRSAD is an area-level measure of socioeconomic status based on combined indicators (i.e., household income, education, and working status). Higher IRSAD scores indicate a more advantaged area.[27] Patient variables included age [18-39, 40-64, 65+], gender [females, males], smoking status [smoker, ex-smoker or non-smoker], recorded history of hypertension, and recorded history of CVD [including heart failure, ischemic heart disease, or stroke] during 2015-2017. Details on the data extraction methods for these variables have been published elsewhere.[14,28]

Statistical Analysis

All analyses were performed in Stata 16.1 (StataCorp, Texas, USA), considering the practices as clusters, using robust standard errors and conditioned to the number of visits to the practice.

The distribution of sociodemographic and clinical characteristics among patients with past or newly recorded diabetes were presented as proportions with their corresponding 95% confidence intervals (95%CI) (categorical variables), or as means with their standard deviation or median with their interquartile range (numerical variables).

All results for the monitoring of parameters or achieving recommended targets in 2018 (i.e. each parameter controlled and all three key parameters controlled) were adjusted for any unbalance in the distribution of sociodemographic (sex, age, IRSAD, remoteness) or clinical variables (smoking, history of hypertension or CVD) between the investigated groups. Therefore, logistic regression models were used to assess differences in diabetes monitoring or diabetes control (binary outcomes) between patients with past or newly recorded diabetes, adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), or CVD risk factors (smoking status, history of hypertension or CVD). The same regression models were used to investigate the association between practice and patient variabl33es with the investigated outcomes (i.e. monitoring or control of clinical parameters). We reported adjusted odds ratios (ORs) with their corresponding 95%CI rather than p-values, following recommendations of the American Statistical Association.[29] Any association between sociodemographic and clinical characteristics was reported as ORs. Furthermore, results from the adjusted logistic regression models were also used to estimate adjusted predicted probabilities (i.e. adjusted proportions) of the investigated outcomes using the command 'margins' in Stata.

Multinomial logistic regression models were used to compare whether the most frequent combination of parameters under control differed between patients with past or newly recorded diabetes, using a similar approach for adjustment and then obtaining the adjusted ORs and adjusted probabilities for each category of the outcome.

Patient and Public Involvement

None

Results

Population Characteristics

Our sample included 111,111 adult patients from 541 practices with recorded diabetes diagnosis who had at least one annual consultation between 2015-2018 (51.7% males; mean age 65.3±15.0 years). Of them, 101,875 patients had past recorded diabetes (diabetes recorded in 2015-2016) and 9,236 had newly recorded diabetes (diabetes recorded in 2017 but not in previous years) (figure S1 and table S1). Patients with past recorded diabetes were older (mean 65.9±14.6 vs. 58.1±17.1 years), had a higher proportion of males (52.2% vs. 46.3%) or had a history of CVD (13.8% vs. 12.9%), but hypertension diagnosis was less frequent (36.5% vs. 38.5%) than those with newly recorded diabetes. However, the distribution according to remoteness, IRSAD, or smoking status was similar in both groups (table S2).

<Figure 1>

Diabetes Monitoring

Figure 1 and tables S3 and S4 report the adjusted proportions and corresponding ORs of patients with past or newly recorded diabetes that had their clinical parameters monitored in 2018. Overall, monitoring of any parameter [i.e., HbA1c, BP, TC, HDL, LDL, triglycerides,

eGFR or ACR] was more frequent among patients with past than newly recorded diabetes. The most frequently monitored parameter was BP [past diabetes, 84.3% (95%CI 83.3-85.3); recent diabetes, 81.4% (95%CI 80.0-82.8)]. The least monitored parameter was ACR [past diabetes, 17.4% (95%CI 16.8-18.0); recent diabetes, 13.5% (95%CI 12.6-14.3)]. Although 45.2% (95% CI 42.6-47.7) of those with past diabetes and 39.4% (95%CI 37.1-41.7) with recent diabetes had their HbA1c levels monitored in 2018, an additional 15% in each group had their glycaemic parameters checked through fasting or random glucose levels (table S3).

All three key parameters were more frequently monitored among people living in rural or remote areas, attending practices in the lowest IRSAD quintile, or the elderly group (65+years) (table 1). However, there was no difference according to smoking status, or history of CVD, either among patients with past or newly recorded diabetes. Nonetheless, males with recent diabetes were more likely to have all parameters assessed than females (adjusted OR=1.27, 95%CI 1.14-1.41), but this difference was not evident among those with past diabetes (adjusted OR=1.09, 95%CI 1.06-1.13). Among patients with recent diabetes, monitoring of all parameters was slightly more frequent among those with a history of hypertension (adjusted OR=1.20, 95%CI 1.07-1.34), but no differences were found among patients with past diabetes (adjusted OR=1.11, 95%CI 1.04-1.19). Table S5 reports the adjusted proportions of these analyses.

Table 1. Adjusted odds ratio† of patients who had all three parameters (HbA1c, blood pressure, and total cholesterol) monitored, among those with past (2015-2016) or newly recorded diabetes (2017), according to sociodemographic and clinical characteristics

All three parameters monitored	Patients monitored among those with past recorded diabetes (n=101,875) Odds Ratio (95%CI)	Patients monitored among those with newly recorded diabetes (n=9,236) Odds Ratio (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	Ref	Ref
Inner regional	1.02(0.77-1.35)	1.08(0.83-1.40)
Outer/Remote/Very	1.56(1.15-2.10)	1.55(1.16-2.09)
GP IRSAD quintiles		
Very low	Ref	Ref
Low	0.73(0.52-1.03)	0.70(0.50-0.97)
Middle	0.83(0.58-1.17)	0.68(0.49-0.94)
High	0.84(0.59-1.20)	0.81(0.57-1.17)
Very High	0.72(0.51-1.04)	0.77(0.54-1.10)
Patient's characteristics		
Gender		
Female	Ref	Ref
Male	1.09(1.06-1.13)	1.27(1.14-1.41)
Age group (years)		
18-39	Ref	Ref
40-64	2.80(2.57-3.04)	3.23(2.66-3.91)
65+	3.12(2.82-3.45)	3.97(3.23-4.88)
Smoking status		
Non-smoker or ex-smoker	Ref	Ref
Smoker	0.90(0.86-0.95)	0.96(0.82-1.12)
History of hypertension		
No	Ref	Ref
Yes	1.11(1.04-1.19)	1.20(1.07-1.34)
History of CVD		
No	Ref	Ref
Yes	0.95(0.90-1.00)	0.98(0.84-1.13)

† Adjusted odds ratio of patients had all three parameters (HbA1c, blood pressure, and total cholesterol) monitored based on logistic regression models that considered differences among patients with past or newly recorded diabetes in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD). The adjusted proportions of these analyses are reported in table S5.

GP: general practice; Ref: reference group; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Well-controlled Diabetes

Table 2 shows the adjusted proportion of patients that achieved clinical goals for diabetes management in 2018 among those with available results for each of the three key parameters (i.e. adjusted for sex, age or other differences between those with past or newly recorded diabetes). Patients with recent diabetes were 44% more likely to have their HbA1c controlled (78.5%) than those with past diabetes (54.4%). Nevertheless, TC control was 31% more frequent among those with past (43.9%) than recent diabetes (33.6%). Systolic-BP control was not different across both groups, but diastolic-BP control was slightly higher among those with past than recent diabetes. The corresponding adjusted ORs are reported in table S6. Furthermore, table S7 shows the proportion of patients with normal kidney function (i.e., eGFR and/or ACR) among those monitored in 2018. Patients with recent diabetes were more likely to have normal kidney function parameters than patients with past diabetes (eGFR: 85.6% vs. 78.0%; ACR: 75.2% vs. 67.9%, respectively).

Table 2. Adjusted proportion† of patients with controlled clinical goals in 2018 for diabetes management among those with available results for the three key parameters (HbA1c, blood pressure, and total cholesterol)

Clinical parameters	Past recorded diabetes (2015-2016) n=40,008		Newly recorded diabetes (2017) n=2,912	
	% (95%CI)	Crude mean ± SD	% (95%CI)	Crude mean ± SD
HbA1c controlled (≤7.0% or ≤53 mmol/mol)				
No	45.6 (44.6-46.6)	8.2 ± 1.1	21.5 (19.9-23.2)	8.2 ± 1.2
Yes	54.4 (53.4-55.4)	6.3 ± 0.5	78.5 (76.8-80.1)	6.1 ± 0.5
Blood pressure controlled				
Systolic (≤140mmHg)				
No	29.5 (28.4-30.5)	150.8 ± 9.2	28.4 (26.6-30.2)	150.5 ± 9.0
Yes	70.5 (69.5-71.6)	127.3 ± 9.2	71.6 (69.8-73.4)	127.2 ± 9.4
Diastolic (≤90mmHg)				
No	5.4 (5.1-5.8)	95.4 ± 4.8	7.3 (6.4-8.1)	95.3 ± 4.5
Yes	94.6 (94.2-94.9)	74.7 ± 8.3	92.7 (91.9-93.6)	76.9 ± 7.8
Total cholesterol controlled (≤4.0mmol/L				
No	56.1 (55.1-57.0)	5.0 ± 0.9	66.4 (64.5-68.2)	5.1 ± 0.8
Yes	43.9 (43.0-44.9)	3.4 ± 0.4	33.6 (31.8-35.5)	3.4 ± 0.4

† Adjusted proportions of patients who had each clinical parameter controlled based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD). The adjusted odds ratios of these analyses are reported in table S7.

95%CI: 95% confidence interval; SD: Standard deviation; HbA1c: Glycated haemoglobin.

Table 3 shows the combination of the three key parameters that were more frequently controlled in 2018. The proportion of patients with diabetes that met the three recommended targets was similar whether they had past (17.4%, 95%CI 16.7-18.1) or newly recorded diabetes (18.8%, 95%CI 17.2-20.3). Nonetheless, the proportion of patients with none of these parameters under control was lower among those with newly (5.1%, 95%CI 4.3-5.9) than past recorded diabetes (8.8%, 95%CI 8.3-9.4). Moreover, patients with newly recorded diabetes were more likely to have their HbA1c controlled, either alone (16.8%) or in combination with a second clinical parameter (35.6% with BP and 7.2% with TC; 42.8% combined) than those with past diabetes (9.9% for HbA1c alone and 27.1% combined with a second parameter). Table S8 reports the corresponding adjusted ORs for the combination of parameters.

Table 3. Adjusted proportion† of the combination of clinical parameters controlled in 2018 among patients with past (2015-2016) or newly recorded diabetes (2017) and available results for all three parameters (HbA1c, blood pressure, and total cholesterol)

	Past recorded diabetes (n= 40,008)		Newly recorded diabetes (n= 2,912)	
	n	**% (95%CI)**	**N**	**% (95%CI)**
None controlled	3,521	8.8 (8.3-9.4)	148	5.1 (4.3-5.9)
Only HbA1c controlled	3,961	9.9 (9.4-10.4)	489	16.8 (15.4-18.3)
Only BP controlled	6,761	16.9 (16.3-17.5)	259	8.9 (7.9-9.9)
Only total cholesterol controlled	2,360	5.9 (5.5-6.2)	61	2.1 (1.6-2.5)
HbA1c and BP controlled	8,202	20.5 (19.8-21.1)	1,036	35.6 (33.7-37.5)
HbA1c and total cholesterol controlled	2,641	6.6 (6.2-7.0)	209	7.2 (6.1-8.3)
BP and total cholesterol controlled	5,601	14.0 (13.6-14.5)	163	5.6 (4.6-6.5)
All controlled	6,961	17.4 (16.7-18.1)	547	18.8 (17.2-20.3)

† Adjusted proportion of the most frequent combination of clinical parameters controlled in 2018 based on multinomial logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD). The adjusted odds ratios of these analyses are reported in table S8.

95%CI: 95% confidence interval; HbA1c: Glycated haemoglobin; BP: blood pressure.

Table 4 explores whether having all three key parameters controlled ("all-controlled") was different by sociodemographic or clinical variables. The frequency of 'all-controlled' diabetes increased with age. Males were more likely to be 'all-controlled' than females, whether they had past (adjusted OR=1.50, 95%CI 1.41-1.58) or newly recorded diabetes (adjusted OR=1.76, 95%CI 1.44-2.16). Patients with a history of CVD were more likely to be 'all-controlled', especially among those with newly (adjusted OR=2.43, 95%CI 1.85-3.19) than past recorded diabetes (adjusted OR=1.39, 95%CI 1.30-1.49). However, the distribution of 'all-controlled' diabetes did not differ according to practice remoteness, IRSAD, patient smoking status or history of hypertension. Tables S9-S11 present the relationship between sociodemographic and clinical characteristics and the control of each separated parameter. Table S12 and S13 report the adjusted proportions of the 'all-controlled' and 'none-controlled' outcome, respectively.

Table 4. Adjusted odds ratio† of distribution of patients with all three clinical parameters controlled according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Variables	'All-controlled' among past recorded diabetes (n=40,008) % (95%CI)	'All-controlled' among newly recorded diabetes (n=2,912) % (95%CI)
	Odds Ratio (95%CI)	Odds Ratio (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	Ref	Ref
Inner regional	1.05(0.93-1.20)	1.11(0.85-1.44)
Outer/Remote/Very Remote	0.94(0.80-1.10)	0.91(0.67-1.24)
GP IRSAD Quintiles		
Very low	Ref	Ref
Low	1.02(0.89-1.16)	0.87(0.63-1.22)
Middle	1.00(0.86-1.18)	1.02(0.75-1.38)
High	0.96(0.81-1.13)	0.80(0.56-1.15)
Very High	1.03(0.89-1.20)	0.74(0.52-1.04)
Patient's characteristics		
Gender		
Female	Ref	Ref
Male	1.50(1.41-1.58)	1.76(1.44-2.16)
Age group (years)		
18-39	Ref	Ref
40-64	1.78(1.38-2.30)	1.24(0.75-2.04)
65+	3.31(2.58-4.24)	2.09(1.26-3.47)
Smoking status		
Non-smoker or ex-smoker	Ref	Ref
Smoker	0.91(0.83-1.00)	1.11(0.85-1.46)
History of hypertension		
No	Ref	Ref
Yes	0.91(0.85-0.96)	1.02(0.84-1.23)
History of CVD		
No	Ref	Ref
Yes	1.39(1.30-1.49)	2.43(1.85-3.19)

† 'All-controlled' are those patients with HbA1c≤7.0%, BP≤140/90mmHg, and total cholesterol ≤4.0mmol/L. Adjusted odds ratio of patients who had each clinical parameter controlled based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD). The adjusted proportions of these analyses are reported in table S12.

GP: general practice; Ref: reference group; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Discussion

This paper highlighted five main findings. Less than half of patients with diabetes had their HbA1c levels assessed over 12 months, and the frequency of monitoring of that or other clinical parameters was less frequent among patients with newly than past recorded diabetes. Second, monitoring of HbA1c, BP, and cholesterol was not more frequent among smokers, patients with hypertension or a history of CVD. Third, although they were less likely to be tested, eight out of ten patients with newly recorded diabetes achieved HbA1c control. Fourth, less than 20% of patients with diabetes who were monitored in 2018 had their HbA1c, BP and TC within targeted levels considered 'well-controlled'. Finally, patients with history of CVD were more likely to be 'well-controlled' than those without CVD, especially among those with newly recorded diabetes.

Current Australian guidelines recommend annual monitoring of clinical parameters for all patients with diabetes.[7] Nonetheless, we found 45.2% of those with past diabetes and 39.4% of those with newly recorded diabetes had their HbA1c levels monitored in 2018. The HbA1c records in the EMRs may be partly underestimated as some patients may be referred to diabetes specialists once they are confirmed to have diabetes, although this may represent a small proportion, as management plans are expected to be reviewed regularly by GPs.[7] Our results are consistent with the 'Rule of Halves' discussed in an Australian review, showing that half of patients with diabetes receive appropriate diabetes care/monitoring, and half of those receiving care achieve management goals.[11] Another recent Australian retrospective study not included in that review and using EMRs from patients attending 50 practices in the inner eastern region of Melbourne (MAGNET database, period 2009-2014) found 66.5% of patients (65+years) with T2D had their HbA1c checked within the last two years. Among those monitored, 42.4% achieved HbA1c control (i.e. levels ≤7.0% in the most recent laboratory result).[30] Our findings are also consistent with evidence from the AHS (2011-2012), which

reported that 54.7% of adults with known diabetes achieved HbA1c levels ≤7.0% (i.e. 54.4% among patients with past recorded diabetes in our study).[12]

Among other clinical parameters, BP was the most frequently monitored. This observed prevalence did not differ from a population-based study in South Australia that showed 81.8% of individuals without diabetes, hypertension or CVD had their BP measured by a GP in the last 12 months.[31] It was concerning that only one in four patients with diabetes had reported results on their kidney function in the last 12 months, even among those with past recorded diabetes. Diabetes and hypertension are the most important causes of CKD, and annual kidney health checks (eGFR and urine ACR) are strongly recommended for these patients.[32]

It is also concerning that a history of smoking, hypertension and CVD did not affect the monitoring of the three investigated parameters because they contribute to absolute CVD risk and diabetes-related co-morbidities.[3] A British EMR-based study indicated that despite optimal control of different CVD risk factors (i.e., HbA1c, systolic-BP, TC, triglycerides, smoking), patients with diabetes still had a 21% higher CVD risk than those without diabetes, reinforcing the need to monitor and control these parameters.[33]

Although patients with newly recorded diabetes were less likely to have their HbA1c monitored, eight out of ten of those monitored achieved HbA1c control. Patients with newly recorded diabetes were, on average, eight years younger than those with past diabetes, which suggests their condition was at an earlier stage when complications are less frequent and diabetes control is more likely to be achieved with first-line medications.[2,3] Additionally, medication adherence among patients with newly diagnosed diabetes can be as high as 65% then reducing over time, which, in turn, has been found to impact diabetes control.[34] Nonetheless, the possibility of information bias introduced by the less frequent HbA1c monitoring among those with newly recorded diabetes cannot be discounted as an alternative explanation.

Another finding that corroborates results from the AHS (2011-2012)[12] is how the proportion of patients with well-controlled diabetes increases with age. Older patients were more likely to achieve diabetes control than younger patients, even among those with newly recorded diabetes. This could be explained by the fact that older patients visit their GP more frequently, allowing more opportunities to have disease management monitored. However, a previous study using the MedicineInsight database showed that despite greater regularity and continuity of care being associated with an increased likelihood of HbA1c monitoring, it did not influence HbA1c control among patients with diabetes.[35]

Our results for the proportion of patients with controlled BP or TC were higher than findings from the review of Australian studies (2020), but comparable for HbA1c control. Overall, that review reported that 52%, 42%, and 15% of patients met treatment targets for HbA1c, BP and TC, respectively.[11] The use of different cut-off points for BP could explain the discrepancies for that parameter, as the criteria used in the review were lower (≤130/80mmHg)[11] than ours (≤140/90mmHg), which was based on the existing Australian guideline during the investigated period (2016-2018). Furthermore, many of the studies in that review analysed data sourced from specialist centres instead of general practices or included non-representative samples, which reduces comparability with our results.

Among those monitored, only one in five achieved targeted goals for the three key parameters. Unexpectedly, the proportion of those 'well-controlled' was higher in men. According to the literature, males are less likely to use health services, have less knowledge on the risk factors for diabetes/CVD or diabetes-related complications, are less adherent to lifestyle recommendations and chronic conditions tend to be diagnosed at a more advanced stage than women.[36-38] However, although men exhibit greater clinical risk overall, the risk substantially increases among women in middle-adulthood when diabetes is more likely to be diagnosed.[37] Additional results (table S11) show the parameter responsible for this finding was TC control,

which was 44-68% more frequent among men, while the other two parameters were slightly more frequent in women.

Our study also found that patients with a history of CVD were more likely to achieve 'well-controlled' parameters, especially when they had recent diabetes diagnoses. This finding might be related to the co-administration of antihypertensive and lipid-lowering therapy among patients with a history of CVD to reduce the risk of new CVD events.[39] Discrepancies between patients with past or recent diabetes diagnosis could result from incidence-prevalence bias, and prospective studies would be necessary to elucidate these findings.

The study has significant strengths, such as the use of a large sample of patients attending primary healthcare services across all Australian states and territories. Furthermore, we explored socioeconomic and clinical variables related to diabetes monitoring and control that were not included in the most recent Australian studies on the same topic. Nonetheless, some other relevant covariates (e.g., diet and exercise) were not explored, as they are not consistently recorded in the EMRs, or are recorded in the progress notes which cannot be extracted because of confidentiality issues. This is a common limitation of EMR-based studies, as data from progress notes may affect completeness of information used for analysis. Additionally, patients may have had their diabetes parameters monitored somewhere else (e.g., different practices or specialists). To minimize it, we used different fields to identify laboratory results that were not requested and automatically reported to the practice by the laboratories. Despite using widely accepted target levels for the clinical parameters investigated, they may be adjusted and tailored to individual characteristics, which may not be feasible to differentiate in large epidemiological studies. Finally, prevalence-incidence bias may have affected some of the investigated associations (e.g., history of CVD and hypertension) among patients with past or newly recorded diabetes.

Conclusions

In Australia, monitoring and achieving clinical targets for diabetes management appears to be suboptimal. Consistent with previous research, we found half of the patients with diabetes had a record of their glycaemic levels being checked over 12 months. However, the recording of other laboratory parameters was less frequent, and only 25% of them had an eGFR or ACR recorded in the previous 12 months. Moreover, 80% of all those monitored did not achieve HbA1c, BP, and TC targets recommended by the guideline, regardless of the time of diabetes diagnosis. Multi-component interventions for early detection and management of risk factors and complications, intensive glycaemic control in persons with newly diagnosed diabetes, statin therapy for secondary CVD prevention, and intensive hypertension control with angiotensin-converting enzyme inhibitors or angiotensin receptor blockers to prevent end-stage renal disease are some of the cost-effective strategies highlighted in the literature that could be incorporated and emphasized in standard diabetes care programs.[40,41] Further studies are necessary to examine whether systematic implementation of these strategies in Australian primary health settings can optimize diabetes management in line with guidelines.

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Data Availability Statement

Data used in this study was obtained from a third party (MedicineInsight) for this specific project and cannot be released. Information about MedicineInsight data and how they can be accessed is available on the website (https://www.nps.org.au/medicine-insight). The data

extraction algorithms used in this study are available from the corresponding author upon request.

Contributors

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Competing Interests

The authors declare no conflict of interest.

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Patient and Public Involvement

It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

Ethics Approval Statement

The independent MedicineInsight Data Governance Committee approved the study (protocol 2016-007). The Human Research Ethics Committee of the University of Adelaide exempted the study from an ethical review as it used de-identified data.

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Supplemental material

Figure S1. Flowchart of the identification of 'regular' adult patients with recorded diabetes and HbA1c control† Table S1. Sociodemographic and clinical profile of regular patients† aged 18+ years in the MedicineInsight database

Table S2. Sociodemographic and clinical profile of regular patients† aged 18+ years with past (2015-2016) or newly recorded diabetes (2017)

Table S3. Adjusted proportion† of patients who had their clinical parameters monitored‡ in 2018 among those with past (2015-2016) or newly recorded diabetes (2017)

Table S4. Adjusted odds ratio† of patients who had their clinical parameters monitored‡ in 2018 among those with past (2015-2016) or newly recorded diabetes (2017)

Table S5. Adjusted proportion† of patients who had all three parameters (HbA1c, blood pressure and total cholesterol) monitored, among those with past (2015-2016) or newly recorded diabetes (2017), according to sociodemographic and clinical characteristics

Table S6. Adjusted odds ratio† of patients with controlled clinical goals in 2018 for diabetes management among those with available results for the three key parameters (HbA1c, blood pressure, and total cholesterol), past recorded diabetes as reference group†

Table S7. Adjusted proportion† of patients with 'normal' kidney function among those with past (2015-2016) or newly recorded diabetes (2017) who had information on eGFR or ACR and the three key parameters (HbA1c, blood pressure, and total cholesterol)

Table S8. Adjusted odds ratio† combination of clinical parameters controlled in 2018 among patients with past (2015-2016) or newly recorded diabetes (2017) and available results for all three parameters (HbA1c, blood pressure, and total cholesterol)

Table S9. Adjusted distribution† of patients with controlled HbA1c according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, blood pressure and total cholesterol)

Table S10. Adjusted distribution† of patients with controlled blood pressure according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, BP and total cholesterol)

Table S11. Adjusted distribution† of patients with controlled total cholesterol according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, blood pressure, and total cholesterol)

S12 Table. Adjusted distribution† of patients with all three clinical parameters controlled according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Table S13. Adjusted distribution of 'none-controlled' † diabetes according to sociodemographic and clinical characteristics among patients with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, blood pressure, and total cholesterol)

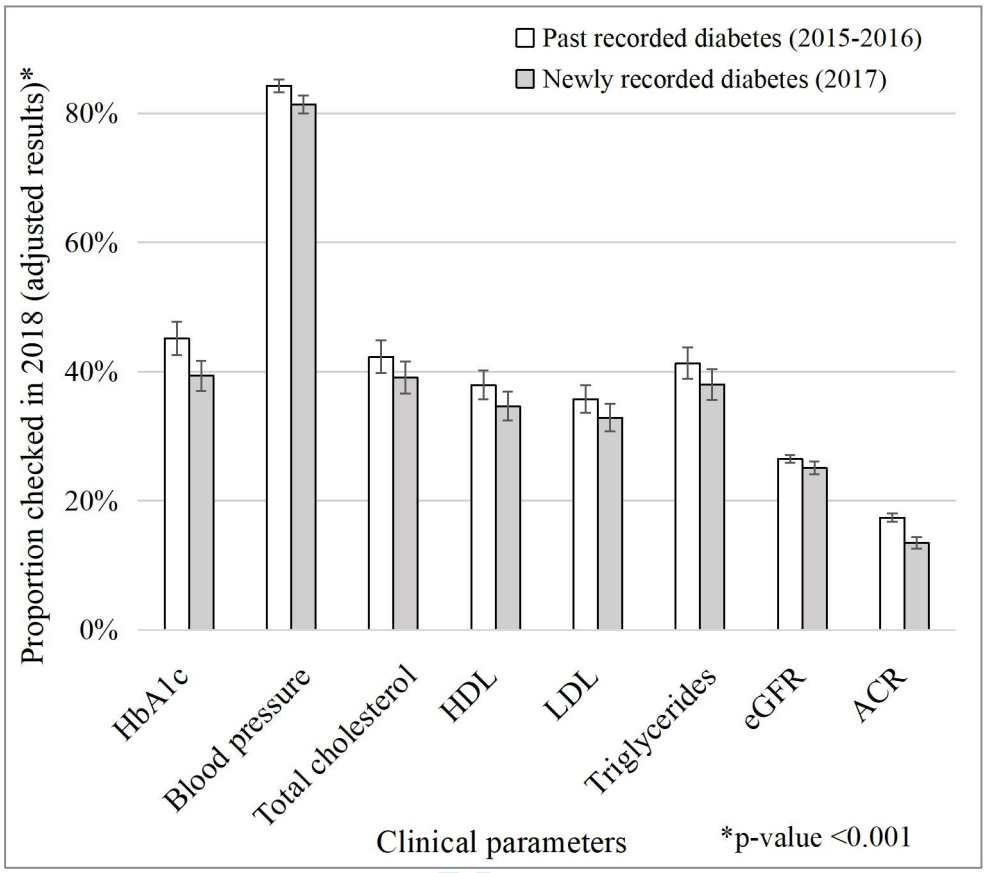


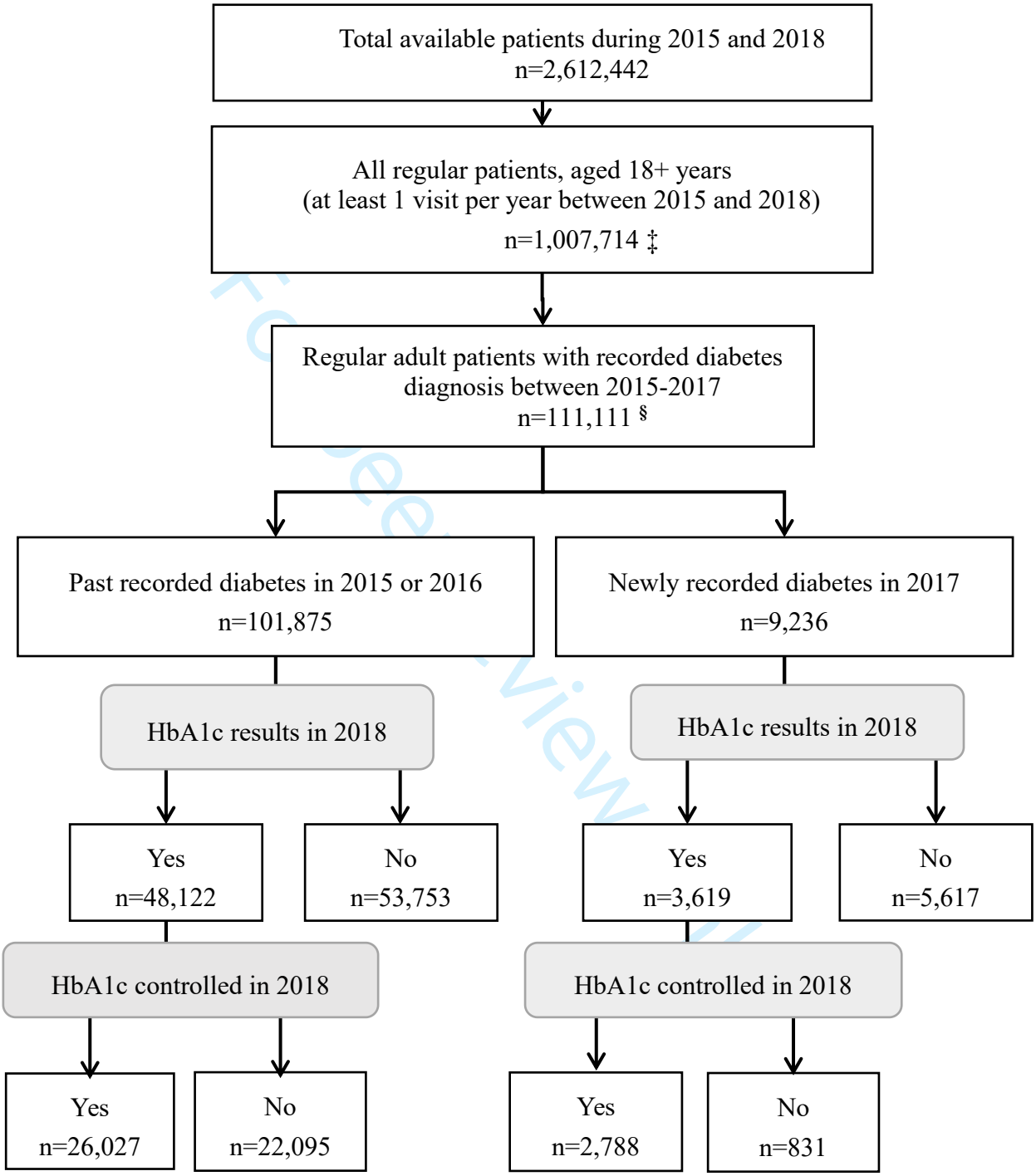
Figure 1. Adjusted proportion of patients with clinical parameters monitored in 2018 among those with past (2015-2016) or newly recorded diabetes (2017).

* Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD) using logistic regression models. Vertical lines represent the 95% CI. Due to the large sample size, all comparisons between patients with past or newly recorded diabetes returned p-values <0.01

HbA1c: Glycated haemoglobin; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; eGFR: estimated Glomerular Filtration Rate; ACR: Urine albumin-to-creatinine ratio.

Supplemental material

Figure S1. Flowchart of the identification of 'regular' adult patients with recorded diabetes and HbA1c control†



† Results are shown as absolute numbers from the dataset without adjusting or weighting. Adjusted proportions are shown in Table 1. ‡ At least one consultation per year between 2015-2018. § Patients were classified as recorded diabetes when 1) 'diabetes' was recorded on two different occasions (as a 'diagnosis', 'reason for encounter', or 'reason for prescription', OR 2) antidiabetic medications were prescribed (Anatomical Therapeutic Chemical A10A or A10B; metformin was considered only in the absence of polycystic ovary syndrome diagnosis), OR 3) diabetes diagnosis was recorded only once, but there was at least one laboratory result (fasting blood glucose, HbA1c or 2-hour oral glucose tolerance test) above the diabetes threshold.

Table S1. Sociodemographic and clinical profile of regular patients[†] aged 18+ years in the MedicineInsight database

	Distribution of regular patients (n=1,007,714) % (95%CI)
Practice characteristics	
Geographical area of GP	
Major Cities	63.8 (59.4-68.2)
Inner regional	24.8 (20.6-28.9)
Outer/Remote/Very Remote	11.4 (8.5-14.4)
GP IRSAD quintiles	
Very low	17.1 (13.2-21.0)
Low	16.0 (12.3-19.7)
Middle	23.6 (19.2-27.9)
High	18.6 (14.8-22.4)
Very High	27.1 (22.7-31.4)
Patient's characteristics	
Gender	
Males	40.4 (39.9-40.9)
Age, Mean ± SD	54.0 ± 19.1
Age group (years)	
18-39	26.2 (25.1-27.2)
40-64	40.9 (40.4-41.4)
65+	33.0 (31.7-34.2)
IRSAD Quintiles	
Very low	17.1 (16.2-18.0)
Low	17.4 (16.2-18.5)
Middle	23.7 (22.4-25.1)
High	19.0 (17.7-20.3)
Very High	25.5 (24.3-26.7)
Smoking status	
Smoker	12.0 (11.6-12.4)
History of hypertension	
Yes	19.5 (18.9-20.0)
History of CVD	
Yes	5.5 (5.4-5.7)
Consultations in 2018, Median (IQR)	4 (2-8)

[†] People had at least one visit per year between 2015 and 2018. Results were adjusted for practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD) using logistic regression models.

GP: general practice; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; IQR: Interquartile range; SD: Standard deviation; CVD: Cardiovascular diseases including heart failure, ischaemic heart disease, and stroke.

Table S2. Sociodemographic and clinical profile of regular patients† aged 18+ years with past (2015-2016) or newly recorded diabetes (2017)

Variables	Sample distribution	
	Past recorded diabetes (n=101,875) % (95%CI) ‡	Newly recorded diabetes (n=9,236) % (95%CI) ‡
Practice characteristics		
Geographical area of GP		
Major Cities	59.4 (54.6-64.2)	62.3 (57.2-67.4)
Inner regional	27.4 (22.8-32.1)	25.0 (20.3-29.7)
Outer/Remote/Very Remote	13.2 (9.8-16.5)	12.7 (9.2-16.1)
GP IRSAD quintiles		
Very low	21.6 (16.9-26.3)	20.3 (15.8-24.9)
Low	17.9 (13.9-22.0)	18.6 (14.1-23.0)
Middle	25.0 (20.3-29.6)	24.6 (19.8-29.4)
High	16.1 (12.6-19.5)	17.8 (13.9-21.7)
Very High	20.9 (17.1-24.7)	20.9 (17.0-24.7)
Patient's characteristics		
Gender		
Male	52.2 (51.6-52.7)	46.3 (44.9-47.7)
Age, Mean ± SD	65.9 ± 14.6	58.1 ± 17.1
Age group (years)		
18-39	5.8 (5.4-6.2)	15.8 (14.6-17.0)
40-64	34.9 (34.0-35.7)	43.0 (41.7-44.4)
65+	59.4 (58.2-60.5)	41.2 (39.5-42.9)
IRSAD Quintiles		
Very low	21.3 (20.2-22.3)	20.7 (19.5-21.9)
Low	18.8 (17.5-20.1)	18.8 (17.3-20.3)
Middle	24.8 (23.4-26.1)	24.3 (22.8-25.8)
High	16.0 (14.8-17.2)	16.0 (14.6-17.5)
Very High	18.4 (17.4-19.5)	19.4 (18.2-20.7)
Smoking status		
Smoker	10.5 (10.1-10.8)	11.0 (10.3-11.7)
History of hypertension		
Yes	36.5 (35.2-37.8)	38.5 (36.9-40.1)
History of CVD		
Yes	13.8 (13.3-14.2)	12.9 (12.1-13.7)
Consultations in 2018, Median (IQR)	7 (4-13)	6 (3-11)

† People had at least one visit per year between 2015 and 2018. ‡ Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD) using logistic regression models.

GP: general practice; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; IQR: Interquartile range; SD: Standard deviation; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Table S3. Adjusted proportion[†] of patients who had their clinical parameters monitored[‡] in 2018 among those with past (2015-2016) or newly recorded diabetes (2017)

Clinical parameters monitored	Patients monitored among those with past recorded diabetes (n=101,875) % (95%CI)	Patients monitored among those with newly recorded diabetes (n=9,236) % (95% CI)
Types of blood glucose monitored [§]		
0	39.8 (37.5-42.1)	45.4 (43.0-47.7)
1	23.8 (22.4-25.2)	21.7 (20.3-23.1)
2	27.4 (25.7-29.2)	25.4 (23.6-27.1)
3	9.0 (7.9-10.1)	7.5 (6.4-8.6)
HbA1c	45.2 (42.6-47.7)	39.4 (37.1-41.7)
Blood pressure [¶]	84.3 (83.3-85.3)	81.4 (80.0-82.8)
Total cholesterol	42.3 (39.8-44.8)	39.1 (36.6-41.6)
HDL	38.0 (35.7-40.2)	34.7 (32.4-36.9)
LDL	35.7 (33.6-37.9)	32.9 (30.7-35.0)
Triglycerides	41.3 (38.9-43.7)	38.0 (35.6-40.4)
Any type of kidney function [#]	26.9 (26.3-27.5)	25.4 (24.4-26.4)
eGFR	26.5 (25.9-27.1)	25.1 (24.1-26.1)
ACR	17.4 (16.8-18.0)	13.5 (12.6-14.3)

[†] Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD) using logistic regression models. [‡] We considered all tests performed, regardless they have valid, invalid, or inconclusive results. [§] Types of blood glucose monitored in 2018 among HbA1c, fasting blood glucose and random blood glucose. [¶] Both systolic and diastolic blood pressure were monitored in 2018. [#] Any types of kidney function monitored in 2018 among eGFR and ACR.

95%CI: 95% confidence interval; HbA1c: Glycated haemoglobin; HDL: High-density lipoprotein cholesterol; LDL: Low-density lipoprotein cholesterol; eGFR: estimated Glomerular Filtration Rate; ACR: Urine albumin-to-creatinine ratio.

Table S4. Adjusted odds ratio† of patients who had their clinical parameters monitored‡ in 2018 among those with past (2015-2016) or newly recorded diabetes (2017)

Clinical parameters monitored	Odds Ratio (95% CI)
HbA1c	
Past recorded diabetes	Ref
Newly recorded diabetes	0.78(0.74-0.83)
Blood pressure¶	
Past recorded diabetes	Ref
Newly recorded diabetes	0.81(0.75-0.87)
Total cholesterol	
Past recorded diabetes	Ref
Newly recorded diabetes	0.87(0.83-0.92)
HDL	
Past recorded diabetes	Ref
Newly recorded diabetes	0.87(0.82-0.92)
LDL	
Past recorded diabetes	Ref
Newly recorded diabetes	0.88(0.83-0.93)
Triglycerides	
Past recorded diabetes	Ref
Newly recorded diabetes	0.87(0.82-0.92)
Any type of kidney function#	
Past recorded diabetes	Ref
Newly recorded diabetes	0.93(0.88-0.97)
eGFR	
Past recorded diabetes	Ref
Newly recorded diabetes	0.93(0.88-0.98)
ACR	
Past recorded diabetes	Ref
Newly recorded diabetes	0.74(0.69-0.79)

† Adjusted odds ratio of patients who had their clinical parameters monitored based on logistic regression models that considered differences among patients with past or newly recorded diabetes in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD). ‡ We considered all tests performed, regardless they have valid, invalid, or inconclusive results. ¶ Both systolic and diastolic blood pressure were monitored in 2018. # Any types of kidney function monitored in 2018 among eGFR and ACR.

Ref: reference group; 95%CI: 95% confidence interval; HbA1c: Glycated haemoglobin; HDL: High-density lipoprotein cholesterol; LDL: Low-density lipoprotein cholesterol; eGFR: estimated Glomerular Filtration Rate; ACR: Urine albumin-to-creatinine ratio.

Table S5. Adjusted proportion† of patients who had all three parameters (HbA1c, blood pressure and total cholesterol) monitored, among those with past (2015-2016) or newly recorded diabetes (2017), according to sociodemographic and clinical characteristics

Variables	Patients monitored among those with past recorded diabetes (n=101,875) % (95%CI)	Patients monitored among those with newly recorded diabetes (n=9,236) % (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	36.0 (32.9-39.2)	27.6 (25.1-30.1)
Inner regional	36.5 (31.2-41.7)	29.1 (24.8-33.3)
Outer/Remote/Very Remote	46.5 (40.6-52.5)	36.7 (31.3-42.1)
GP IRSAD quintiles		
Very low	42.2 (35.7-48.6)	34.2 (28.5-39.9)
Low	35.0 (30.1-39.8)	26.9 (23.0-30.9)
Middle	37.7 (32.7-42.6)	26.4 (22.9-29.9)
High	38.1 (33.1-43.0)	30.0 (25.4-34.6)
Very High	34.7 (30.2-39.3)	28.9 (24.9-33.0)
Patient's characteristics		
Gender		
Females	36.5 (34.3-38.7)	26.9 (25.0-28.9)
Males	38.5 (36.2-40.9)	31.6 (29.2-33.9)
Age group (years)		
18-39	17.6 (15.9-19.3)	12.0 (9.9-14.0)
40-64	37.1 (34.9-39.3)	30.1 (27.9-32.4)
65+	39.7 (37.2-42.2)	34.6 (32.0-37.2)
Smoking status		
Non-smoker or ex-smoker	37.8 (35.5-40.1)	29.2 (27.3-31.1)
Smoker	35.5 (33.2-37.8)	28.4 (25.2-31.6)
History of hypertension		
No	36.6 (34.3-39.0)	27.8 (25.7-29.8)
Yes	39.1 (36.6-41.5)	31.4 (29.1-33.6)
History of CVD		
No	37.7 (35.4-40.0)	29.2 (27.2-31.1)
Yes	36.6 (34.2-39.0)	28.7 (25.7-31.7)

† Adjusted proportion of patients who had all three parameters monitored based on logistic regression models that considered differences among patients with past or newly recorded diabetes in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Table S6. Adjusted odds ratio† of patients with controlled clinical goals in 2018 for diabetes management among those with available results for the three key parameters (HbA1c, blood pressure, and total cholesterol), past recorded diabetes as reference group†

	Patients achieved the targets of each clinical parameter
	Odds Ratio (95%CI)
HbA1c controlled (≤ 7.0% or ≤53 mmol/mol)	
Past recorded diabetes	Ref
Newly recorded diabetes	3.11(2.84-3.41)
Systolic blood pressure controlled (≤140mmHg)	
Past recorded diabetes	Ref
Newly recorded diabetes	1.05(0.97-1.15)
Diastolic blood pressure controlled (≤90mmHg)	
Past recorded diabetes	Ref
Newly recorded diabetes	0.72(0.63-0.82)
Total cholesterol controlled (≤4.0mmol/L)	
Past recorded diabetes	Ref
Newly recorded diabetes	0.63(0.57-0.69)

† Adjusted odds ratio of patients with controlled clinical goals in 2018 for diabetes management among those with available results for the three key parameters (HbA1c, blood pressure, and total cholesterol) based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

Ref: reference group; 95%CI: 95% confidence interval; SD: Standard deviation; HbA1c: Glycated haemoglobin.

Table S7. Adjusted proportion[†] of patients with 'normal' kidney function among those with past (2015-2016) or newly recorded diabetes (2017) who had information on eGFR or ACR and the three key parameters (HbA1c, blood pressure, and total cholesterol)

	Among patients with past recorded diabetes		Among those with newly recorded diabetes	
	Patients monitored (n)	Patients with normal kidney function % (95% CI)	Patients monitored (n)	Patients with normal kidney function % (95% CI)
eGFR				
Normal eGFR (≥60 mL/min/1.73 m^2)	21,912	78.0 (77.4-78.6)	1,620	85.6 (83.8-87.5)
ACR				
Normal ACR (women <3.5, men <2.5 mg/mmol)	16,589	67.9 (67.0-68.8)	1,073	75.2 (72.7-77.7)
Any kidney function				
Normal eGFR or ACR	22,109	85.9 (85.3-86.4)	1,631	90.9 (89.5-92.3)

[†] Adjusted proportions of patients who had each clinical parameter 'controlled' based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

95%CI: 95% confidence interval; eGFR: Estimated Glomerular Filtration Rate, ARC: albumin-to-creatinine ratio.

Table S8. Adjusted odds ratio† combination of clinical parameters controlled in 2018 among patients with past (2015-2016) or newly recorded diabetes (2017) and available results for all three parameters (HbA1c, blood pressure, and total cholesterol)

	Odds Ratio (95%CI) n=42,919
None controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	0.54(0.45-0.65)
Only HbA1c controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	1.62(1.40-1.87)
Only blood pressure controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	0.49(0.42-0.58)
Only total cholesterol controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	0.33(0.25-0.42)
HbA1c and blood pressure controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	1.65(1.46-1.87)
HbA1c and total cholesterol controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	1.01(0.84-1.22)
Blood pressure and total cholesterol controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	0.36(0.30-0.44)
All controlled	
Past recorded diabetes	Ref
Newly recorded diabetes	(base outcome)

† Adjusted odds ratio of the most frequent combination of clinical parameters controlled in 2018 based on multinomial logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

Ref: reference group; 95%CI: 95% confidence interval; HbA1c: Glycated haemoglobin.

Table S9. Adjusted distribution[†] of patients with controlled HbA1c according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, blood pressure and total cholesterol)

Variables	Patients with controlled HbA1c among those with past recorded diabetes (n=40,008) % (95%CI)	Patients with controlled HbA1c among those with newly recorded diabetes (n=2,912) % (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	53.7 (52.3-55.2)	77.1 (74.6-79.6)
Inner regional	56.9 (54.7-59.1)	80.3 (76.8-83.7)
Outer/Remote/Very	53.2 (50.8-55.5)	73.8 (69.0-78.6)
GP IRSAD quintiles		
Very low	52.9 (50.3-55.4)	78.5 (74.8-82.1)
Low	56.1 (53.9-58.4)	78.9 (74.0-83.7)
Middle	53.8 (51.8-55.7)	78.3 (74.6-81.9)
High	54.7 (52.4-56.9)	77.0 (72.7-81.3)
Very High	56.2 (54.1-58.2)	74.3 (70.3-78.2)
Patient's characteristics		
Gender		
Females	56.2 (55.2-57.3)	80.4 (78.3-82.6)
Males	53.1 (52.0-54.1)	74.4 (72.1-76.7)
Age group (years)		
18-39	43.3 (39.9-46.7)	71.1 (64.2-77.9)
40-64	48.0 (46.8-49.3)	74.5 (71.9-77.1)
65+	58.5 (57.4-59.5)	80.6 (78.5-82.7)
Smoking status		
Non-smoker or ex-	54.9 (53.9-55.9)	77.8 (76.0-79.6)
Smoker	50.9 (49.2-52.6)	74.1 (69.0-79.1)
History of hypertension		
No	53.2 (52.1-54.3)	76.4 (74.3-78.4)
Yes	56.5 (55.3-57.7)	78.7 (76.2-81.2)
History of CVD		
No	55.2 (54.2-56.2)	77.5 (75.7-79.3)
Yes	50.6 (49.1-52.2)	76.3 (72.0-80.6)

[†] Adjusted proportions of patients who had information on the three key parameters (HbA1c, blood pressure and total cholesterol) and had HbA1c controlled (≤7.0%) based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

GP: general practice; 95%CI: 95% confidence interval, IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage, CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Table S10. Adjusted distribution† of patients with controlled blood pressure according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, BP and total cholesterol)

Variables	Patients with controlled BP among those with past recorded diabetes (n=40,008) % (95%CI)	Patients with controlled BP among those with newly recorded diabetes (n=2,912) % (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	70.2 (68.8-71.6)	71.6 (69.1-74.1)
Inner regional	66.4 (64.0-68.7)	66.8 (62.6-71.0)
Outer/Remote/Very Remote	67.5 (64.0-71.0)	66.3 (61.2-71.5)
GP IRSAD quintiles		
Very low	71.4 (68.8-73.9)	72.5 (68.0-77.0)
Low	67.7 (65.5-69.9)	69.3 (64.8-73.7)
Middle	68.9 (66.5-71.4)	69.5 (65.8-73.3)
High	67.1 (64.1-70.2)	68.6 (64.4-72.9)
Very High	66.9 (64.8-69.0)	67.5 (63.1-71.9)
Patient's characteristics		
Gender		
Females	68.5 (67.2-69.7)	72.0 (69.5-74.6)
Males	68.9 (67.7-70.2)	67.4 (64.8-70.0)
Age group (years)		
18-39	79.5 (76.8-82.2)	77.5 (71.3-83.8)
40-64	70.8 (69.5-72.1)	72.4 (69.8-74.9)
65+	67.2 (66.0-68.4)	66.2 (63.6-68.7)
Smoking status		
Non-smoker or ex-smoker	68.6 (67.5-69.7)	69.3 (67.4-71.3)
Smoker	69.5 (67.8-71.2)	71.7 (66.2-77.1)
History of hypertension		
No	73.6 (72.5-74.7)	73.5 (71.2-75.8)
Yes	61.2 (59.8-62.6)	64.1 (61.3-66.9)
History of CVD		
No	68.0 (66.9-69.1)	68.8 (66.8-70.7)
Yes	72.8 (71.4-74.1)	75.3 (70.8-79.8)

† Adjusted proportions of patients who had information on the three key parameters (HbA1c, blood pressure and total cholesterol) and had BP controlled (≤140/90mmHg) based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

GP: general practice; BP: blood pressure; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Table S11. Adjusted distribution[†] of patients with controlled total cholesterol according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, blood pressure, and total cholesterol)

Variables	Patients with controlled total cholesterol among those with past recorded diabetes (n=40,008) % (95%CI)	Patients with controlled total cholesterol among those with newly recorded diabetes (n=2,912) % (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	44.5 (43.1-45.8)	31.0 (28.4-33.7)
Inner regional	45.1 (43.0-47.2)	30.4 (26.8-34.0)
Outer/Remote/Very Remote	41.8 (39.7-44.0)	29.4 (24.5-34.3)
GP IRSAD quintiles		
Very low	44.0 (42.3-45.7)	31.7 (27.5-35.8)
Low	44.3 (41.8-46.9)	30.1 (25.6-34.5)
Middle	44.2 (42.2-46.2)	36.4 (32.4-40.4)
High	42.9 (40.0-45.7)	26.2 (21.6-30.9)
Very High	45.4 (43.0-47.7)	27.4 (23.1-31.7)
Patient's characteristics		
Gender		
Females	35.7 (34.6-36.8)	22.6 (20.4-24.8)
Males	51.3 (50.3-52.3)	37.9 (35.2-40.7)
Age group (years)		
18-39	19.7 (17.0-22.3)	19.3 (12.8-25.8)
40-64	34.0 (32.9-35.2)	24.0 (21.6-26.3)
65+	50.7 (49.6-51.8)	37.8 (35.2-40.5)
Smoking status		
Non-smoker or ex-smoker	44.3 (43.3-45.3)	30.7 (28.9-32.5)
Smoker	43.4 (41.7-45.1)	29.9 (25.2-34.5)
History of hypertension		
No	44.1 (43.1-45.2)	30.5 (28.3-32.8)
Yes	44.3 (43.0-45.5)	30.7 (28.1-33.3)
History of CVD		
No	42.2 (41.2-43.2)	27.7 (25.9-29.6)
Yes	56.0 (54.5-57.4)	49.7 (44.1-55.2)

[†] Adjusted proportions of patients who had information on the three key parameters (HbA1c, blood pressure and total cholesterol) and had total cholesterol controlled (≤4.0mmol/L) based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

GP: general practice; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Table S12. Adjusted distribution† of patients with all three clinical parameters controlled according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Variables	'All-controlled' among past recorded diabetes (n=40,008) % (95%CI)	'All-controlled' among newly recorded diabetes (n=2,912) % (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	17.5 (16.6-18.3)	16.9 (14.9-18.9)
Inner regional	18.2 (16.7-19.8)	18.4 (15.2-21.6)
Outer/Remote/Very Remote	16.6 (14.7-18.5)	15.7 (12.2-19.1)
GP IRSAD quintiles		
Very low	17.5 (15.9-19.1)	18.8 (15.4-22.2)
Low	17.7 (16.5-19.0)	16.8 (13.3-20.3)
Middle	17.6 (16.0-19.1)	19.0 (15.8-22.2)
High	16.9 (15.2-18.5)	15.6 (12.1-19.1)
Very High	18.0 (16.7-19.3)	14.5 (11.5-17.5)
Patient's characteristics		
Gender		
Females	14.5 (13.7-15.2)	13.0 (11.2-14.8)
Males	20.1 (19.3-20.9)	20.8 (18.6-22.9)
Age group (years)		
18-39	7.4 (5.7-9.0)	11.3 (6.6-16.0)
40-64	12.4 (11.6-13.2)	13.6 (11.6-15.6)
65+	20.7 (19.9-21.5)	20.8 (18.6-23.1)
Smoking status		
Non-smoker or ex-smoker	17.6 (17.0-18.3)	16.9 (15.5-18.4)
Smoker	16.4 (15.0-17.7)	18.4 (14.5-22.3)
History of hypertension		
No	18.1 (17.3-18.9)	17.0 (15.2-18.8)
Yes	16.7 (15.8-17.6)	17.2 (15.1-19.3)
History of CVD		
No	16.7 (16.0-17.4)	15.1 (13.6-16.6)
Yes	21.8 (20.6-22.9)	29.7 (24.6-34.8)

† 'All-controlled' are those patients with HbA1c≤7.0%, BP≤140/90mmHg, and total cholesterol ≤4.0mmol/L. Adjusted proportions of patients who had each clinical parameter controlled based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

Table S13. Adjusted distribution of 'none-controlled' † diabetes according to sociodemographic and clinical characteristics among patients with past (2015-2016) or newly recorded diabetes (2017) who had information on the three key parameters (HbA1c, blood pressure, and total cholesterol)

Variables	'None-controlled' among past recorded diabetes (n=40,008) % (95%CI)	'None-controlled' among newly recorded diabetes (n=2,912) % (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	8.2(7.6-8.9)	5.0(3.9-6.2)
Inner regional	9.0(7.8-10.2)	5.4(3.6-7.3)
Outer/Remote/Very Remote	10.3(8.8-11.9)	6.8(4.2-9.4)
GP IRSAD quintiles		
Very low	9.0(7.9-10.2)	6.1(4.0-8.2)
Low	9.5(8.1-10.9)	6.5(4.1-8.8)
Middle	9.0(7.8-10.3)	4.6(2.9-6.3)
High	8.3(7.5-9.2)	4.3(2.5-6.2)
Very High	8.4(7.2-9.5)	5.5(3.5-7.4)
Patient's characteristics		
Gender		
Females	9.5(8.9-10.1)	5.3(4.1-6.5)
Males	8.2(7.6-8.8)	5.5(4.4-6.7)
Age group (years)		
18-39	9.8(7.7-11.8)	2.2(0.1-4.3)
40-64	11.0(10.2-11.8)	7.3(5.8-8.9)
65+	7.6(7.1-8.1)	4.1(3.1-5.0)
Smoking status		
Non-smoker or ex-smoker	8.7(8.2-9.2)	5.2(4.3-6.0)
Smoker	9.6(8.5-10.6)	7.0(4.3-9.8)
History of hypertension		
No	7.7(7.1-8.2)	4.6(3.6-5.7)
Yes	10.7(9.9-11.4)	6.5(5.2-7.9)
History of CVD		
No	9.1(8.6-9.7)	5.8(4.8-6.7)
Yes	6.7(6.0-7.5)	2.8(1.1-4.5)

† 'None-controlled' was defined as patients who cannot control all three key parameters (HbA1c, blood pressure and total cholesterol) who had information on the three key parameters, the proportions were based on logistic regression models adjusted for (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD).

GP: general practice; 95%CI: 95% confidence interval; IRSAD: Index of Relative Socioeconomic Advantage and Disadvantage; CVD: Cardiovascular diseases including heart failure, ischemic heart disease, and stroke.

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Lines 17-41
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			Lines 59-95
Objectives	3	State specific objectives, including any prespecified hypotheses			Lines 96-101
Methods					
Study Design	4	Present key elements of study design early in the paper			Lines 103-111
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection			Lines 103-121
Participants	6	*(a) Cohort study* - Give the		RECORD 6.1: The methods of study	Lines 122-141

		eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Lines 109-111 n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Lines 142-179
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group			Lines 142-179
Bias	9	Describe any efforts to address potential sources of bias			Lines 187-202

Study size	10	Explain how the study size was arrived at			n/a
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			Lines 142-166
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			Lines 180-206
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	Lines 104-111 Lines 441-446
Linkage		..		RECORD 12.3: State whether the	

				study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	n/a
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Lines 211-220
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)			Lines 211-220
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or			Lines 222-332

		summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			Lines 222-309
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			Lines 307-309
Discussion					
Key results	18	Summarise key results with reference to study objectives			Lines 325-334
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Lines 409-421
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			Lines 335-405

Generalisability	21	Discuss the generalisability (external validity) of the study results			Lines 406-409, 402-429
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based			Lines 458-461
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Lines 441-446

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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Diabetes mellitus monitoring and control among adults in Australian general practice: a national retrospective cohort study

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ABSTRACT

Objectives: This study investigated whether the monitoring and control of clinical parameters are better among patients with newly compared to past recorded diabetes diagnosis.

Design: Retrospective cohort study.

Setting: MedicineInsight, a national general practice database in Australia.

Participants: 101,875 'regular' adults aged 18+ years with past (2015-2016) and 9,236 with newly recorded (2017) diabetes diagnosis.

Main outcome measures: Two different groups of outcomes were assessed in 2018. The first group of outcomes was the proportion of patients with clinical parameters (i.e., HbA1c, blood pressure [BP], total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides, estimated glomerular filtration rate-eGFR, albumin-to-creatinine ratio) monitored at least once in 2018. The second group of outcomes were those related to diabetes control in 2018 (HbA1c ≤7.0%, (BP) ≤140/90mmHg, total cholesterol <4.0mmol/L, and LDL-C <2.0mmol/L). Adjusted odds ratios (OR_{adj}) and adjusted probabilities (%) were obtained based on logistic regression models adjusted for practice variables and patients' sociodemographic and clinical characteristics.

Results: The study included 111,111 patients (51.7% males; mean age 65.3±15.0 years) with recorded diabetes diagnosis (11.0% of all 1,007,714 adults in the database). HbA1c was monitored in 39.2% (95%CI 36.9;41.6) of patients with newly and 45.2% (95%CI 42.6;47.8) with past recorded diabetes (OR_{adj} 0.78, 95%CI 0.73;0.82). HbA1c control was achieved by 78.4% (95%CI 76.7;80.0) and 54.4% (95%CI 53.4;55.4) of monitored patients with newly or past recorded diabetes, respectively (OR_{adj} 3.11, 95%CI 2.82;3.39). Less than 20% of patients with newly or past recorded diabetes had their HbA1c, BP, and total cholesterol levels controlled (OR_{adj} 1.08, 95%CI 0.97;1.21).

Conclusions: The monitoring of clinical parameters was lower among patients with newly than past recorded diabetes. However, diabetes control was similarly low in both groups, with only one in five monitored patients achieving control of all clinical parameters.

Keywords: Epidemiological Monitoring, Evidence-Based Practice, Population Health

Strengths and limitations of this study

- This retrospective cohort used a large sample of patients attending primary healthcare services across all Australian states and territories.
- A wide range of sociodemographic and clinical variables related to diabetes monitoring and control were included for adjustment.
- Lifestyle variables were not included for adjustment, as they are not consistently recorded in the electronic medical records.
- Patients may have had their diabetes parameters monitored somewhere else (e.g., different practices or by specialists).

INTRODUCTION

Diabetes mellitus is a lifelong disease that requires regular monitoring and control to reduce the risk of diabetes-related complications.[1-5] Micro- and macrovascular complications of uncontrolled diabetes (e.g., hypertension, dyslipidaemia, chronic kidney disease-CKD, cardiovascular disease-CVD) increase the health burden worldwide.[6] Blood glucose control is the most critical clinical goal of diabetes management, but other clinical variables also require regular monitoring.[3] The Royal Australian College of General Practitioners (RACGP) guidelines recommend patients with diabetes should have their haemoglobin A1c (HbA1c), blood pressure (BP), and lipid levels evaluated annually to improve management and control of these clinical parameters.[7] Treatment options may vary depending on individual characteristics (e.g., age, gender, presence of comorbidities)[7, 8] and the stage of diabetes progression (i.e. recent or past diagnosis, presence of diabetes complications).[9]

Maintaining optimal levels of diabetes control with a combination of drug monotherapy and lifestyle changes is often possible for several years, after which a combination therapy may be necessary. The evaluation and modification of treatment plans in diabetes hinge on the information obtained from close monitoring of clinical parameters.[10] However, gaps between real-world practice and guideline recommendations for diabetes management have been reported worldwide.[4, 11-13] For instance, a survey of 305 primary care physicians in the US showed that only 38% of clinicians use guidelines in the management of diabetes.[11]

A systematic review of 123 Australian studies found that approximately 50% of patients with diabetes received ‘standard care’ (i.e., assessment of HbA1c, BP, lipids, weight, eye health, foot health). Among those assessed, 40-60% met management targets for HbA1c, BP, or lipid levels, but the study did not report the proportion that had all three parameters under control.[13] Most studies included in that review used electronic health records (EHRs) to

investigate diabetes control. However, these studies also tended to source data from specialised centres rather than primary healthcare settings, and used non-representative samples, hindering the generalisability of the results at a national level. Additionally, other potential determinants of diabetes management and control (e.g., sociodemographic and clinical variables) were not widely investigated. Despite these limitations, figures in the review were consistent with measured data from the Australian Health Survey (AHS) (2011-2012), which reported that 54.7% of adults with known diabetes met HbA1c targets, 39% met recommended BP levels, and 38%, total cholesterol targets.[14]

Despite concerns about the completeness and feasibility of using EHR-based primary care databases in research, studies conducted in countries such as the United States, Canada, the United Kingdom, France, Sweden, India and Australia have shown EHRs can provide accurate information on diabetes prevalence,[15-17] management and control.[13, 18-20] EHR-based research can improve diabetes management without increasing overall treatment costs.[21, 22] Moreover, EHR databases minimise self-report bias by providing information on doctor-reported diagnoses, objective laboratory results, and prescribed medications.[15, 16, 23]

Thus, this study used retrospective data from a national general practice database to investigate if (1) the monitoring of clinical parameters for diabetes management (HbA1c, BP, total cholesterol, low-density lipoprotein cholesterol [LDL-C], high-density lipoprotein cholesterol, triglycerides [HDL], estimated glomerular filtration rate [eGFR], albumin-to-creatinine ratio [ACR]) is better among patients with newly than past recorded diabetes diagnosis, and (2) the proportion of those monitored who achieved diabetes control (i.e., HbA1c, BP, total cholesterol, LDL-C) is higher in patients with newly compared to those with past recorded diabetes diagnosis.

METHODS

Data source

We used retrospective data from an open cohort database (MedicineInsight) that includes de-identified EHRs from approximately 662 general practices (8.2% of all Australian practices) and over 2,700 general practitioners (GPs) across Australia.[23] Details of data extraction and database characteristics have been published elsewhere.[23] Although practices in MedicineInsight were selected using a non-random process, all Australian states and territories, urban and rural settings and socioeconomic settings are represented in the database. Diagnostic algorithms used for identifying patients with chronic disease using MedicineInsight have been validated, showing sensitivity of 89% against the recording of diabetes in the original EHR.[16]

Study sample

This study was reported according to the REporting of studies Conducted using Observational Routinely-collected Data (RECORD) statement.[20] Only data from practices with regular data provision (i.e., no gap of more than 6-weeks in data provision in the previous two years) was included. The sample was adults (18+ years) who regularly attended the practice (i.e., those with at least one consultation per year between 2015 and 2018) and who had a diagnosis of diabetes mellitus (either type 1 or type 2). Data from consultations between January 2015 and December 2017 were used to identify the level of exposure: patients with past (i.e., diabetes diagnosis recorded in 2015 or 2016) or newly recorded diabetes (i.e., first diagnosis recorded in 2017, but not during appointments in 2015 or 2016). The outcome was assessed using data from January to December 2018, considering all recordings of clinical parameters related to diabetes monitoring and control in that year.[7]

Three fields ('diagnosis', 'reason for encounter', 'reason for prescription') were initially searched to identify patients with recorded diabetes diagnoses. The original search was based on the methods for data extraction used by MedicineInsight.[16, 23] It included standard clinical terminology, misspellings, and abbreviations, and then expanded to include prescribed medications and laboratory results. Using as much information as possible from EHRs (i.e., observations, medications, diagnostic information) can provide a more accurate picture for identifying diabetes.[24] Besides, including laboratory results from EHRs are associated with higher rates of diabetes ascertainment.[25, 26]

Patients were classified as having past recorded diabetes (i.e., past diabetes) if between January 2015 and December 2016: (1) 'diabetes' was recorded in two different fields; or (2) antidiabetic medications were prescribed [Anatomical Therapeutic Chemical A10A or A10B;[27] metformin was considered only in the absence of polycystic ovary syndrome diagnosis]; or (3) a diabetes diagnosis was recorded only once but there was at least one recorded laboratory result (fasting blood glucose, HbA1c or 2-hour oral glucose tolerance test) above the diabetes diagnosis threshold within the same timeframe.[7] Patients were classified as having newly recorded diabetes (i.e., recent diabetes) if: (1) they did not meet the criteria for past recorded diabetes (i.e. attended the practice in 2015 and 2016 but diabetes was not recorded) and (2) between January 2017 and December 2017 they presented any of the three criteria mentioned above for diabetes diagnosis (i.e., 'diabetes' recorded in two fields, antidiabetic medications were prescribed OR 'diabetes' was recorded once only but there was at least one abnormal glycaemic result recorded in 2017).

Outcomes

The outcome was assessed considering data related to diabetes monitoring and control reported between January and December 2018. The first group of outcomes was the proportion of

patients with diabetes who had their clinical parameters for diabetes management monitored at least once in 2018 (i.e., HbA1c, BP, total cholesterol, LDL-C, HDL-C, triglycerides, eGFR, or ACR).[7] These clinical parameters were obtained from the fields 'observations' and 'laboratory results' using Logical Observation Identifiers Names and Codes.[28]

According to the RACGP guidelines, patients with diabetes should achieve recommended targets for all clinical parameters (i.e. HbA1c, lipids [total cholesterol, HDL-C, LDL-C, non-HDL, triglycerides], BP, and urine albumin excretion).[7] However, three key parameters (HbA1c, BP, and total cholesterol) can be used to define 'well-controlled' diabetes, since they indicate that patients can comprehensively manage their diabetes and reduce the risk of complications.[12, 13] Therefore, the second group of outcomes was the proportion of patients that achieved in 2018, among those checked, generally recommended targets (HbA1c≤7.0%, BP≤140/90mmHg, and total cholesterol <4.0mmol/L). Considering LDL-C is also commonly used to monitor cardiovascular risk[9], we performed additional analysis reporting the proportion of patients who achieved well-controlled LDL-C (<2.0mmol/L). When multiple results were reported in 2018 for the same parameter and patient, the mean of these results was estimated and used for analysis.

'Well-controlled' diabetes was then explored using two different approaches. First, we analysed each clinical parameter as a different outcome: (1) controlled HbA1c, (2) controlled BP, or (3) controlled total cholesterol or LDL-C. Second, based on whether each of these three parameters was controlled or not, we created an outcome variable with eight categories to explore the most frequent combination of parameters that were under control: (1) none controlled, (2) HbA1c only, (3) BP only, (4) total cholesterol only, (5) HbA1c and BP controlled, (6) HbA1c and total cholesterol controlled, (7) BP and total cholesterol controlled, or (8) all controlled. The same combination was analysed considering LDL-C rather than total cholesterol and results were reported as supplementary material.

Covariates

Covariates included a group of sociodemographic and cardiovascular risk factors/history of CVD that may affect diabetes control.[5, 29] Practice data included practice remoteness (major cities, inner regional, or outer regional/remote/very remote] and practice Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD quintiles). Remoteness and IRSAD were defined based on postcodes. Remoteness is determined according to the population size and average distance to services, while IRSAD is an area-level measure of socioeconomic status based on combined indicators (i.e., household income, education, and working status). Higher IRSAD scores indicate a more advantaged area.[30] Patient variables included age (18-39, 40-64, 65+), gender (females, males), smoking status (smoker, ex-smoker or non-smoker), recorded history of hypertension, and recorded history of CVD (including heart failure, ischemic heart disease, or stroke), dyslipidaemia, CKD, liver disease, and depressive symptoms during 2015-2017. Details on the data extraction methods for these variables have been published elsewhere.[16, 31]

Statistical analysis

All analyses were performed in Stata 16.1 (StataCorp, Texas, USA), considering the practices as clusters, using robust standard errors and conditioned to the number of visits to the practice.

The distribution of sociodemographic and clinical characteristics among patients with past or newly recorded diabetes were presented as proportions with their corresponding 95% confidence intervals (95%CI) (categorical variables), or as means with their standard deviation or median with their interquartile range (numerical variables).

Logistic regression models were used to assess differences in diabetes monitoring or diabetes control in 2018 (binary outcomes: each parameter controlled) between patients with past (i.e. diagnosis recorded in 2015 or 2016, reference group) or newly recorded diabetes (i.e. first

diagnosis recorded in 2017). All results were adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), or clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, and depressive symptoms. We reported adjusted odds ratios (OR_{adj}) with their corresponding 95%CI, following recommendations of the American Statistical Association.[32] Furthermore, results from the adjusted logistic regression models were also used to estimate adjusted predicted probabilities (i.e., adjusted proportions) of the investigated outcomes using the command 'margins' in Stata.

Multinomial logistic regression models were used to compare whether the most frequent combination of parameters under control differed between patients with past or newly recorded diabetes, using a similar approach for adjustment and then obtaining the OR_{adj} and adjusted probabilities for each category of the outcome.

Patient and Public Involvement

No patient involved.

RESULTS

Population Characteristics

The database included 1,007,714 regular patients (at least one visit per year between 2015 and 2018) aged 18+ years attending 541 practices (Figure 1 and table 1). Of these, 111,111 individuals (11.0%) had recorded diabetes diagnosis (51.7% males; mean age 65.3±15.0 years): 101,875 with past and 9,236 with newly recorded diabetes. Table 1 shows that patients with past recorded diabetes were older (mean 65.9±14.6 vs. 58.1±17.1 years), and had a higher proportion of males (52.4% vs. 44.0%), and history of CKD (4.7% vs. 2.9%) than those with newly recorded diabetes. However, diagnosis of hypertension (35.0% vs. 36.8%),

dyslipidaemia (17.6% vs. 20.2%), or depressive symptoms (18.4% vs. 20.9%) was less frequent in patients with past recorded diabetes. The distribution according to remoteness, IRSAD, smoking status, history of CVD or history of liver disease was similar in both groups.

<Figure 1 here>

Table 1. Sociodemographic and clinical profile of regular patients† aged 18+ years in the database.

Variables	All adults in MedicineInsight (N=1,007,714)	Patients with diabetes	
		Past recorded diabetes (n=101,875) % (95%CI)	Newly recorded diabetes (n=9,236) % (95%CI)
Practice characteristics			
Geographical area of GP			
Major cities	63.8 (59.4–68.2)	59.4 (54.6–64.2)	62.3 (57.2–67.4)
Inner regional	24.8 (20.6–28.9)	27.4 (22.8–32.1)	25.0 (20.4–29.7)
Outer regional/remote/very remote	11.4 (8.5–14.4)	13.2 (9.8–16.5)	12.6 (9.1–16.0)
GP IRSAD			
More disadvantaged	33.8 (32.4–35.2)	39.2 (34.0–44.4)	38.3 (33.0–43.7)
Middle	23.7 (22.4–25.1)	25.0 (20.3–29.6)	24.6 (19.8–29.4)
More advantaged	43.8 (42.5–45.1)	36.6 (32.1–41.0)	38.1 (33.5–42.8)
Patient's characteristics			
Gender			
Male	40.4 (39.9–40.9)	52.4 (51.9–53.0)	44.0 (42.7–45.4)
Age, mean ± SD	54.0 ± 19.1	65.9 ± 14.6	58.1 ± 17.1
Age group (years)			
18–39	26.2 (25.1–27.2)	5.8 (5.4–6.2)	15.8 (14.6–17.1)
40–64	40.9 (40.4–41.4)	34.9 (34.0–35.7)	43.0 (41.7–44.4)
65+	33.0 (31.7–34.2)	59.4 (58.2–60.5)	41.2 (39.5–42.9)
Smoking status			
Smoker	12.0 (11.6–12.4)	10.5 (10.1–10.8)	10.8 (10.0–11.5)
History of hypertension			
Yes	19.0 (18.5–19.5)	35.0 (33.9–36.2)	36.8 (35.4–38.3)
History of CVD			
Yes	5.3 (5.2–5.4)	13.2 (12.8–13.5)	12.5 (11.7–13.3)
History of dyslipidaemia			
Yes	11.0 (10.5–11.4)	17.6 (16.7–18.6)	20.2 (19.0–21.3)
History of CKD			
Yes	1.3 (1.2–1.4)	4.7(4.3–5.1)	2.9 (2.5–3.4)
History of liver disease			
Yes	0.2 (0.2–0.2)	0.5 (0.5–0.6)	0.6 (0.5–0.8)
History of depressive symptoms			
Yes	20.7 (20.1–21.4)	18.4 (17.6–19.1)	20.9 (19.9–22.0)
Consultations in 2018, median (IQR)	4 (2–8)	7 (4–13)	6 (3–11)

GP: General practice; 95%CI: 95% Confidence interval; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage; IQR: Interquartile range; SD: Standard deviation; CVD: Cardiovascular diseases, including heart failure, ischemic heart disease, and stroke; CKD: Chronic kidney disease. All results were adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), or clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, and depressive symptoms.

† People had at least one visit per year between 2015 and 2018.

Diabetes Monitoring

Table 2 reports the proportion and OR_{adj} of individuals who had their clinical parameters monitored in 2018, according to whether they had past or newly recorded diabetes. The most frequently monitored parameter was BP (past diabetes, 84.3% [95%CI 83.3;85.3]; newly diagnosed diabetes, 81.4% [95%CI 80.0;82.8]). The least monitored parameter was ACR (past diabetes, 17.4% [95%CI 16.8;18.0]; newly recorded diabetes, 13.5% [95%CI 12.6;14.3]). Although 45.2% (95% CI 42.6;47.8) of those with past diabetes and 39.2% (95%CI 36.9;41.6) with newly recorded diabetes had their HbA1c levels monitored in 2018 (table 2), an additional 15 percentage points in each group (absolute difference) had their glycaemic parameters checked through fasting and/or random glucose levels (table S1).

Table 2 also shows that OR_{adj} of monitoring of any parameter (i.e., HbA1c, BP, total cholesterol, HDL-C, LDL-C, triglycerides, eGFR, or ACR) was lower among patients with newly than past recorded diabetes, especially HbA1c (OR_{adj} 0.78, 95%CI 0.73;0.82) and ACR (OR_{adj} 0.74, 95%CI 0.69;0.79). Table S2 presents the ORadj of distribution of patients with all three clinical parameters nontiered (HbA1c, blood pressure, and total cholesterol) according to sociodemographic and clinical characteristics among those with past or newly recorded diabetes.

Table 2. Clinical parameters monitored in 2018 according to whether patients had past (2015–2016) or newly recorded diabetes (2017)

Clinical parameters monitored	Past recorded diabetes (n=101,875) % (95%CI)	Newly recorded diabetes (n=9,236) % (95%CI)	Adjusted† odds ratio (95%CI)
HbA1c	45.2 (42.6–47.8)	39.2 (36.9–41.6)	0.78 (0.73–0.82)
Blood pressure¶	84.3 (83.3–85.3)	81.4 (80.0–82.8)	0.81 (0.75–0.87)
Total cholesterol	42.3 (39.8–44.8)	38.9 (36.4–41.4)	0.86 (0.82–0.91)
HDL-C	38.0 (35.7–40.2)	34.5 (32.2–36.7)	0.86 (0.81–0.91)
LDL-C	35.8 (33.6–37.9)	32.9 (30.5–34.8)	0.87 (0.82–0.92)
Triglycerides	41.3 (38.9–43.7)	37.8 (35.4–40.1)	0.86 (0.81–0.90)
Any type of kidney function#	26.9 (26.3–27.5)	25.5 (24.4–26.4)	0.93 (0.88–0.98)
eGFR	26.5 (25.9–27.1)	25.1 (24.1–26.2)	0.93 (0.88–0.98)
ACR	17.4 (16.8–18.0)	13.5 (12.6–14.3)	0.74 (0.69–0.79)

95%CI: 95% Confidence interval; HbA1c: Haemoglobin A1C; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; eGFR: Estimated glomerular filtration rate; ACR: Urine albumin-to-creatinine ratio; CVD: Cardiovascular diseases, including heart failure, ischemic heart disease, and stroke; CKD: Chronic kidney disease.

† Past recorded diabetes was used as the reference category. Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD, CKD, dyslipidaemia, liver disease, and depressive symptoms using logistic regression models.

Well-controlled Diabetes

Table 3 shows the proportion of patients that achieved clinical goals for diabetes management in 2018 among those with available results for each of the three key parameters. Patients with newly recorded diabetes had higher chance of having their HbA1c controlled than those with past diabetes (OR_{adj} 3.11, 95%CI 2.82;3.39). Nevertheless, the odds of having diastolic BP (OR_{adj} 0.72, 95%CI 0.63;0.82), total cholesterol (OR_{adj} 0.63, 95%CI 0.57;0.69), and LDL-C (OR_{adj} 0.58, 95%CI 0.53;0.63) controlled were lower among those with newly recorded diagnosis than their peers. Systolic BP control was not different across groups.

Table 3. Clinical parameters controlled in 2018 according to whether patients had past (2015-2016) or newly recorded diabetes (2017) among those with available results for the three key parameters (HbA1c, blood pressure, and total cholesterol/LDL-C)

Clinical parameter controlled	Past recorded diabetes n=40,008 % (95%CI)	Newly recorded diabetes n=2,912 % (95%CI)	Adjusted† odds ratio (95%CI)
HbA1c (≤7.0% or ≤53 mmol/mol)	54.4 (53.4–55.4)	78.4 (76.7–80.0)	3.11 (2.82–3.39)
Systolic blood pressure (≤140mmHg)	70.6 (69.5–71.6)	71.4 (69.6–73.3)	1.04 (0.96–1.14)
Diastolic blood pressure (≤90mmHg)	94.6 (94.2–94.9)	92.8 (91.9–93.6)	0.72 (0.63–0.82)
Total cholesterol (<4.0mmol/L)	43.9 (43.0–44.9)	33.8 (31.9–35.6)	0.63 (0.57–0.69)
LDL-C (<2.0mmol/L)	47.1 (46.1–48.1)	34.7 (32.7–36.6)	0.58 (0.53–0.63)

95%CI: 95% Confidence interval; HbA1c: Haemoglobin A1c; LDL-C: low-density lipoprotein cholesterol; CVD: Cardiovascular diseases, including heart failure, ischemic heart disease, and stroke; CKD: Chronic kidney disease.

† Past recorded diabetes was used as the reference category. Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD, CKD, dyslipidaemia, liver disease, and depressive symptoms using logistic regression models.

Table 4 shows the combination of the three key parameters that were more frequently controlled in 2018. The proportion of individuals that met the three recommended targets was clinically similar, whether they had past (17.4%, 95%CI 16.7;18.1) or newly recorded diabetes (18.8%, 95%CI 17.2;20.3). Patients with newly recorded diabetes were more likely to have their HbA1c controlled, either alone (OR_{adj} 1.62, 95%CI 1.40;1.87) or in combination with BP controlled (OR_{adj} 1.64, 95%CI 1.45;1.86) than their peers. In contrast, the odds of total cholesterol being controlled (either alone or with BP) was ~65% lower among those with newly recorded diabetes than their counterpart. Analyses using LDL-C rather than total cholesterol showed similar results to those presented above (table S3).

The association between sociodemographic and clinical variables with the monitoring of the three key parameters (HbA1c, BP and total cholesterol or LDL-C) are presented as supplementary materials (tables S4 and S5).

Table 4. Combination of clinical parameters controlled in 2018 according to whether patients had past (2015–2016) or newly recorded diabetes (2017) among those with available results for all three parameters (HbA1c, blood pressure, and total cholesterol)

Parameter(s) controlled	Past recorded diabetes (n= 40,008)		Newly recorded diabetes (n= 2,912)		Adjusted† odds ratio (95%CI)
	n	% (95%CI)	n	% (95%CI)	
None controlled	3,521	8.8 (8.3–9.3)	149	5.1 (4.3–5.9)	0.54 (0.45–0.66)
Only HbA1c	3,961	9.9 (9.4–10.4)	492	16.9 (15.4–18.3)	1.62 (1.40–1.87)
Only BP	6,761	16.9 (16.3–17.5)	259	8.9 (7.9–9.9)	0.49 (0.42–0.57)
Only total cholesterol	2,360	5.9 (5.5–6.2)	61	2.1 (1.6–2.6)	0.33 (0.25–0.43)
HbA1c and BP	8,202	20.5 (19.8–21.1)	1,031	35.4 (33.5–37.3)	1.64 (1.45–1.86)
HbA1c and total cholesterol	2,641	6.6 (6.2–7.0)	210	7.2 (6.1–8.4)	1.02 (0.84–1.24)
BP and total cholesterol	5,601	14.0 (13.6–14.5)	163	5.6 (4.7–6.5)	0.37 (0.30–0.45)
All controlled	6,961	17.4 (16.7–18.1)	547	18.8 (17.2–20.3)	1.08 (0.97;1.21)

95%CI: 95% Confidence interval; HbA1c: Glycated haemoglobin; BP: Blood pressure; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage; CVD: Cardiovascular diseases, including heart failure, ischemic heart disease, and stroke; CKD: Chronic kidney disease.

† Past recorded diabetes was used as the reference category. Past recorded diabetes was used as the reference category. Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and CVD risk factors (smoking status, history of hypertension or CVD, CKD, dyslipidaemia, liver disease, and depressive symptoms using multinomial logistic regression models.

DISCUSSION

General findings

Based on a large retrospective cohort study of the national general practice database, this paper highlighted three main findings. Less than half of patients with diabetes had their HbA1c levels assessed over 12 months, and the monitoring of HbA1c or other clinical parameters was less

frequent among patients with newly than past recorded diabetes. Although patients with newly recorded diabetes were less likely to be monitored, 8 out of 10 of these patients achieved HbA1c control. In general, less than 20% of patients with diabetes who were monitored in 2018 had their HbA1c, BP and total cholesterol within targeted levels considered well-controlled.

Comparison with literature

Current Australian guidelines recommend annual monitoring of clinical parameters for all patients with diabetes.[7] Nonetheless, we found that only 45.2% of those with past diabetes and 39.4% of those with newly recorded diabetes had their HbA1c levels monitored in 2018. Our results are consistent with the 'Rule of Halves' discussed in an Australian review, showing that half of patients with diabetes receive appropriate diabetes care/monitoring.[13] On the other hand, another recent Australian retrospective study not included in that review and using EHRs from patients attending 50 practices in the inner eastern region of Melbourne (MAGNET database, period 2009-2014) found a higher proportion of monitoring. Findings showed that 66.5% of patients aged 65+years with T2D had their HbA1c checked within the last two years.[33] However, it is important to note that the population in that study was older, probably triggering a more frequent monitoring.

Among other clinical parameters, BP was the most frequently monitored regardless of having past (84.3%) or newly recorded diabetes (81.4%). In fact, having a newly recorded diagnosis of diabetes does not seem to affect BP monitoring in comparison with the general population, as a population-based study in South Australia found that 81.8% of individuals without diabetes, hypertension, or CVD had their BP measured by a GP in the last 12 months.[34]

People with past recorded diabetes had a slightly higher proportion of kidney function monitoring than newly recorded diabetes. However, it is concerning that only 1 in 4 patients had these results reported in the last 12 months, even among those with past diabetes,

considering that diabetes is one of the most important causes of CKD and annual kidney health checks (eGFR and urine ACR) are strongly recommended for patients living with diabetes.[35]

It is also concerning that a history of smoking or CVD did not affect the monitoring of the three main parameters (HbA1c, BP and total cholesterol) in any of the groups (past or newly recorded diabetes). These health conditions contribute to absolute CVD risk, diabetes-related comorbidities and, consequently, mortality.[3] However, it is plausible that healthcare professionals have monitored these patients in other settings, such as smoking cessation programs or CVD secondary prevention[7, 36] that would not be captured by our study.

Although patients with newly recorded diabetes were less likely to have their HbA1c monitored, 8 out of 10 of those monitored achieved HbA1c control. Patients with newly recorded diabetes were, on average, eight years younger than those with past diabetes, which suggests their condition was at an earlier stage when complications are less frequent and diabetes control is more likely to be achieved with first-line medications.[2, 3] Additionally, medication adherence among patients with newly diagnosed diabetes can be as high as 65% then reduce over time, which, in turn, has been found to impact diabetes control.[37] A previous study using the MedicineInsight database showed that greater regularity and continuity of care was associated with an increased likelihood of HbA1c monitoring, but it did not influence HbA1c control among patients with diabetes.[38] Our results differ substantially from the findings of a longitudinal study carried out with newly diagnosed patients (within 6 months before screening) from 81 hospitals in China.[39] The investigation found only 36.8% of HbA1c control (< 7.0%),[39] but it is important to consider the different settings and patients characteristics in each study, as patients in hospital or specialised centres tend to need extra care or have a deteriorated health condition. Nonetheless, the possibility of information bias introduced by the less frequent HbA1c monitoring among those with newly recorded diabetes in our study cannot be discounted as an alternative explanation.

Despite the known effect of behavioural aspects[40] such as denial or anxiety in the patient's ability to monitor and manage their HbA1c when diabetes is diagnosed, according to our results, the management tend to weaken years after the diagnosis. The literature indicates that it happens due to the distress of living with diabetes and the high level of self-care needed to manage blood glucose, but also the lack of appropriate support or patient willpower over time.[1, 40-43] In our study, 54.4% of patients with past recorded diabetes achieved HbA1c control, very similar to results from the AHS (2011-2012), which reported 54.7% of control (HbA1c ≤7.0%) among adults with known diabetes.[14] Results from the MAGNET database, 2009 to 2014, found that among patients monitored for HbA1c, 42.4% achieved control (i.e., levels ≤7.0% in the most recent laboratory result).[33]

On the other hand, control of other clinical parameters in our study was better among patients with past than those with newly recorded diabetes. This could be related to the fact that patients with past diabetes were older (almost 60% were 65+ years compared to 41% among newly recorded diabetes), and older patients were at least twice more likely to achieve diabetes control than younger patients (table S4). Results from the AHS (2011-2012)[14] also found that the proportion of patients with well-controlled diabetes increased with age. The reason might be that older patients visit their GP more frequently, allowing more opportunities to have disease management monitored.

Our findings showed that among patients who had the three key parameters monitored (HbA1c, BP and total cholesterol or LDL-C), only 1 in 5 achieved targeted goals for the three parameters. A British EHR-based study indicated that despite optimal control of different CVD risk factors (HbA1c, systolic-BP, total cholesterol, triglycerides, smoking), patients with diabetes still had a 21% higher CVD risk than those without diabetes, reinforcing the need to monitor and control these parameters.[44] Patients with a history of CVD were more likely to achieve well-controlled parameters, especially when they had newly recorded diabetes diagnosis. This finding might be related to the co-administration of antihypertensive and lipid-lowering therapy

among patients with a history of CVD to reduce the risk of new CVD events.[45] And the fear of own mortality increases the chances of compliance to medication in the short-term. Besides, this may be because patients with history of CVD were given more intensive treatments or combined use of antidiabetic medications.[46] Discrepancies between patients with past or newly recorded diabetes diagnosis could result from prevalence-incidence bias, and prospective studies would be necessary to elucidate these findings.

Strengths and limitations

The study has significant strengths, such as the use of a large sample of patients attending primary healthcare services across all Australian states and territories. Furthermore, we explored sociodemographic and clinical variables related to diabetes monitoring and control that were not included in the most recent Australian studies on the same topic. Nonetheless, some other relevant covariates (e.g., diet and exercise) were not explored, as they are not consistently recorded in EHRs, or are recorded in the progress notes which cannot be extracted because of confidentiality issues. This is a common limitation of EHR-based studies, as data from progress notes may affect completeness of information used for analysis. Additionally, patients may have had their diabetes parameters monitored somewhere else (e.g., different practices or specialists). To minimise the effect of this, we used different fields to identify laboratory results that were not requested and automatically reported to the practice by the laboratories. Despite using widely accepted target levels for the clinical parameters investigated, they may be adjusted and tailored to individual characteristics, which may not be feasible to differentiate in large epidemiological studies. Finally, prevalence-incidence bias may have affected some of the investigated associations (e.g., history of CVD and hypertension) among patients with past or newly recorded diabetes.

CONCLUSION

In Australia, monitoring and achieving clinical targets for diabetes management appears to be suboptimal. Consistent with previous research, we found half of the patients with diabetes had a record of their glycaemic levels being checked over 12 months. However, 80% of all those monitored did not achieve all targets of HbA1c, BP, and total cholesterol recommended by the RACGP guidelines, regardless of the time of diabetes diagnosis. Multi-component interventions for early detection and management of risk factors and complications, intensive glycaemic control and education on self-monitoring of blood glucose in persons with newly diagnosed diabetes, monitoring diabetes distress as part of routine care since the initial diagnosis, statin therapy for secondary CVD prevention, and intensive hypertension control with angiotensin-converting enzyme inhibitors or angiotensin receptor blockers to prevent end-stage renal disease are some of the cost-effective strategies highlighted in the literature that could be incorporated and emphasized in standard diabetes care programs.[40, 42, 43, 47, 48] Further studies are necessary to examine whether systematic implementation of these strategies in Australian primary healthcare settings, in addition to the continuous promotion of behaviour changes through clear and engaged communication within health professionals and patients, can optimise diabetes management in line with guidelines.

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Data Availability Statement

Data used in this study was obtained from a third party (MedicineInsight) for this specific project and cannot be released. Information about MedicineInsight data and how they can be

accessed is available on the website (https://www.nps.org.au/medicine-insight). The data extraction algorithms used in this study are available from the corresponding author upon request.

Contributors

MZ and DGC contributed to the conception and design of the study. MZ performed the statistical analysis and prepared the manuscript. CB and DGC assisted with data extraction, analysis, and manuscript writing. NS and PH contributed to the design and structure of the manuscript. All authors critically revised the manuscript and provided intellectual support to enhance the manuscript. All authors approved the final version for publication.

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Competing Interests

The authors declare no conflict of interest.

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Ethics Approval Statement

The independent MedicineInsight Data Governance Committee approved the study (protocol 2016-007). The Human Research Ethics Committee of the University of Adelaide exempted the study from an ethical review as it used de-identified data.

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Supplemental material

Table S1. Proportion† of patients with different blood glucose parameters monitored in 2018 among those with past (2015–2016) or newly recorded diabetes (2017)

Table S2. Adjusted odds ratio† of patients who had all three parameters (HbA1c, blood pressure, and total cholesterol) monitored, among those with past (2015–2016) or newly recorded diabetes (2017), according to sociodemographic and clinical characteristics

Table S3. Adjusted proportion† of the combination of clinical parameters controlled in 2018 among patients with past (2015-2016) or newly recorded diabetes (2017) and available results for all three parameters (HbA1c, blood pressure, and LDL-C)

Table S4. Adjusted odds ratio† of distribution of patients with all three clinical parameters controlled (HbA1c, blood pressure, and total cholesterol) according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Table S4. Adjusted odds ratio† of distribution of patients with all three clinical parameters controlled (HbA1c, blood pressure, and total cholesterol) according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

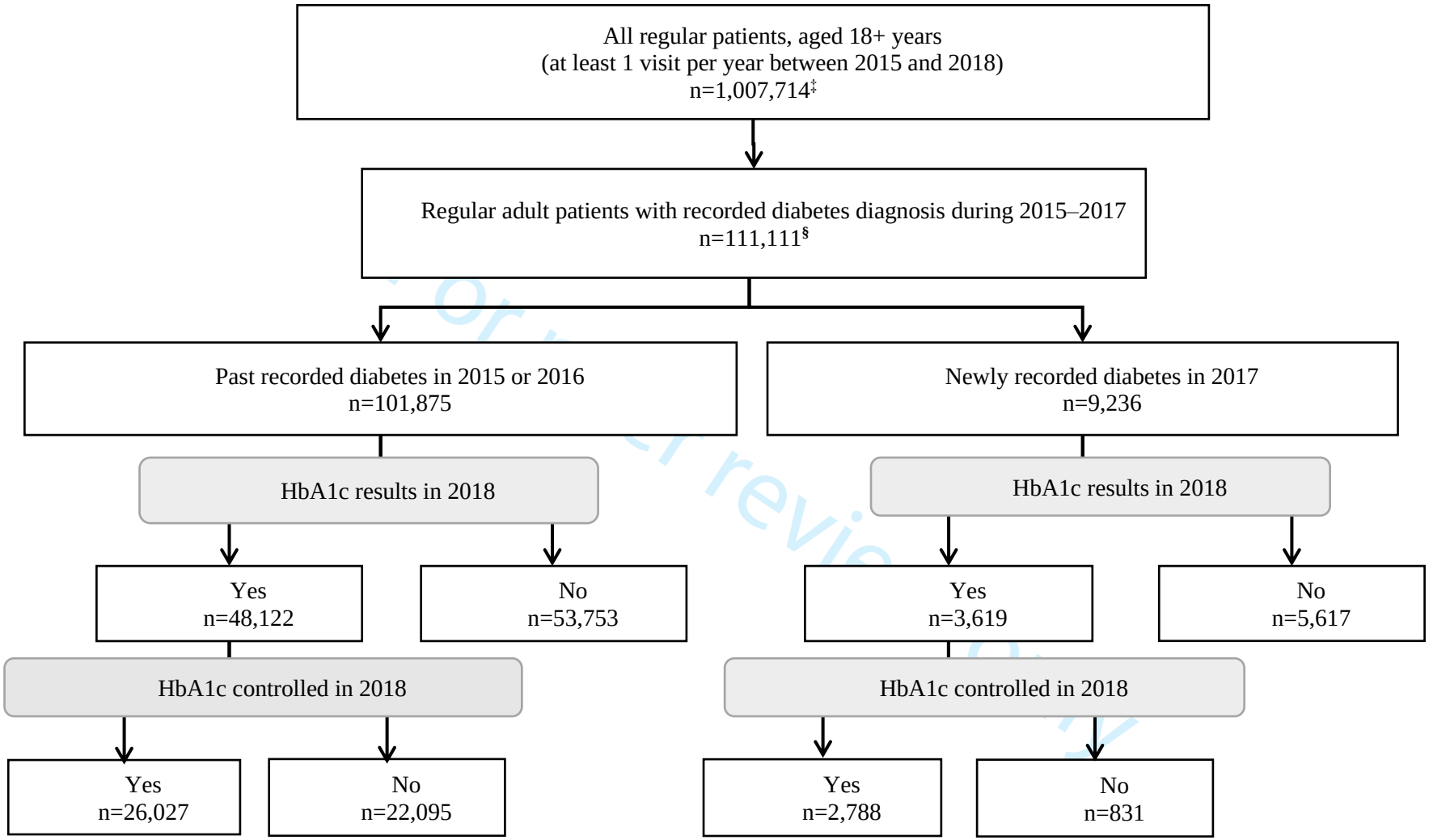
Table S5. Adjusted odds ratio† of distribution of patients with all three clinical parameters controlled (HbA1c, blood pressure, and LDL-C) according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Figure Legend/Caption

Figure 1. Flowchart of the identification of 'regular' adult patients with recorded diabetes and HbA1c control†

† Results are shown as absolute numbers from the dataset without adjusting or weighting. ‡ At least one consultation per year between 2015 and 2018. § Patients were classified as recorded

diabetes when (1) ‘diabetes’ was recorded on two different occasions (as a ‘diagnosis’, ‘reason for encounter’, or ‘reason for prescription’, or (2) antidiabetic medications were prescribed (Anatomical Therapeutic Chemical A10A or A10B; metformin was considered only in the absence of polycystic ovary syndrome diagnosis), or (3) diabetes diagnosis was recorded only once, but there was at least one laboratory result (fasting blood glucose, HbA1c or 2-hour oral glucose tolerance test) above the diabetes threshold.



† Results are shown as absolute numbers from the dataset without adjusting or weighting. ‡ At least one consultation per year between 2015 and 2018. § Patients were classified as recorded diabetes when (1) 'diabetes' was recorded on two different occasions (as a 'diagnosis', 'reason for encounter', or 'reason for prescription', or (2) antidiabetic medications were prescribed (Anatomical Therapeutic Chemical A10A or A10B; metformin was considered only in the absence of polycystic ovary syndrome diagnosis), or (3) diabetes diagnosis was recorded only once, but there was at least one laboratory result (fasting blood glucose, HbA1c or 2-hour oral glucose tolerance test) above the diabetes threshold.

Figure 1. Flowchart of the identification of 'regular' adult patients with recorded diabetes and HbA1c control†

Table S1. Proportion† of patients with different blood glucose parameters monitored in 2018 among those with past (2015–2016) or newly recorded diabetes (2017)

Clinical parameters monitored	Patients monitored among those with past recorded diabetes (n=101,875) % (95%CI)	Patients monitored among those with newly recorded diabetes (n=9,236) % (95% CI)
Number of different blood glucose tests monitored§		
0	39.8 (37.5–42.0)	45.5 (43.2–47.9)
1	23.8 (22.4–25.2)	21.7 (20.3–23.1)
2	27.5 (25.7–29.2)	25.2 (23.5–27.0)
3	9.0 (7.9–10.1)	7.5 (6.4–8.6)

95%CI: 95% Confidence interval

† Results adjusted for differences between these two groups in terms of practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, or depressive symptoms using logistic regression models.

§ Considering either HbA1c, fasting blood glucose and/or random blood glucose.

Table S2. Adjusted odds ratio† of patients who had all three parameters (HbA1c, blood pressure, and total cholesterol) monitored, among those with past (2015–2016) or newly recorded diabetes (2017), according to sociodemographic and clinical characteristics

All three parameters monitored	Patients monitored among those with past recorded diabetes (n=101,875) Odds ratio (95%CI)	Patients monitored among those with newly recorded diabetes (n=9,236) Odds ratio (95%CI)
Practice characteristics		
Geographical area of GP		
Major cities	Ref	Ref
Inner regional	1.04 (0.79–1.37)	1.11 (0.86–1.44)
Outer regional/remote/very remote	1.64 (1.22–2.19)	1.64 (1.22–2.20)
GP IRSAD		
More disadvantaged	Ref	Ref
Middle	0.96 (0.72–1.28)	0.81 (0.62–1.05)
More advantaged	0.90 (0.70–1.17)	0.95 (0.74–1.22)
Patient's characteristics		
Gender		
Female	Ref	Ref
Male	1.08 (1.04–1.12)	1.26 (1.13–1.40)
Age group (years)		
18–39	Ref	Ref
40–64	2.72 (2.50–2.97)	3.15 (2.60–3.82)
65+	3.05 (2.76–3.38)	3.87 (3.15–4.76)
Smoking status		
Non-smoker or ex-smoker	Ref	Ref
Smoker	0.91 (0.86–0.96)	0.97 (0.82–1.12)
History of hypertension		
No	Ref	Ref
Yes	1.11 (1.04–1.18)	1.17 (1.04–1.30)
History of CVD		
No	Ref	Ref
Yes	0.97 (0.92–1.02)	0.98 (0.84–1.13)
History of dyslipidaemia		
No	Ref	Ref
Yes	1.26 (1.18–1.35)	1.23 (1.09–1.39)
History of CKD		
No	Ref	Ref
Yes	0.91 (0.81–1.02)	0.84 (0.62–1.14)
History of liver disease		
No	Ref	Ref
Yes	1.02 (0.85–1.22)	0.93 (0.53–1.63)
History of depressive syndrome		
No	Ref	Ref
Yes	0.89 (0.84–0.94)	0.91 (0.81–1.03)

GP: General practice; Ref: Reference group; 95%CI: 95% Confidence interval; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage; CVD: Cardiovascular disease (including heart failure, ischemic heart disease, and stroke); CKD: Chronic kidney disease.

† Adjusted odds ratio of patients who had all three parameters (HbA1c, blood pressure, and total cholesterol) monitored based on logistic regression models that considered differences among patients with past or newly recorded diabetes adjusted for practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, or depressive symptoms.

Table S3. Adjusted proportion† of the combination of clinical parameters controlled in 2018 among patients with past (2015-2016) or newly recorded diabetes (2017) and available results for all three parameters (HbA1c, blood pressure, and LDL-C)

	Past recorded diabetes (n= 34,476)		Newly recorded diabetes (n= 2,521)		
	n	% (95%CI)	N	% (95%CI)	Adjusted† odds ratio (95%CI)
None controlled	2,784	8.1 (7.6–8.6)	117	4.6 (3.8–5.4)	0.33 (0.27–0.40)
Only HbA1c controlled	3,223	9.3 (8.9–9.8)	428	16.9 (15.3–18.6)	1.05 (0.92–1.20)
Only BP controlled	5,373	15.6 (15.0–16.2)	231	9.2 (8.0–10.3)	0.34 (0.29–0.39)
Only LDL-C controlled	2,224	6.5 (6.1–6.8)	50	2.0 (1.5–2.5)	0.18 (0.13–0.23)
HbA1c and BP controlled	6,867	19.9 (19.2–20.6)	871	34.5 (32.5–36.6)	base outcome
HbA1c and LDL-C controlled	2,518	7.3 (6.9–7.7)	173	6.9 (5.7–8.0)	0.54 (0.44–0.65)
BP and LDL-C controlled	5,144	14.9 (14.4–15.4)	131	5.2 (4.2–6.2)	0.20 (0.16–0.24)
All controlled	6,343	18.4 (17.7–19.1)	520	20.6 (18.9–22.4)	0.64 (0.56–0.72)

95%CI: 95% Confidence interval; HbA1c: Haemoglobin A1c; BP: Blood pressure; LDL-C: Low-density lipoprotein cholesterol; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage; CVD: Cardiovascular disease (including heart failure, ischemic heart disease, and stroke); CKD: Chronic kidney disease.

† Adjusted proportion of the most frequent combination of clinical parameters controlled in 2018 based on multinomial logistic regression models adjusted for practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, or depressive symptoms.

Table S4. Adjusted odds ratio† of distribution of patients with all three clinical parameters controlled (HbA1c, blood pressure, and total cholesterol) according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Variables	'All-controlled' among past recorded diabetes (n=40,008) Odds ratio (95%CI)	'All-controlled' among newly recorded diabetes (n=2,912) Odds ratio (95%CI)
Practice characteristics		
Geographical area of GP		
Major Cities	Ref	Ref
Inner regional	1.05 (0.93–1.20)	1.12 (0.86–1.45)
Outer/Remote/Very Remote	0.93 (0.80–1.10)	0.94 (0.70–1.27)
GP IRSAD		
More disadvantaged	Ref	Ref
Middle	1.00 (0.87–1.14)	1.08 (0.82–1.41)
More advantaged	0.99 (0.80–1.09)	0.81 (0.63–1.06)
Patient's characteristics		
Gender		
Female	Ref	Ref
Male	1.50 (1.41–1.58)	1.77 (1.44–2.16)
Age group (years)		
18–39	Ref	Ref
40–64	1.78 (1.38–2.30)	1.25 (0.76–2.05)
65+	3.31 (2.58–4.25)	2.09 (1.26–3.49)
Smoking status		
Non-smoker or ex-smoker	Ref	Ref
Smoker	0.91 (0.83–1.00)	1.10 (0.83–1.44)
History of hypertension		
No	Ref	Ref
Yes	0.89 (0.84–0.95)	0.98 (0.81–1.19)
History of CVD		
No	Ref	Ref
Yes	1.38 (1.28–1.47)	2.42 (1.81–3.22)
History of dyslipidaemia		
No	Ref	Ref
Yes	1.07 (0.99–1.15)	1.16 (0.93–1.43)
History of CKD		
No	Ref	Ref
Yes	0.97 (0.85–1.11)	0.86 (0.42–1.77)
History of liver disease		
No	Ref	Ref
Yes	1.29 (0.92–1.80)	3.30 (1.33–8.19)
History of depressive syndrome		
No	Ref	Ref
Yes	0.91 (0.84–1.00)	0.87 (0.67–1.11)

GP: General practitioner; Ref: Reference group; 95%CI: 95% Confidence interval; HbA1c: Hemoglobin A1c; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage; CVD: Cardiovascular disease (including heart failure, ischemic heart disease, and stroke); CKD: Chronic kidney disease.

† 'All-controlled' are those patients with HbA1c≤7.0%, BP≤140/90mmHg, and total cholesterol <4.0mmol/L. Adjusted odds ratio of patients who had each clinical parameter controlled based on logistic regression models adjusted for practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, or depressive symptoms.

Table S5. Adjusted odds ratio† of distribution of patients with all three clinical parameters controlled (HbA1c, blood pressure, and LDL-C) according to sociodemographic and clinical characteristics among those with past (2015-2016) or newly recorded diabetes (2017)

Variables	'All-controlled' among past recorded diabetes (n=34,475) Odds ratio (95%CI)	'All-controlled' among newly recorded diabetes (n=2,521) Odds ratio (95%CI)
Practice characteristics		
Geographical area of GP		
Major cities	Ref	Ref
Inner regional	1.11 (0.98–1.26)	1.14 (0.88–1.50)
Outer/remote/very remote	1.05 (0.90–1.21)	1.07 (0.77–1.49)
GP IRSAD		
More disadvantaged	Ref	Ref
Middle	1.02 (0.89–1.17)	0.80 (0.58–1.12)
More advantaged	1.03 (0.92–1.16)	0.94 (0.70–1.27)
Patient's characteristics		
Gender		
Female	Ref	Ref
Male	1.18 (1.11–1.25)	1.23 (1.00–1.51)
Age group (years)		
18-39	Ref	Ref
40-64	2.29 (1.67–3.14)	2.18 (1.13–4.19)
65+	4.38 (3.20–5.98)	3.80 (1.97–7.35)
Smoking status		
Non-smoker or ex-smoker	Ref	Ref
Smoker	0.94 (0.84–1.04)	1.15 (0.84–1.56)
History of hypertension		
No	Ref	Ref
Yes	0.89 (0.84–0.95)	0.97 (0.80–1.17)
History of CVD		
No	Ref	Ref
Yes	1.33 (1.22–1.43)	2.09 (1.54–2.83)
History of dyslipidaemia		
No	Ref	Ref
Yes	1.10 (1.01–1.19)	1.40 (1.11–1.76)
History of CKD		
No	Ref	Ref
Yes	1.05 (0.91–1.20)	1.19 (0.62–2.30)
History of liver disease		
No	Ref	Ref
Yes	1.14 (0.78–1.68)	3.37 (1.08–10.57)
History of depressive syndrome		
No	Ref	Ref
Yes	0.94 (0.87–1.03)	0.87 (0.67–1.13)

HbA1c: Haemoglobin A1c; LDL-C: Low-density lipoprotein cholesterol; GP: General practitioner; Ref: Reference group; 95%CI: 95% Confidence interval; IRSAD: Index of Relative Socio-economic Advantage and Disadvantage; CVD: Cardiovascular disease (including heart failure, ischemic heart disease, and stroke); CKD: Chronic kidney disease.

† 'All-controlled' are those patients with HbA1c≤7.0%, BP≤140/90mmHg, and total cholesterol <4.0mmol/L. Adjusted odds ratio of patients who had each clinical parameter controlled based on logistic regression models adjusted for practice characteristics (remoteness, IRSAD quintiles), patient sociodemographics (gender, age), and clinical characteristics (smoking status, history of hypertension, CVD, CKD, dyslipidaemia, liver disease, or depressive symptoms.

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Lines 15-41
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			Lines 54-91
Objectives	3	State specific objectives, including any prespecified hypotheses			Lines 92-99
Methods					
Study Design	4	Present key elements of study design early in the paper			Lines 101-109
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection			Lines 110-140
Participants	6	*(a) Cohort study* - Give the		RECORD 6.1: The methods of study	Lines 122-142

		eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Lines 110-121 n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Lines 143-184
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group			Lines 144-170
Bias	9	Describe any efforts to address potential sources of bias			Lines 196-202

Study size	10	Explain how the study size was arrived at			n/a
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			Lines 144-170
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			Lines 185-206
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	Lines 104-109
Linkage		..		RECORD 12.3: State whether the	

				study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	n/a
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Lines 220-220
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)			Lines 214-220
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or			Lines 233-306

		summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			Lines 233-306
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			Lines 290-294
Discussion					
Key results	18	Summarise key results with reference to study objectives			Lines 309-316
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Lines 394-410
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			Lines 317-393

Generalisability	21	Discuss the generalisability (external validity) of the study results			Lines 393-408
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based			Lines 449-452
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Lines 432-437

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.