Trends in the Incidence of Hospitalization for Major Diabetes-Related Complications in People With Type 1 and Type 2 Diabetes in Australia, 2010–2019

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OBJECTIVE

To determine trends in the incidence of major diabetes-related complications in Australia.

RESEARCH DESIGN AND METHODS

This study included 70,885 people with type 1 and 1,089,270 people with type 2 diabetes registered on the Australian diabetes registry followed from July 2010 to June 2019. Outcomes (hospitalization for myocardial infarction [MI], stroke, heart failure [HF], lower-extremity amputation [LEA], hypoglycemia, and hyperglycemia) were obtained via linkage to hospital admissions databases. Trends over time in the age-adjusted incidence of hospitalizations were analyzed using joinpoint regression and summarized as annual percent changes (APCs).

RESULTS

In type 1 diabetes, the incidence of all complications remained stable, except for stroke, which increased from 2010–2011 to 2018–2019 (financial years; APC: +2.5% [95% CI 0.1, 4.8]), and hyperglycemia, which increased from 2010–2011 to 2016–2017 (APC: +2.7% [1.0, 4.5]). In type 2 diabetes, the incidence of stroke remained stable, while the incidence of MI decreased from 2012–2013 to 2018–2019 (APC: −1.7% [95% CI −2.8, −0.5]), as did the incidence of HF and hypoglycemia from 2010–2011 to 2018–2019 (APCs: −0.8% [−1.5, 0.0] and −5.3% [−6.7, −3.9], respectively); the incidence of LEA and hyperglycemia increased (APCs: +3.1% [1.9, 4.4], and +7.4% [5.9, 9.0]). Most trends were consistent by sex, but differed by age; in type 2 diabetes most improvements were confined to individuals aged ≥60 years.

CONCLUSIONS

Trends in admissions for diabetes-related complications were largely stable in type 1 diabetes. In type 2 diabetes, hospitalization rates for MI, HF, and hypoglycemia fell over time, while increasing for LEA and hyperglycemia.

The cost and personal burden of diabetes is in large part attributable to common major diabetes-related complications, such as acute myocardial infarction (MI),

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stroke, and lower extremity amputations (LEA) (1,2). Concomitant with the large worldwide increase in diabetes prevalence, there has also been a large increase in the burden of diabetes-related complications in recent decades (3). However, the nature of diabetes-related complications appears to be shifting across the world.

In the U.S., the incidence of MI, stroke, LEA, end-stage kidney disease, and death from hyperglycemic crisis fell from 1990 to 2010 (4), before increasing from 2010 to 2015 (5). Other U.S. analyses show similar stabilization or increase in the incidence of several major diabetes-related complications in recent years (6–8). However, overall health in the U.S. has progressively worsened in the last decade (9), and the U.S. health care system is increasingly an outlier among high-income countries. Thus, whether the resurgence generalizes to other populations with diabetes is unclear. Data from other high-income countries have been published, yet the trends, like U.S. data, are usually not stratified by type of diabetes (10–12) or only focus on one type of diabetes (13–18), and data from 2015 onward are scarce.

Trends in diabetes-related complications since 2015 are of particular interest due to the high uptake of newer antihyperglycemic drug classes occurring during this period (Morton et al., unpublished data). Correspondingly, it will also be important to contrast recent trends in diabetes-related complications by diabetes type, as this may provide insight into which changes are due to more general improvements in diabetes care versus specific effects of new drug classes (because newer drug classes are only widely available for people with type 2 diabetes in Australia). These trends are not only critical to our understanding of recent performance of diabetes care but will also guide health policy and strategy into the future.

Therefore, to estimate trends in the incidence of major diabetes-related complications in people with type 1 and type 2 diabetes in Australia from 2010 to 2019, we linked the Australian diabetes registry, one of the largest in the world, to hospital admission databases in four Australian states.

RESEARCH DESIGN AND METHODS

Data Sources

The population for this study was derived from the National Diabetes Services Scheme (NDSS), the Australian diabetes registry, which is estimated to capture 80–90% of all people with diagnosed diabetes in Australia (19). We included NDSS registrants with type 1 or type 2 diabetes from the states of Victoria, New South Wales, the Australian Capital Territory, and Queensland (~80% of all people on the NDSS) who were registered on the NDSS as of 1 July 2010 and all new registrants up until 30 June 2019. A health care practitioner assigns diabetes type at the time of registration on the NDSS; however, we also required several clinical characteristics to be satisfied for assignment of diabetes type in this study (Supplementary Appendix). Our analysis was restricted to Australians who do not identify as Aboriginal or Torres Strait Islander because Aboriginal and Torres Strait Islander Australians are able to access services the NDSS provides via separate programs and are consequently not well represented on the NDSS.

This cohort was linked to the National Death Index (NDI) and hospital admissions data sets by the Australian Institute of Health and Welfare. The NDI records all deaths that occur in Australia; date of death was derived from the NDI. Hospital admissions data sets collect information on all hospital admissions to public and private hospitals within each state. Australia's hospital network consists of both private and public hospitals. Public hospitals provide free medical care to all, while private hospitals are accessible to people with private health insurance. More complex care is usually undertaken in public hospitals. We selected the four states for our study because public and private hospital admissions are both administered by the same body in these states, while processes to obtain private data are more complex in other states. However, due to unforeseen regulatory constraints, private hospital data were ultimately only available for Queensland and Victoria (2010–2017 only) in this linked data set. Therefore, the primary analysis in this study only included data from public hospitals. However, we also conducted sensitivity analyses including and excluding private hospital data from Queensland and Victoria to assess the effect of excluding private hospitals. Admissions data are released in financial years; therefore, all analyses in this study were by financial (July–June), not calendar, year.

This study was approved by the Alfred Hospital Ethics Committee (Project No.: 463/18) and the Australian Institute of Health and Welfare Ethics Committee (EO2018/5/501).

Definitions

The major diabetes-related complications considered in this study were hospitalization for MI, stroke, heart failure (HF), LEA, hypoglycemia, and hyperglycemia (diabetic ketoacidosis [DKA] and hyperglycemic hyperosmolar state [HHS]). MI, stroke, HF, and hyperglycemia were defined by the presence of one of the following ICD-10 Australian Modification (ICD-10 AM) diagnosis codes as the primary diagnosis recorded for an admission: MI (ICD-10-AM codes: I21-I22), stroke (I60-I64), HF (I110, I130, I132, or I50), and hyperglycemia (DKA: E1*X*11, E1*X*12, E1*X*15, or E1*X*16; or HHS: E1*X*01 or E1*X*02; where $X = 0, 1, 2, 3,$ or 4). Hypoglycemia was defined by the presence of E1*X*64, E160, E161, or E162 as the primary diagnosis for an admission or when one of these codes were the first secondary diagnosis and the primary diagnosis was "poisoning by insulin and oral hypoglycemic drugs" (ICD-10 AM code: T383). LEAs were defined as an admission with any procedure code for a major amputation (through or above the ankle; procedure codes: 4436700, 4436701, 4436702, 4437000, 4437300) or minor amputation (below the ankle; procedure codes: 4433800, 4435800, 4436100, 4436101, 4436400, 4436401, 9055700). We also stratified by major and minor amputations, using the highest level amputation for the admission when more than one amputation procedure code was present (20,21).

Data Analysis

NDSS registrants were followed from 1 July 2010, date of registration on the NDSS, or date of migration into one of the four states, whichever came last, until the first of admission for a complication, migration out of one of the four states (within Australia), death, or end of follow-up. If admission occurred and the individual survived the admission,

individuals were subsequently followed from discharge until readmission, migration out, death, or end of follow-up. Thus, one person could have multiple admissions for multiple complications in a given year. Because a single event can be recorded multiple times in admissions data, internal transfers and transfers between hospitals were considered part of the same admission. Furthermore, because admissions are only recorded in hospital admissions data sets upon discharge, we terminated follow-up prior to 30 June 2019 for admissions data to ensure we did not underestimate the incidence of admissions in the final year; follow-up ended on 15 June 2019 for MI, HF, hypoglycemia, and hyperglycemia, and 25 May 2019 for stroke and LEA. These dates were selected based on the 90th percentile of length of stay for each complication in our admissions data.

Incidence rates and 95% CIs were calculated by dividing the number of incident cases by the total number of person-years of follow-up. Age-adjusted incidence rates were calculated using the direct method, standardizing to either the type 1 or type 2 diabetes population structure at the midpoint year (2014–2015) using 5-year age-groups. Incidence rates were stratified by diabetes type, sex, and age. Sex-specific rates were standardized to the overall type 1 and type 2 diabetes population structure to enable comparison of rates between males and females. Age-specific rates were standardized to the age structure within that age-group in 2014–2015.

Trends over time were analyzed using the Joinpoint Regression Program. Joinpoint trend analysis identifies points where a significant change (direction or magnitude) in a linear trend occurs and calculates an annual percent change (APC) for each segment identified (22). We specified a maximum of one joinpoint for the 9-year period from 2010–2011 to 2018–2019, with a P value of <0.05 considered statistically significant.

Statistical analyses were performed in Stata 16 statistical software (StataCorp, College Station, TX), and the Joinpoint Regression Program 4.7 (National Cancer Institute, Bethesda, MD).

Data Resource and Availability

The data sets analyzed during the current study are not publicly available due to privacy concerns.

RESULTS

Population Characteristics

Characteristics of the population used in this study are reported in Table 1. This study included 70,885 people with type 1 diabetes and 1,089,270 people with type 2 diabetes. The change in population characteristics over time is reported in Supplementary Table 1. From 2010–2011 to 2018–2019, the median age of people with type 1 diabetes increased from 38.0 (interquartile range 24.9, 51.9) to 39.4 (26.5, 54.8) years, and the median duration of diabetes increased from 15.6 (7.0, 22.6) to 17.1 (7.9, 27.9) years. In type 2 diabetes, the median age and duration were 66.1 (interquartile range 56.6, 75.3) and 7.7 (3.4, 13.1) years in 2010–2011, increasing to 68.4 (58.6, 76.9) and 10.1 (5.3, 16.5) years in 2018–2019, respectively. During a total of 7,391,823 person-years of follow-up, there were a total of 62,799, 40,733, 98,128, 22,395, 32,208, and 40,561 admissions for MI, stroke, HF, LEA, hypoglycemia, and hyperglycemia, respectively.

Trends in Hospitalization for Major Diabetes-Related Complications

Figure 1 shows age-adjusted trends in the incidence of hospitalization for major diabetes-related complications for people with type 1 and type 2 diabetes from 2010 to 2019; crude incidence rates are shown in Supplementary Fig. 1. The age-adjusted incidence of hospitalization for MI, HF, LEA, and hypoglycemia was stable in people with type 1 diabetes, while the age-adjusted incidence of stroke increased from 2010–2011 to 2018–2019 (APC: 2.5% [95% CI 0.1, 4.8]) and the incidence of hyperglycemia increased from 2010–2011 to 2016–2017 (APC: 2.7% [1.0, 4.5]), plateauing thereafter (Fig. 1 and Supplementary Table 2). Crude APCs were generally larger than age-adjusted APCs, with significant increases over time in stroke, LEA, and hyperglycemia (Supplementary Table 2).

In people with type 2 diabetes, the age-adjusted incidence of hospitalization for MI decreased from 2012–2013 to 2018–2019 (APC: −1.7% [95% CI −2.8, −0.5]), as did the incidence of HF and hypoglycemia from 2010–2011 to 2018–2019 (Fig. 1 and Supplementary Table 2). Conversely, from 2010–2011 to 2018–2019, there was an increase in the incidence of LEA (APC: 3.1% [1.9,

Table 1—Population characteristics and number of hospitalizations for major diabetes-related complications during follow-up from 2010 to 2019, by diabetes type

	Type 1 diabetes	Type 2 diabetes
n	70,885	1,089,270
Male sex	38,638 (54.5)	597,022 (54.8)
Person-years of follow-up	521,020	6,870,803
Age at diagnosis of diabetes, years	22.3 (12.0, 33.2)	58.2 (48.7, 67.2)
Duration of diabetes, years[1]	17.6 (8.0, 27.7)	10.3 (5.4, 16.7)
Age, years[1]	40.5 (27.1, 56.1)	70.2 (60.2, 79.3)
Age category, years[1]		
0–19	9,502 (13.4)	378 (0.0)
20–39	25,317 (35.7)	26,987 (2.5)
40–59	22,400 (31.6)	241,429 (22.2)
60–79	13,157 (18.6)	567,649 (52.1)
≥80	509 (0.7)	252,827 (23.2)
Hospitalizations during follow-up		
MI	2,432	60,367
Stroke	1,146	39,587
HF	1,987	96,141
LEA	2,371	20,024
Hypoglycemia	10,397	21,811
Hyperglycemia	28,944	11,617

Data are presented as *n*, *n* (%), or median (25th, 75th centile). [1]At end of follow-up.

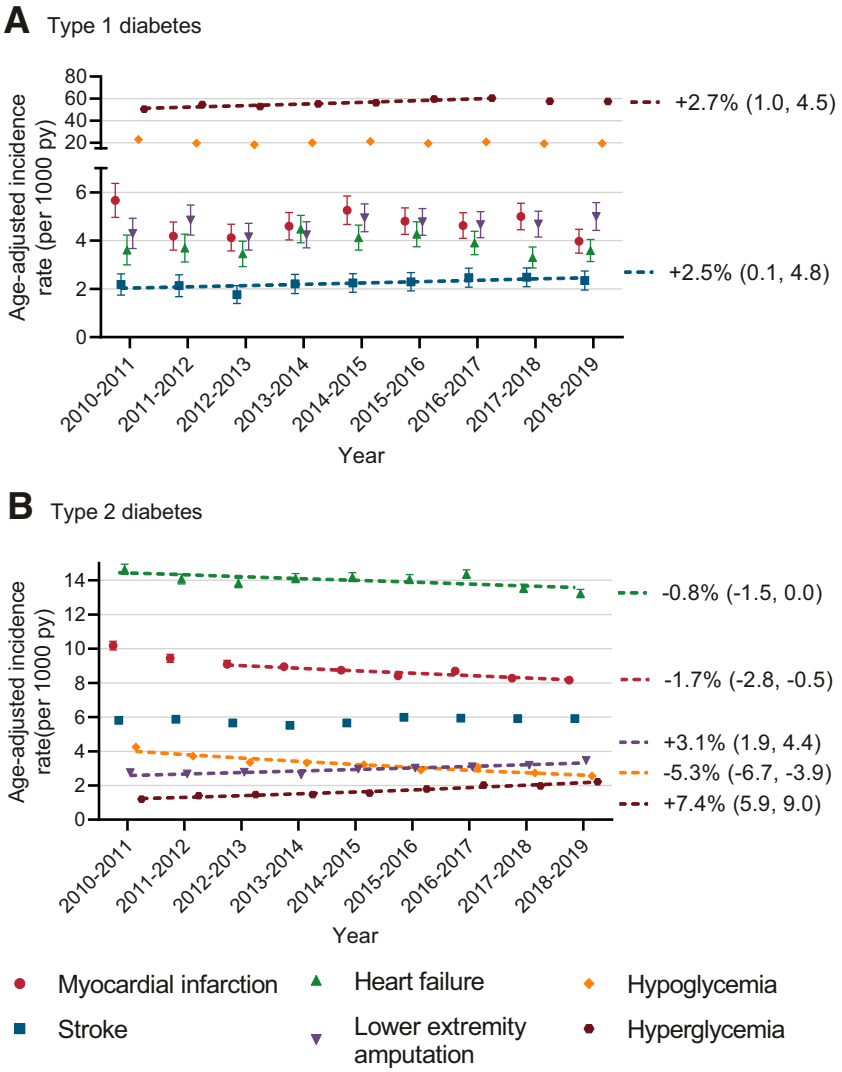

Figure 1—Age-adjusted incidence of hospitalization for major diabetes-related complications among people with type 1 diabetes (*A*) and type 2 diabetes (*B*) from 2010–2011 to 2018–2019. py, person-years. Trends significantly different from zero at $P < 0.05$ are displayed as dashed lines and labeled with the APC (95% CI).

4.4]) and hyperglycemia (APC: 7.4% [5.9, 9.0]), while stroke incidence remained stable. Crude APCs were larger than age-adjusted APCs, with significant increases in stroke, LEA, and hyperglycemia (Supplementary Fig. 1 and Supplementary Table 2).

In people with type 2 diabetes, the proportion of hospitalizations for hyperglycemia that were for DKA and HHS did not change substantially over time (67% DKA and 33% HHS, respectively) and the proportion of hyperglycemia admissions that were for DKA decreased with increasing age (from 92% among those aged 20–39 years to 44% among people aged ≥80 years).

When considering only the highest-level amputation per admission, minor amputations accounted for 79% of LEAs, with this proportion increasing over time (from 74% to 79% in type 1 diabetes and from 73% to 82% in type 2 diabetes from 2010–2011 to 2018–2019). When stratified by major versus minor LEAs, age-adjusted incidence rates were stable over time for both major and minor amputations in people with type 1 diabetes (APCs of 0.3% [95% CI −1.9, 2.6] and 1.7% [−0.6, 4.1], respectively) (Supplementary Table 3). In type 2 diabetes, the age-adjusted incidence of minor amputations increased from 2.0 (95% CI 1.9, 2.1) to 2.9 (2.7, 3.0) per 1,000 person-years (APC: 4.5% [3.5, 5.4]), while the rate of major amputations was stable over time (APC: −1.7% [−4.2, 0.9]).

Trends in Hospitalization for Major Diabetes-Related Complications by Sex

Among people with type 1 diabetes, males were generally at higher risk for hospitalization for MI and LEA than females, while females were at higher risk of hyperglycemia (Fig. 2). Among people with type 2 diabetes, males were at higher risk of MI, stroke, HF, and LEA than females.

In people with type 1 diabetes, trends in hospitalization for MI, HF, LEA, and hypoglycemia were broadly consistent in males and females. However, the age-adjusted incidence of stroke increased more in females than males with type 1 diabetes (APC: 6.1% [95% CI 1.3, 11.0] in females vs. 0.2% [−2.9, 3.4] in males) (Fig. 2 and Supplementary Table 4). In people with type 2 diabetes, trends in hospitalization for hypoglycemia and hyperglycemia were consistent in males and females. Conversely, the increase in the incidence over time in stroke and LEA was greater for males than females, and there was a greater relative decrease in the incidence of MI in females (APC: −3.6% [−4.8, −2.4]) versus males (−1.8% [−2.3, −1.3]). Trends in HF also differed by sex; HF incidence decreased throughout the study period for females, while there was no significant change in males until 2016–2017, with HF incidence decreasing thereafter.

Trends in Hospitalization for Major Diabetes-Related Complications by Age

In both type 1 and 2 diabetes, the incidence of hospitalization for MI, stroke, HF, and LEA increased with age (Fig. 3). In type 1 diabetes, incidence of hypoglycemia and hyperglycemia was highest in people aged 0–19 years. Conversely, in type 2 diabetes, hypoglycemia incidence increased with increasing age, while incidence of hyperglycemia was highest in people aged 20–39 years.

Uncertainty around age-stratified APCs in type 1 diabetes was high. Nevertheless, some patterns were apparent. APCs for the incidence of hospitalization for stroke and LEA were lowest in the 60–79 age-group, while APCs for the incidence

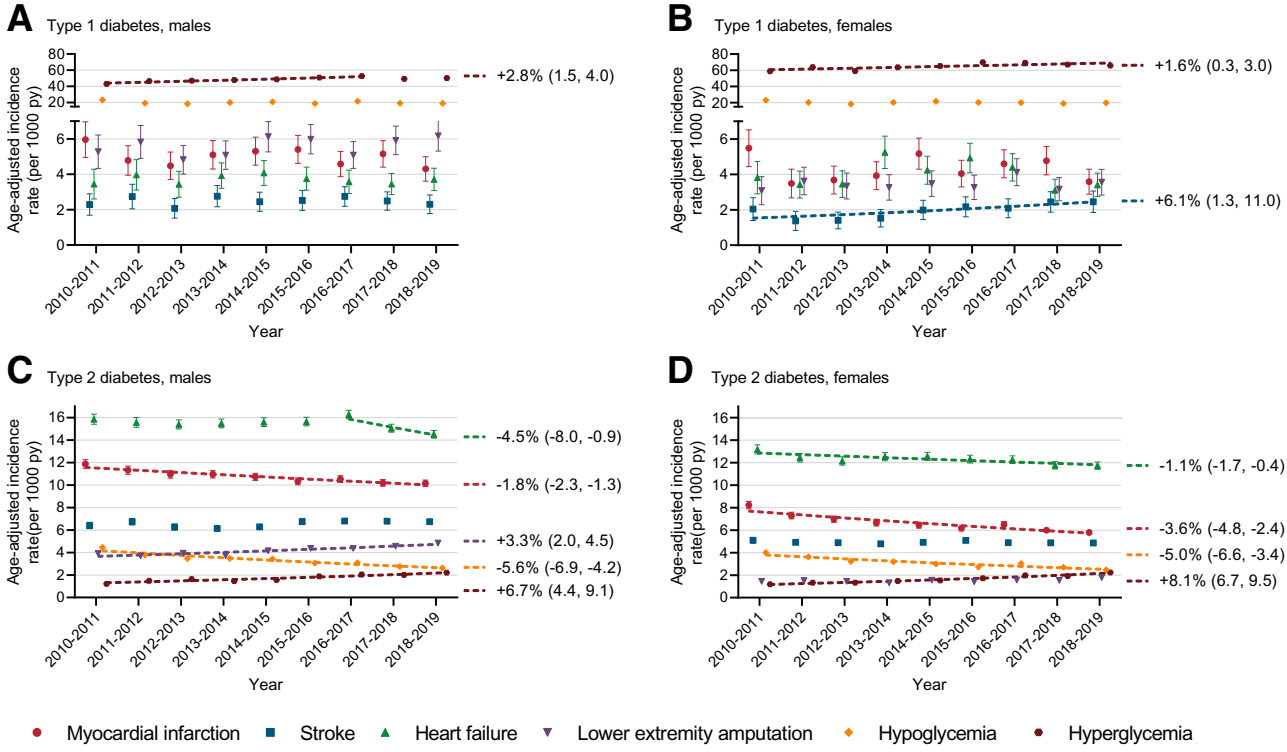

Figure 2—Age-adjusted incidence of hospitalization for major diabetes-related complications among people with type 1 diabetes (*A* and *B*) and type 2 diabetes (*C* and *D*) from 2010–2011 to 2018–2019, stratified by male (*A* and *C*) and female (*B* and *D*) sex. py, person-years. Trends significantly different from zero at $P < 0.05$ are displayed as dashed lines and labeled with the APC (95% CI).

of hyperglycemia increased with increasing age (Fig. 3 and Supplementary Table 5). Among people with type 2 diabetes, trends over time were more favorable for older age-groups. The decline in the incidence of MI was restricted to those aged ≥60 years. Similarly, the decline in HF was specific to people aged 60–79 years, while HF incidence actually increased in the 20–39 and 40–59 age-groups. APCs for the incidence of hypoglycemia decreased with increasing age, while the APCs for the incidence of stroke and LEA were highest in people aged <80 years.

Sensitivity Analyses

The proportion of admissions in public hospitals (vs. private) varied for each complication, from 97% for hyperglycemia in Victoria to 76% for HF and LEA in Queensland (Supplementary Table 6). This proportion also varied by age (e.g., 8% of MI admissions in Queensland occurred in private hospitals for people aged 40–59 vs. 18% in people aged ≥80), and thus, the difference in incidence rates was greatest for older people (Supplementary Table 7). In Victoria, these proportions did not change significantly over time for any complication, except HF, which decreased from 84 to 82%; nevertheless, all APCs were consistent in analyses including and excluding private hospital data (Supplementary Table 7). However, in Queensland, the proportion of admissions that occurred in public hospitals increased from 2010–2011 to 2018–2019 for stroke (from 81% to 87%), HF (74% to 77%), LEA (74% to 79%), hypoglycemia (88% to 89%), and hyperglycemia (93% to 95%) (Supplementary Table 6). Consequently, APCs from analyses including private hospitals were lower than analyses of public hospitals alone, but this effect was mostly confined to people aged ≥80 years for all complications. However, because the absolute change in the proportion of public versus private over time was small, the magnitude of this effect was minimal for all complications except stroke and LEA. Nevertheless, APCs were directionally consistent for analyses of LEA including and excluding private hospitals in Queensland for people aged ≥80 years, while the APC for stroke including private admissions was −1.0% (95% CI −2.4, 0.5) and excluding was 1.4% (−0.2, 3.0) (Supplementary Table 7).

CONCLUSIONS

This analysis has produced several important findings. In people with type 1 diabetes, the incidence of diabetes-related complications was largely stable, except for stroke and hyperglycemia, which increased. Whereas, in people with type 2 diabetes, the incidence of stroke was stable, but MI, HF, and hypoglycemia decreased, and the incidence of LEA and hyperglycemia increased. However, the increase in LEA was entirely attributable to minor amputations, while the incidence of major amputations was stable. Trends in type 2 diabetes were also largely dependent on age, with more favorable trends in older age-groups. Indeed, while the incidence of MI, HF and hypoglycemia decreased in people aged ≥60 years, in people aged <60 years, the incidence of MI and hypoglycemia was stable, and the incidence of HF actually increased.

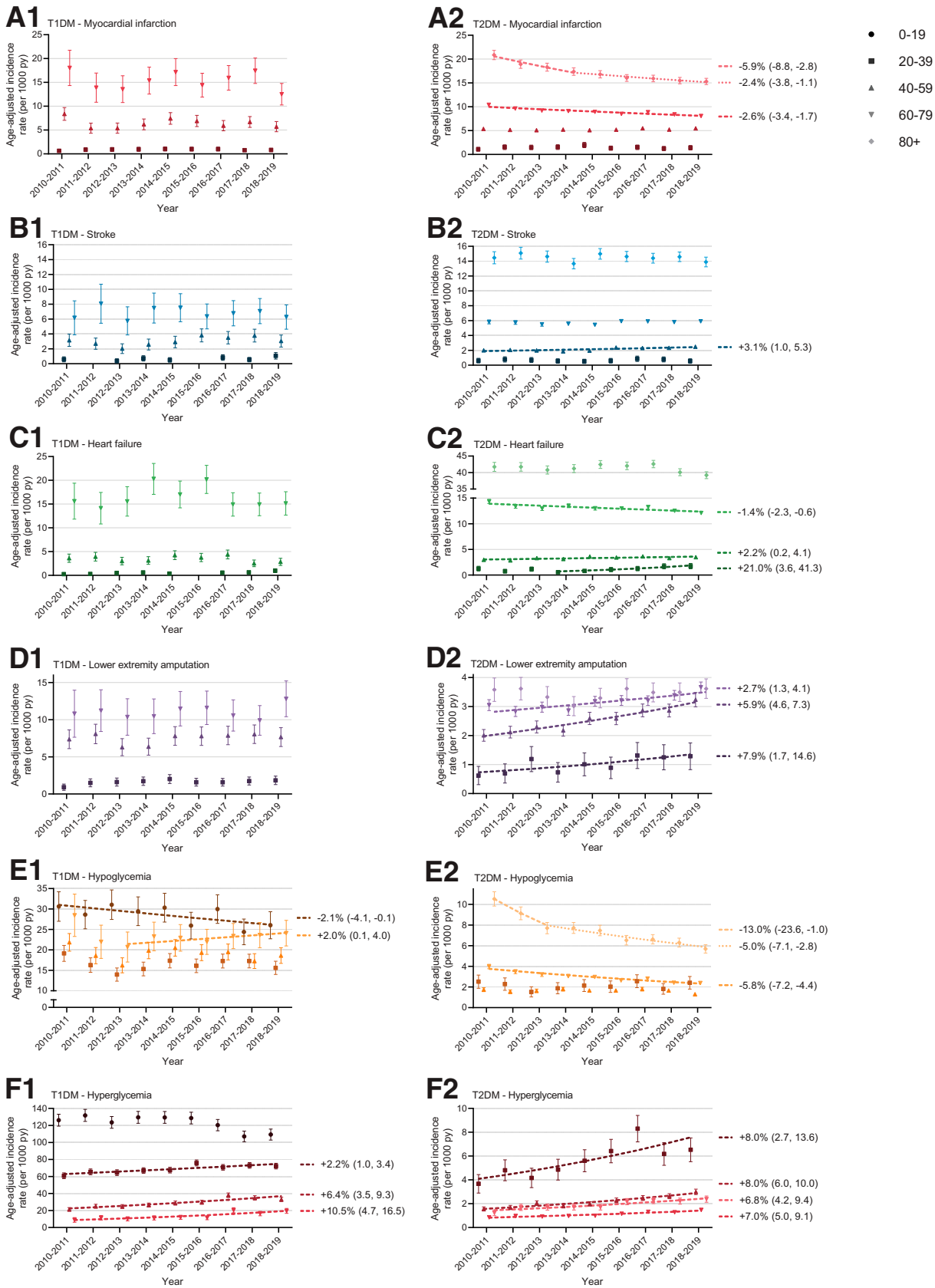

Figure 3—Age-adjusted incidence of hospitalization for major diabetes-related complications, including myocardial infarction (*A1* and *A2*), stroke (*B1* and *B2*), HF (*C1* and *C2*), LEA (*D1* and *D2*), hypoglycemia (*E1* and *E2*), and hyperglycemia (*F1* and *F2*) among people with type 1 diabetes (T1DM) (*A1*, *B1*, *C1*, *D1*, *E1*, and *F1*) and type 2 diabetes (T2DM) (*A2*, *B2*, *C2*, *D2*, *E2,* and *F2*) from 2010–2011 to 2018–2019, stratified by age-group. py, person-years. Trends significantly different from zero at $P < 0.05$ are displayed as dashed lines and labeled with the APC (95% CI). Note: Incidence not displayed when fewer than five events occurred in a given year for the age-group.

It is difficult to directly compare incidence rates between studies because of variation in age distributions and comorbidities, definitions of complications, and admission criteria. Nevertheless, the magnitude of the incidence of each diabetes-related complication in the present work is generally consistent with studies from comparable countries (7,13,23–25), supporting the generalizability of our findings to other high-income nations, although our rates of stroke are noticeably lower than in the U.S. (5). Moreover, while this is, to our knowledge, the most recent analysis of its kind, there are several patterns in the trends that align with contemporaneous studies from Australia and other countries.

A study from Victoria (Australia) recently showed a reduction in the incidence of cardiovascular complications (MI, HF, and stroke) from 2004 to 2016 in people with and without diabetes, with a more prominent decline in people with diabetes (26). Similarly, data from the Fremantle Diabetes Study in Western Australia showed a decline in MI and HF in people with type 2 diabetes over time as well as a decrease in the excess risk of MI, stroke, and HF for people with type 2 diabetes compared with matched control subjects without diabetes (18). Studies from Scotland (13), Sweden (27), Finland (16), and Hong Kong (10) all show a continual decrease in cardiovascular complications in people with type 1 and type 2 diabetes. Thus, while we show that these trends continue in Australia for MI and HF in type 2 diabetes, the increase in stroke incidence warrants further investigation. Indeed, this is consistent with data from the U.S., which showed an increase in the incidence of ischemic stroke from 2009 to 2014, while the incidence of acute coronary syndromes and HF remained stable (6). Several potential causes of these trends, such as improved risk factor control, cannot be established from surveillance data of the kind used in the current study, exposing a gap in health care monitoring in Australia. However, we have observed an increase in the use of glucagon-like peptide 1 receptor agonists and sodium–glucose cotransporter inhibitors in the current cohort with type 2 diabetes (Morton et al., unpublished data), which may have had an impact on rates of MI. Moreover, sodium–glucose cotransporter inhibitors considerably reduce the incidence of HF (28) and thus may have contributed to declines in HF. However, given that declines in the incidence of MI and HF predate widespread use of these drugs, it is unlikely that these drugs played a major role in these declines.

The uptake of newer antihyperglycemic drugs, with a concomitant reduction in the use of sulfonylureas (Morton et al., unpublished data), may also be in part responsible for the reduction in hospitalization for hypoglycemia in people with type 2 diabetes, a finding consistent with the available literature (12, 15,23). Another key driver of this result is likely the publication of the Action to Control Cardiovascular Risk in Diabetes (ACCORD), Action in Diabetes and Vascular Disease: Preterax and Diamicron MR Controlled Evaluation (ADVANCE), and Veterans Affairs Diabetes Trial (VADT) trials (29–31) in 2008/2009, which raised doubt about stringent glycemic targets in older people with type 2 diabetes. Indeed, selective relaxation of glycemic targets in older, and not younger, individuals with type 2 diabetes may explain why the decline in hypoglycemia was specific to people aged $\geq$60 years.

Conversely, the incidence of hospitalization for hyperglycemia increased in both type 1 and type 2 diabetes across all age-groups throughout the study, with the exception of people with type 1 diabetes aged 0–19 years. Other studies have found similar trends. The incidence of DKA in type 1 diabetes increased from 2004 to 2018 in Scotland for all age-groups except people aged 10–19 years (14) and hospitalization for DKA and HHS increased from 2009 to 2015 in the U.S. (8). Additionally, while the incidence of DKA increased in people with type 2 diabetes in England from 1998 to 2013, the incidence plateaued from 2007 to 2013 in people with type 1 diabetes (24). The reason for these trends remains unknown. Notably, risk for DKA has a strong socioeconomic component (14), highlighting its preventable nature, and DKA is second only to CVD as a cause of premature mortality in type 1 diabetes (32). Therefore, ongoing efforts to explain these trends and thus prevent DKA morbidity and mortality should be intensified.

We also observed a rise in minor amputations and stabilization in major amputations, a trend consistent with most recent studies on LEA (7,33,34). LEAs are also an important benchmark of multifaceted diabetes care, as they can be prevented by access to and engagement with preventive foot care and multidisciplinary diabetes foot services (21,35–37). Therefore, the rise of minor amputations in people with type 2 diabetes suggests an ongoing need to improve early detection and treatment of diabetic foot ulcers. It is also worth noting that while frequently overlooked as a public health problem in Australia (38), LEAs were one of the most common major diabetes-related complications, especially among young and middle-aged people, and are responsible for a large proportion of the disability burden of diabetes (39).

Our results highlight the impact of age on shaping the burden of diabetes-related complications. Moreover, this is shifting. APCs in this study were higher in younger individuals, a pattern that is becoming increasingly common in the diabetes complication literature (5–7,10), and one that extends to mortality trends (40,41). While this may suggest disparities in diabetes care by age, that would not explain the change over time. A more plausible explanation is a greater effect of recent socioeconomic conditions on younger individuals (5), but this phenomenon is hitherto unexplained.

Another factor driving some of the observed trends may be increased survival in the population with diabetes, evident from the increased median age and duration of diabetes from 2010 to 2019, allowing more time for complications to develop. Additionally, the median age at diagnosis of diabetes progressively fell from 2010 to 2019, which may be a result of improved detection of diabetes, or a relative increase in the prevalence of younger-onset diabetes, both factors that could conceivably influence these trends. Finally, it is worth noting that while we reported trends in rates among people with diabetes, the actual crude counts of all events increased over time, concomitant with increasing diabetes prevalence and highlighting continued growth in the burden of diabetes on health care systems.

The size and representativeness of this data set allowed us to generate robust estimates of trends in hospitalization for major diabetes-related complications across the entire age range of people with both type 1 and type 2 diabetes. However, there are important

limitations that warrant discussion. Foremost is the exclusion of private hospital data, which has two important implications. The first is that we will have underestimated the true incidence of complications and that this underestimation will vary by complication and age. Fortunately, we were able to quantify this using private hospital data for a subsection of our population, and in each case, the vast majority of admissions occurred in the public sector. Second, any change in the proportion of admissions in private versus public hospitals over time could affect the estimated APCs. Indeed, while there was no such effect in Victoria, the APCs for stroke and LEA in older individuals from Queensland may have been an overestimate of the true APCs. While what happened in New South Wales, the largest state, is unknown, we expect the impact on our broader conclusions is minimal given that *1*) there was no effect in Victoria, *2*) the shift from public to private over time was relatively small and thus had only a small effect on APCs, and *3*) our results are highly consistent with data from other countries.

Additionally, we are limited in that we only captured hospital admissions for complications, which will vary in their degree of accuracy for each complication. ICD-10 codes are highly accurate for acute events in admissions data, but not perfect (42), and it is likely that HF is not as robust a diagnosis as many other complications. Admissions data will also vary in terms of what proportion of events led to a hospital admission; for example, while virtually all LEAs will occur during a hospital admission, only ~10% of severe hypoglycemia events result in an admission (43). Nevertheless, complications resulting in hospitalization are associated with the highest health care resource utilization and expense. However, using admissions data does mean that these trends are subject to changes in coding practices and admission or treatment criteria over time. Moreover, using admissions data meant we could not estimate the incidence of complications that occur earlier in the disease course. Indeed, the NDSS lacks clinical information, such as HbA_{1c} and estimated glomerular filtration rate, so we could not evaluate the contribution of these factors to the observed trends.

While we have endeavored to correct for erroneous diabetes type coding in the NDSS using medication patterns and age of onset, the nature of registry data are that there will inevitably be some misclassification of diabetes type. Nonetheless, we believe the level of misclassification is minor and unlikely to affect our conclusions, because the characteristics of our population are similar to known populations with type 1 and type 2 diabetes. Indeed, even in the 20–39 age-group, where there is the greatest potential for misclassification, the incidence of hospitalization for hyperglycemia in people with type 1 diabetes was >10 times that of people with type 2 diabetes, further supporting the notion that any degree of misclassification is small. Furthermore, while the NDSS likely includes the overwhelming majority of people with type 1 diabetes, the 10–20% of people with type 2 diabetes in Australia who are not registered on the NDSS may be more likely to manage diabetes with diet and exercise alone, as these individuals would not require the services the NDSS provides. However, >20% of people with type 2 diabetes in the present cohort do not receive any prescriptions for glucose-lowering drugs (Morton et al. unpublished data), suggesting that the present cohort does is not comprised solely of people with medication-treated diabetes. Finally, we lacked admissions data from the general population and, therefore, could not compare trends to people without diabetes.

In conclusion, trends in hospitalization for major diabetes-related complications are largely stable for people with type 1 diabetes, although there are some worrying increases in stroke and DKA. In type 2 diabetes, there were declines in MI, HF, and hypoglycemia, and increases in minor amputations and hyperglycemia, and trends were less favorable for younger and middle-aged people. Importantly, the causes of these trends remain almost completely unknown, highlighting critical deficiencies in diabetes surveillance. Future research to identify the causes of these trends will be critical to mount an effective response.

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