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Evaluating quality of overall care among older adults with diabetes with comorbidities: a retrospective cohort study

Short title: Quality of overall care among older adults with diabetes with comorbidities

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Abstract

Objectives: This study aimed to: 1) explore whether the quality of overall care for older people with diabetes is differentially affected by types and number of comorbid conditions, and 2) examine the association between process of care measures and the likelihood of all-cause hospitalizations.

Design A population-based, retrospective cohort study

Setting The province of Ontario, Canada

Participants: We identified 673,197 Ontarians aged 65 years and older who had diabetes comorbid with hypertension, chronic ischemic heart disease, osteoarthritis or depression on April 1, 2010.

Main outcome measures: The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. Process of care measures specific to older adults with diabetes and these comorbidities, developed by means of a Delphi panel, were used to assess the quality of care. A generalized estimating equations approach was used to examine associations between the process of care measures and the likelihood of hospitalizations.

Results: The study findings suggest that patients are at risk of suboptimal care with each additional comorbid condition, while the incidence of hospitalizations and number of prescribed drugs markedly increased in patients with 2 vs. 1 selected comorbid condition, especially in those with discordant comorbidities. The median continuity of care score was higher among patients with diabetes-concordant conditions compared to those with diabetes-discordant conditions; and it declined with additional comorbid conditions in both groups. Greater continuity of care was associated with lower hospital utilization for older diabetes patients with both concordant and discordant conditions.

Conclusions: There is a need for focusing on improving continuity of care and prioritizing treatment in older adults with diabetes with any multiple conditions, but especially in those with diabetes-discordant conditions (e.g., depression).

Strengths and limitations of this study

- This population-based study included a large sample size to examine the quality of overall care for older adults with four disease combinations representing the most prevalent clusters of concurrent conditions across multimorbidity groupings.
- The study takes advantage of linked patient-level health administrative databases with detailed demographic and clinical information.
- The study used process of care measures for assessing ambulatory care among older adults with selected disease combinations that were developed using a Delphi technique integrating clinical expertise with systematic reviews of each disease combination.
- The study measures were limited to those available in Ontario administrative data.
- Data regarding other covariates (eg, severity of selected conditions, frailty) and health outcomes (eg, quality of life) were not available for this cohort and should be explored in future research.

Introduction

Evidence shows that the majority of care for adults with multiple chronic conditions is provided in ambulatory care settings and primary care, and is an important locus from which to develop approaches of care to better meet the needs of this population (1, 2). Older adults are more likely than younger individuals to have comorbid chronic conditions that can be complex and difficult to manage (3, 4). Recent research has demonstrated that more than 90% of older adults with diabetes in Ontario had at least one comorbid condition (5). In particular, arthritis, other cardiovascular conditions and mood disorders also commonly appear in older adults with diabetes (3, 5). Hypertension consistently appears as a comorbidity in older adults with diabetes (3, 5, 6).

A growing body of evidence shows that people with multiple chronic conditions are more likely to experience negative health outcomes, including increased healthcare utilization, poor quality of life and increased care costs compared to those a with single disease (7-10). Prior research found that Ontarians with three or more diagnoses had 56% more primary care visits, 76% more specialist visits, 256% more inpatient hospital stays, 11% more emergency department visits, and 68% more prescriptions, as compared to those with a single condition (11, 12).

Primary care physicians face difficulties in addressing the complex multifaceted needs of older adults with multiple chronic conditions (13). Treatment of people with multiple chronic conditions often requires “trade-off” decisions, because current clinical guidelines may be impractical in the presence of multiple chronic conditions (14). Treating one condition in older diabetes patients with comorbid conditions may cause undesirable consequences with regard to their other conditions. Optimal approach to treat patients with any combination of co-existing diseases is not the same as the sum of treatments for the separate diseases (15). However, a

single condition focus in both clinical care and research persists and limits the assessment of care for the whole person with multiple chronic conditions. Thus, there remains a need to examine the quality of care of older adults with diabetes with specific comorbid conditions in order to better inform their care management.

To address this knowledge gaps, the objectives of this study were to: 1) explore whether the quality of care for older people with diabetes is differentially affected by types and number of comorbid chronic conditions; and 2) examine the association between quality of care (process) measures and the likelihood of all-cause hospitalizations among older adults with diabetes with selected comorbid conditions.

Methods

Study design and study participants

This was a retrospective cohort study conducted in Ontario, Canada using linked provincial health administrative databases. We identified a cohort of people 65 years of age and older who had diabetes as of April 1, 2010, using the Ontario Diabetes Database (ODD). The ODD is a validated database that identifies all adults aged 20 years and older with diabetes in Ontario from April 1, 1991 (16, 17). The ODD has demonstrated high sensitivity (86%) and specificity (97%) in identifying individuals compared to primary care electronic medical records (16, 18). We also ascertained concurrent diagnoses of hypertension, chronic ischemic heart disease, osteoarthritis and depression. All diagnoses (including diabetes, hypertension, ischemic heart diseases, osteoarthritis and depression) were identified if they had either one hospital admission or two ambulatory physician claims with each respective diagnosis within 2 years. Depression in this study connotes major depression and dysthymia, since most clinical practice

guidelines only address treatment of major depression (19). Each condition was defined with health administrative data from April 1, 2001 to April 1, 2010 (index date). Patients were excluded if they fell under the following criteria: had an invalid health card number, were younger than 65 or older than 105 years old, died before the index date (April 1, 2010), or had no contact with the health care system in the last 5 years before the index date.

The selected five chronic diseases were categorized into two groups by comorbidity type relative to diabetes (20), including: 1) diabetes-concordant conditions that share a common management plan (a) diabetes with comorbid hypertension and without chronic ischemic heart disease, and b) diabetes with comorbid hypertension and chronic ischemic heart disease), and 2) diabetes-discordant conditions that are not directly related in the disease management plan (a)diabetes with comorbid osteoarthritis and without major depression, and b) diabetes with osteoarthritis and major depression). These four disease combinations represented most prevalent clusters of concurrent conditions across multimorbidity groupings based on the prior research results (3).

Data sources

Data sources for this study included: the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) which consists of data on all hospital discharges in Ontario; the OHIP database which contains information on patient contact with physicians in both ambulatory and hospital settings; the Registered Persons Database (RPDB) which contains information regarding the demographics of persons eligible for health care coverage in Ontario; the Client Agency Program Enrolment (CAPE) database which identifies patients belonging to the primary care models; and the Ontario Drug Benefit (ODB) claims database which contains

comprehensive records of prescription medications dispensed in outpatient pharmacies to Ontario residents eligible for public drug coverage, specifically those aged 65 and over. Canada census data were also used to derive population estimates by age and sex in each year. All databases were linked using unique, encoded identifiers and analyzed at the Institute of Clinical Evaluative Sciences (ICES) in Toronto, Ontario.

All provinces in Canada hold administrative data for the full population under a universal health care system that is similar to other health systems internationally including diagnoses and utilization from physician, hospital and pharmacy billing data.

The study received approval from the Sunnybrook Health Sciences Research Ethics Board and the University of Toronto (# 32497).

Study outcome

The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. This outcome measure had a value 1 (yes) if any study subject had at least one all-cause hospitalization in each year, and 0 (no) if not.

Process of care measures

This study uses process and outcome measures for diabetes with comorbidities. A specific set of process and outcome measures was developed by means of a Delphi panel (21) for assessing the quality of care for older adults with each particular disease combination in ambulatory care settings (Table 1). Each disease combination has a unique set of quality indicators that were deemed to be appropriate for monitoring the quality of care for patients with each disease combination.

Processes of care measures were calculated using the same data sources. The measures included: having 1 or 2 glycated hemoglobin (HbA1c) tests per year, having 3 or more HbA1c tests per year, annual eye examination, use of oral hypoglycemic drugs in each, use of angiotensin-converting-enzyme (ACE) inhibitors in each, use of angiotensin II receptor blockers (ARBs) in each, number of prescribed drugs in each year (22, 23), use of non-steroidal anti-inflammatory drugs (NSAIDs) in each year. There were also a series of "negative" indicators which related to contraindicated processes because they increase the risk of adverse outcomes. Theses included use of tetracyclic antidepressants in each year, use of monoamine oxidase (MAO) inhibitors in each year, use of gaba receptor agonists in each year, and use of benzodiazepines in each year. Continuity of care was measured use Bice's COC index that measures both the dispersion and concentration of care among all providers seen, and can be adapted to capture aspects of the coordination of care by attributing referral visits back to the referring provider (24, 25). To align with the prior research in this population, we categorized COC index as having a high vs. low continuity or concentration of care using the median COC score for each selected disease combination, respectively (26-28).

Covariates

We included patient demographic and clinical factors that could confound the relationship between process of care measures and the study outcomes as covariates in all regression models, including: 1) age (coded as 65-74; 75-84; 85-94; 95 and over); 2) sex (coded as male/female), 3) geographic location measured by the Rurality Index of Ontario (RIO) (≤40 = non-rural and >40 = rural) (29), 4) neighbourhood income quintile (ranging from Q1 = lowest

income to Q5=highest income) (30), 5) level of multimorbidity (i.e., chronic disease burden) as the number of prevalent chronic conditions in addition to the five selected chronic conditions (3, 5), including heart failure, acute myocardial infarction, cardiac arrhythmia, stroke, COPD, asthma, cancer, renal disease, other mood disorders, dementia, psychiatric diseases other than mood disorders and dementia, rheumatoid arthritis, or osteoporosis (Appendix 1) - this was coded as zero, one, two, three, four, or five-plus; as well as 6) the duration of each condition of interest in the particular disease combinations, including diabetes, hypertension, chronic ischemic heart disease, major depression or osteoarthritis (in years). We also included health system factors including 7) patient's primary care model categorized into: a) non-capitated models where physicians largely operate on a fee-for-service basis; b) capitated rostered models; and c) capitated+, including family health teams and other rostered models with additional incentives for interdisciplinary care (31, 32), and 8) number of primary care visits, including office-based visits with a general practitioner or family physician.

Statistical analysis

All analyses were stratified by condition combinations (diabetes with each of hypertension, hypertension with ischemic heart disease, osteoarthritis and osteoarthritis and depression) for which quality indicators were established.

Participant characteristics were described using proportions, means (standard deviation (SD)), and medians (inter-quartile range (IQR)) where appropriate. Marginal logistic models using a generalized estimating equations approach (PROC GENMOD in SAS) were performed to examine associations between the likelihood of hospitalisations during the follow-up period, from 2011-2014, based on the process of care measures in the year prior, among older adults

with each particular disease combination, respectively. Generalized estimating equations were used to make inferences about the mean response in the population, to make inference about differences in quality of care between two groups of patients, to account for within-subject correlation among the repeated responses, to deal with different numbers of observations per patient, and to estimate model parameters, using the available information (33). Risk estimates are presented as adjusted odds ratios (AORs) and corresponding 95 % Confidence Intervals (CIs). All data analyses were performed with SAS package version 9.3 (SAS Institute, Cary, 145 North Carolina). The level of statistical significance was considered p less than 0.05.

Results

Table 2 presents baseline characteristics of the study population. The cohort of older adults with diabetes with comorbid hypertension and without chronic ischemic heart disease included 273,592 patients, while the cohort with comorbid hypertension and chronic ischemic heart disease contained 141,947 patients. The cohort of older adults with diabetes with comorbid osteoarthritis and without depression included 255,214 patients, while the cohort of older adults with diabetes with comorbid osteoarthritis and major depression contained 2,444 individuals.

About 85% of diabetes patients were between 65 and 84 years, and over half were female. Women were more prevalent than men in the cohort of diabetes patients with comorbid osteoarthritis and depression. Nearly half of the people comorbid with hypertension (44.7%) and 76.6% of patients with comorbid osteoarthritis and depression were prescribed 11 or more medications. More than 25% of the latter group were classified as having 5 or more concurrent conditions amongst those measured in this study.

Table 3 presents the distribution of process measures and all-cause hospitalizations among older adults with four selected disease combinations. The proportion of patients who met the recommended HbA1c testing goal, had an annual eye examination performed, or were prescribed oral hypoglycemic drugs was lower in older diabetes patients with 2 comorbid conditions compared to those with 1 condition (both concordant and discordant); this decline was more significant in patients with comorbid discordant conditions (with comorbid osteoarthritis and major depression). The median score of continuity of care was greater in older diabetes patients with concordant rather than discordant comorbid conditions (0.57 vs. 0.53 in patients with one concordant vs. discordant condition); however, it declined with additional comorbid conditions, especially in those with discordant conditions (0.36 in patients with comorbid osteoarthritis and major depression).

The proportion of patients who were prescribed ACE inhibitors and ARBs was higher in older adults with comorbid hypertension and chronic ischemic heart disease compared to those without ischemic heart disease. About 14% of older diabetes patients with comorbid osteoarthritis with and without major depression were prescribed tetracyclic antidepressants; 20% were prescribed NSAID therapy; 40% were prescribed benzodiazepines. The incidence of all-cause hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions.

Table 4 presents results of multivariable association of process of care indicators and all-cause hospitalizations among older adults with four selected disease combinations. Meeting HbA1c testing frequency goals, having an annual eye exam, or oral hypoglycemic drug therapy were significantly associated with reduction in the likelihood of all-cause hospitalizations in older people with diabetes comorbid with both concordant and discordant conditions. There was

no association between use of ACE inhibitors or ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease. The majority of older diabetes patients with comorbid conditions were living in lower income neighborhoods.

Antiplatelet therapy was significantly associated with an increase in the likelihood of all-cause hospitalizations among older adults with comorbid hypertension and chronic ischemic heart disease. There was a significant association between NSAID therapy and reduction in all-cause hospitalizations in older diabetes patients with comorbid osteoarthritis. There was a significant association between use of benzodiazepines and increase in all-cause hospitalizations, while there was no association found between use of tetracyclic antidepressants and all-cause hospitalizations among patients with comorbid osteoarthritis and depression. The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older people with diabetes with comorbid concordant and discordant conditions. The likelihood of all-cause hospitalizations increased by 6% with each additional filled prescription among older adults with comorbid concordant or discordant conditions.

Discussion

The study findings demonstrate that the quality of overall care declined in older adults with diabetes with each additional selected comorbid condition, and was especially low for those with comorbid osteoarthritis and major depression. Previous research demonstrates that people with diabetes with 2 or more comorbid conditions were more likely to achieve the target HbA1c testing frequency or have annual eye examination compared to those with no or one comorbid condition (34). However, the authors assessed the role of number of concordant and discordant

conditions on the achievement of diabetes testing goals without specifying individual concordant and discordant conditions, despite the fact that certain conditions may have a greater impact on diabetes care than other conditions.

The study findings support the underlying premise of the framework of Concordance and Discordance proposed by Piette and Kerr that hypothesizes that the effects of comorbidity on patients with diabetes differ depending on the nature of comorbid conditions (20). The literature suggests that physicians may prioritize treatment of concordant conditions over discordant conditions, because a single treatment plan can improve the status of more than one condition (35). Blood pressure and cholesterol targets, increased physical activity, as well as the use of antihypertensive therapy are identical for patients with diabetes and cardiovascular conditions, including hypertension and ischemic heart disease (36). Thus, for the majority of patients, management of cardiovascular conditions enhances the management of diabetes.

The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older people with diabetes with comorbid concordant and discordant conditions. This finding is consistent with other study results (37-39). Grunier and colleagues (26) found that the risk of hospitalizations was reduced in people with one or more chronic conditions, when visits and referrals are concentrated with a single physician.

We found that older diabetes patients with comorbidities, especially with discordant conditions, are likely to be prescribed a large number of drugs, and the more drugs they are prescribed the higher is the risk of hospitalizations. This study finding is consistent with previous research results (40, 41). The study results demonstrate that the mean number of prescribed drugs increased in older diabetes patients with 2 vs. 1 comorbid condition, especially in those with discordant conditions (17 vs. 12 prescriptions). There was no association observed between use

of ACE inhibitors and ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease. The information regarding the benefit of ACE inhibitors or ARBs on vascular protection among older adults with diabetes remains controversial in diabetes patients with comorbidities.

The incidence of hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions (diabetes comorbid with osteoarthritis and depression). This study finding is consistent with previous research that found a higher rate of hospital admission among people with diabetes with discordant than concordant comorbid conditions, especially in those with mental conditions (42). A recent study indicated that there is a trend of increasing use of healthcare services, including hospitalizations, emergency department visits and physician visits, with increase in number of comorbid conditions among older adults with diabetes (24).

Strengths and limitations

Our study sheds light on limited research evidence regarding the assessment of the quality of care among older adults with diabetes comorbid with concordant/discordant comorbid conditions. The study cohort was drawn from the entire Ontario population with a diagnosis of diabetes aged 65 and older. Administrative data have the advantage of being population-based and are relatively inexpensive compared to the other potential sources of data for ambulatory care evaluation. We used validated algorithms to define chronic diagnoses. In our study, multiple databases were used to ascertain the cases, including hospital stay (DAD), physician visits (OHIP), and validated disease cohorts. The process of care measures, as judged to be relevant by the Delphi Panel (21), were used for assessing clinical aspects of ambulatory care among older

adults with selected disease combinations. The development of process of care measures integrated clinical expertise with scientific evidence form systematic research.

Nonetheless, the results of the study should be interpreted in light of the following limitations. The study measures were limited to those available in Ontario administrative data. We lacked data related to laboratory tests done in hospitals or paid for privately. Ambulatory prescriptions and tests represent the majority of the care that patients receive over the course of their treatment out of hospital. Several quality measures not measurable in this study, such as blood glucose level control, life style changes, patient education, as well as patient preferences and goals of care and self-management ability, could reveal and explain important aspects of the associations between process of care measures and hospitalizations as reported here. There is a potential for misclassifying people based on their comorbidity profiles.

We were not able to account for severity of selected chronic conditions due to limitation of the administrative data that may lead to biased estimates. We focused on all-cause hospitalizations, without stratifying by reasons for hospitalization that could potentially inform interventions. The common chronic co-existing conditions that were selected for this study do not represent all existing comorbidities in patients with diabetes.

Conclusions

For an older diabetes patient with comorbidities the challenge is to find a way to encourage health care providers to manage all chronic conditions collectively instead of focusing on a single disease treatment. Any additional comorbid condition may affect the older adult to a greater or lesser magnitude at any one time, and may or may not be a dominant condition (43). Our study showed that the number of conditions was the strongest predictor of hospitalization but higher achievement on diabetes quality of care measures and physician continuity of care

along with fewer prescribed medications were also protective with all-cause hospitalizations. These represent opportunities to improve ambulatory care that should lead to reductions in hospital use. Primary care physicians must be supported to achieve these improvements. Research should focus on the evaluation of those programs whilst developing more robust measurement of health outcomes beyond hospitalization.

Authors' contributions

All coauthors fulfill the criteria required for authorship. WPW was the lead for the creation of the cohort. YP and WPW substantially contributed to the conception, analysis, and interpretation of the data for the work and to the drafting of the work. JB, KK, and BL substantially contributed to the analysis and interpretation of the data for the work. YP drafted the manuscript. YP and WPW revised the drafting of the work critically for important intellectual content. All authors contributed to the final approval of the version to be published and are in agreement to be accountable for all aspects of the work and in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

No researcher or panel member involved in this study had any declared or otherwise known conflicts of interest.

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Data sharing statement

The data from this study are held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination of our research.

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Table 1. Process of care measures

Measure	Concordant conditions		Discordant conditions	
	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Process measures				
*HbA1c testing	✓	✓	✓	✓
Eye examination	✓	✓	✓	✓
Use of oral hypoglycemic drugs	✓	✓	✓	✓
Use of angiotensin-converting enzyme (ACE) inhibitors	✓	✓		

Use of angiotensin II receptor blockers (ARBs)	✓	✓		
Us of antiplatelet drugs		✓		
Use of statins		✓		
Use of *NSAIDs-*** "negative" indicator			✓	✓
Use of tetracyclic antidepressant – "negative indicator"				✓
Use of monoamine oxidase inhibitors (MAO) – "negative indicator"				✓
Use of benzodiazepines – "negative indicator"				✓
Use of gaba receptor agonists – "negative indicator"				✓

*HbA1c=glycated hemoglobin
**NSAIDs=non-steroidal anti-inflammatory drugs
*** "Negative" indicators related to contraindicated processes because they increase the risk of adverse outcomes

Table 2. Baseline characteristics

Characteristic	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Number of individuals	273,592	141,947	255,214	2,444
Age in years, mean (SD)	76.2 (7.18)	77.4 (7.12)	76.6 (7.24)	75.7 (7.12)
Age in groups, n (%)				
65 – 74	127,469 (46.6)	54,593 (38.4)	112,046 (43.9)	1,194 (48.9)
75 – 84	106,336 (38.9)	61.883 (43.6)	102,717 (40.2)	906 (37.1)
85 – 94	37,194 (13.6)	23,950 (16.9)	37,900 (14.9)	333 (13.6)
95+	2,593 (0.9)	1,521 (1.1)	2,551 (1.0)	11 (0.4)
Sex, n (%)				
Female	154,565 (56.5)	81,987 (57.8)	139,951 (54.8)	1,545 (63.2)
Male	119,027 (43.5)	59,960 (42.2)	115,263 (45.2)	899 (36.8)
Number of drugs, mean	10.6 (5.89)	13.4 (6.52)	12.1 (6.42)	17.1 (7.6)

(SD)				
Number of drugs, n (%)				
≤5 drugs	48,210 (17.6%)	10,924 (7.7%)	33,768 (13.2%)	136 (5.7%)
6-10 drugs	103,032 (37.7%)	39,583 (27.9%)	80,695 (31.6%)	433 (17.7%)
≥11 drugs	122,350 (44.7%)	91,440 (64.4%)	140,751 (55.2%)	1,875 (76.6%)
Income quintiles, n (%)				
Q1 lowest income	57,053 (21.7)	29,478 (22.0)	53,174 (21.6)	589 (26.1)
Q2	58,237 (22.1)	29,496 (22.0)	53,884 (22.0)	504 (22.3)
Q3	52,967 (20.1)	26,765 (20.0)	48,922 (20.0)	414 (18.4)
Q4	50,668 (19.2)	25,649 (19.1)	47,143 (19.3)	360 (15.0)
Q5 highest income	44,653 (16.9)	22,657 (16.9)	41,855 (17.1)	388 (17.2)
*RIO index, n (%)				
≤40 (urban)	214,443 (78.4)	131,065 (92.3)	237,312 (93.0)	2,293 (93.8)
>40 (rural)	59,149 (21.6)	10,882 (7.7)	17,.902 (7.0)	151 (6.2)
**Primary care models, n (%)				
Fee-for-service	140,465 (68.3)	120,557 (63.7)	128,522 (69.2)	1450 (67.8)
Capitated+	29,203 (14.2)	26,685 (14.1)	26,930 (14.5)	297 (13.9)
Capitated	35,990 (17.5)	42,015 (22.2)	30,273 (16.3)	391 (18.3)
Comorbidities, n (%)				
0 CC	59,149 (21.6)	15,859 (11.2)	12,061 (4.7%)	77 (3.1%)
1 CC	88,411 (32.3)	33,105 (23.3)	58,547 (22.9%)	335 (13.7%)
2 CC	64,965 (23.7)	34,350 (24.2)	67,635 (26.5%)	495 (20.3%)
3 CC	34,914 (12.8)	26,547 (18.7)	50,641 (19.8%)	490 (20.1%)
4 CC	16,382 (6.0)	16,972 (12.0)	32,778 (12.8%)	428 (17.5%)
5 or more CC	9,771 (3.6)	15,114 (10.7)	33,552 (13.3%)	619 (25.3%)
Number of primary care visits, mean (SD)	6.1 (5.77)	7.6 (6.99)	7.34 (6.60)	7.8 (7.4)
Duration of diabetes in years, mean (SD)	9.90 (5.80)	10.7 (6.02)	10.0 (5.88)	10.3 (6.01)
Duration of hypertension in years, mean (SD)	13.1 (5.65)	13.8 (5.44)	------	------
Duration of chronic ischemic heart disease, mean (SD)	------	7.13 (2.68)	------	-------
Duration of osteoarthritis in years, mean (SD)	------	-------	7.17 (2.57)	7.4 (2.61)
Duration of major depression, mean (SD)	-------	-------	-------	3.3 (1.62)

* Geographic location (≤40=non-rural; >40=rural).

**Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

Table 3. Distribution of process and outcome measures among adults with diabetes with comorbidities

Measure, n (%)	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
Process measures, n (%)				
Having 1 or 2 *HbA1c tests per year	124,336 (45.4)	61,505 (43.3)	114,746 (45.0)	964 (39.4)
Having 3 or more HbA1c tests per year	77,942 (28.5)	42,194 (29.7)	72,469 (28.4)	669 (27.9)
Annual eye examination	177,080 (64.7)	92,623 (65.3)	171,803 (67.3)	1,386 (56.7)
Use of oral hypoglycemic drugs	148,344 (54.2)	72,686 (51.2)	130,599 (51.2)	1,102 (45.1)
Use of **ACE inhibitors	110,641 (40.4)	69,296 (48.8)	-----	-----
Use of ***ARBs	62,169 (22.7)	32,997 (23.3)	-----	-----
Use of antiplatelet drugs	-----	34,868 (24.6)	-----	-----
Use of statins	-----	12,845 (79.5)	-----	-----
Use of ****NSAIDs– “negative”	-----	-----	52,952 (20.8)	452 (18.5)
Use of tetracyclic antidepressants– “negative”	-----	-----	-----	348 (14.2)
Use of benzodiazepines– “negative”	-----	-----	-----	860 (35.2)
Use of gaba receptor agonist– “negative”	-----	-----	-----	<6 (0.2)
Use of *****MAOIs– “negative”	-----	-----	-----	9 (0.4)
****** Continuity of care (COC) index				
Mean, (SD)	0.59 (0.28)	0.51 (0.27)	0.55 (0.26)	0.42 (0.26)
Median, (IQR)	0.57 (0.36-0.82)	0.49 (0.29-0.73)	0.53 (0.32-0.77)	0.36 (0.21-0.59)
Outcome measure, n (%)				
All-cause hospitalizations	45,520 (15.6)	35,157 (24.8)	49,873 (19.5)	536 (29.0)

*HbA1c- glycated hemoglobin
** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index

Table 4. Multivariable associations between process measures and the likelihood of all-cause hospitalizations among older adults with selected disease combinations

Characteristic	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)
Having *HbA1c tests				
No	Ref.	Ref.	Ref.	Ref.
1 or 2 HbA1c tests	0.90 (0.88-0.92)	0.88 (0.85-0.91)	0.88 (0.86-0.90)	0.93 (0.76-1.13)
3 or more HbA1c tests	0.84 (0.82-0.86)	0.86 (0.83-0.88)	0.83 (0.81-0.85)	0.82 (0.69-1.03)
Annual eye examination				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.85 (0.84-0.87)	0.90 (0.88-0.92)	0.89 (0.87-0.91)	0.85 (0.75-0.97)
Use of oral hypoglycemic drugs				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.88 (0.86-0.90)	0.88 (0.86-0.90)	0.92 (0.89-0.93)	0.93 (0.78-1.10)
Use of **ACE-inhibitors				
No	Ref.	Ref.	-----	-----
Yes	1.04 (0.99-1.06)	1.03 (0.98-1.05)	-----	-----
Use of ***ARBs				
No	Ref.	Ref.	-----	-----
Yes	0.93 (0.92-1.02)	0.98 (0.96-1.01)	-----	-----
Use of antiplatelet drugs				
No	------	Ref.	-----	-----
Yes	------	1.08 (1.06-1.11)	-----	-----
Use of statins				
No	------	Ref.	-----	-----
Yes	------	0.89 (0.86-0.92)	-----	------
Use of ****NSAIDs				
No	------	------	Ref.	Ref.
Yes	------	------	0.99 (0.97-0.99)	0.99 (0.88-1.12)
Use of tetracyclic antidepressants				
No	------	------	------	Ref.
Yes	------	------	------	1.14 (0.86-1.32)
Use of benzodiazepines				
No	------	------	------	Ref.
Yes	------	------	------	1.33 (1.20-1.48)
*****Continuity of Care index**				

COC≤ median value	Ref.	Ref.	Ref.	Ref.
COC>median value	0.70 (0.69-0.72)	0.74 (0.72-0.77)	0.73 (0.72-0.74)	0.84 (0.72-0.93)
Number of drugs	1.06 (1.04-1.07)	1.05 (1.02-1.07)	1.06 (1.04-1.08)	1.06 (1.05-1.07)
Age	1.04 (1.03-1.05)	1.03 (1.02-1.04)	1.03 (1.02-1.04)	1.02 (1.01-1.04)
Sex				
Female	Ref.	Ref.	Ref.	Ref.
Male	1.40 (1.36-1.44)	1.15 (1.12-1.18)	1.22 (1.20-1.24)	1.15 (0.97-1.23)
Income quintiles				
Q1 lowest income	Ref.	Ref.	Ref.	Ref.
Q2	0.93 (0.90-0.97)	0.99 (0.97-1.03)	1.02 (0.96-1.05)	1.02 (0.79-1.3)
Q3	0.95 (0.90-0.99)	1.03 (0.99-1.07)	0.97 (0.94-0.99)	0.99 (0.78-1.28)
Q4	0.89 (0.83-0.93)	1.05 (0.98-1.09)	0.97 (0.94-0.99)	1.03 (0.79-1.34)
Q5 highest income	0.87 (0.82-0.92)	1.04 (0.95-1.07)	1.48 (1.40-1.56)	1.05 (0.82-1.35)
******RIO index**				
≤40	Ref.	Ref.	Ref.	Ref.
>40	1.14 (1.09-1.19)	1.16 (1.12-1.20)		1.27 (0.95-1.57)
Duration of diabetes	1.03 (1.01-1.05)	1.02 (1.01-1.03)	1.19 (1.16-1.24)	1.01 (0.99-1.02)
Duration of hypertension	1.02 (1.01-1.03)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	-------
Duration of ischemic heart disease	-----	1.01 (1.00-1.02)	------	-------
Duration of osteoarthritis	-----	-----	0.99 (0.97-1.01)	0.92 (0.97-1.03)
Duration of depression	-----	-----	------	0.95 (0.89-1.01)
Number of primary care visits	1.02 (1.0-1.04)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	1.02 (1.01-1.03)
*******Primary care models**				
Capitated+	Ref.	Ref.	Ref.	Ref.
Fee-for-service	0.77 (0.76-0.79)	0.78 (0.76-0.80)	0.77 (0.76-0.78)	0.83 (0.68-1.02)
Capitated	1.09 (1.02-1.13)	1.08 (0.99-1.13)	1.04 (1.02-1.06)	0.97 (0.51-1.89)
Comorbidities				
0 CC	Ref.	Ref.	Ref.	Ref.
1 CC	1.17 (1.13-1.22)	1.21 (1.16-1.27)	1.10 (1.04-1.15)	0.81 (0.62-1.02)
2 CC	1.37 (1.33-1.40)	1.43 (1.37-1.48)	1.26 (1.19-1.32)	1.05 (0.68-1.21)
3 CC	1.65 (1.58-1.70)	1.69 (1.61-1.75)	1.48 (1.40-1.56)	1.27 (0.71-1.81)
4 CC	2.00 (1.89-2.12)	1.98 (1.89-2.09)	1.77 (1.68-1.86)	1.39 (0.82-1.98)
5 or more CC	2.32 (2.16-2.44)	2.27 (2.15-2.35)	2.12 (1.60-1.46)	1.55 (0.97-2.23)

*HbA1c- glycated hemoglobin

** ACE inhibitors – angiotensin-converting enzyme inhibitors

***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index
******* Geographic location (≤40=non-rural; >40=rural).
******** Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

S1 Appendix. Comorbid chronic conditions

S1 Appendix. Comorbid chronic conditions

Condition	ICD 9 / OHIP	ICD 10
Rheumatoid arthritis	714	M05-M06
Osteoporosis	733	M81 M82
Other mood disorders	300, 309	F38—F42, F431, F432, F438, F44, F450, F451, F452, F48, F530, F680, F930, F99
Psychiatric conditions other than mood disorders and dementia	291 292 295 297 298 299 301 302 303 304 305 306 307 313 314 315 319	F04 F050 F058 F059 F060 F061 F062 F063 F064 F07 F08 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F340 F35 F36 F37 F430 F439 F453 F454 F458 F46 F47 F49 F50 F51 F52 F531 F538 F539 F54 F55 F56 F57 F58 F59 F60 F61 F62 F63 F64 F65 F66 F67 F681 F688 F69 F70 F71 F72 F73 F74 F75 F76 F77 F78 F79 F80 F81 F82 F83 F84 F85 F86 F87 F88 F89 F90 F91 F92 F931 F932 F933 F938 F939 F94 F95 F96 F97 F98
Dementia	290, 331 (OHIP) / (DAD: 046.1, 290, 294, 331.0, 331.1, 331.5, 331.82)	F00, F01, F02, F03, G30 ODB subclnam =: 'CHOLINESTERASE INHIBITOR'
Renal failure	403,404,584,585,586,v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Asthma	493	J45
Cancer	140-239 (broad algorithm from ICD table)	C00-C26, C30-C44, C45-C97
Cardiac Arrythmia	427.3 (DAD) / 427 (OHIP)	I48.0, I48.1
CHF	428	I500, I501, I509
COPD	491, 492, 496	J41-J44
Stroke	430, 431, 432, 434, 436	I60-I64

Research checklist

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
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	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	8-9
		(*c*) Explain how missing data were addressed	8-9
		(*d*) If applicable, explain how loss to follow-up was addressed	8-9
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 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	10-11 10-11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
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	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Evaluating quality of overall care among older adults with diabetes with comorbidities in Ontario, Canada: a retrospective cohort study

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Evaluating quality of overall care among older adults with diabetes with comorbidities in Ontario, Canada: a retrospective cohort study

Short title: Quality of overall care among older adults with diabetes with comorbidities

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Abstract

Objectives: This study aimed to: 1) explore whether the quality of overall care for older people with diabetes is differentially affected by types and number of comorbid conditions, and 2) examine the association between process of care measures and the likelihood of all-cause hospitalizations.

Design A population-based, retrospective cohort study

Setting The province of Ontario, Canada

Participants: We identified 673,197 Ontarians aged 65 years and older who had diabetes comorbid with hypertension, chronic ischemic heart disease, osteoarthritis or depression on April 1, 2010.

Main outcome measures: The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. Process of care measures specific to older adults with diabetes and these comorbidities, developed by means of a Delphi panel, were used to assess the quality of care. A generalized estimating equations approach was used to examine associations between the process of care measures and the likelihood of hospitalizations.

Results: The study findings suggest that patients are at risk of suboptimal care with each additional comorbid condition, while the incidence of hospitalizations and number of prescribed drugs markedly increased in patients with 2 vs. 1 selected comorbid condition, especially in those with discordant comorbidities. The median continuity of care score was higher among patients with diabetes-concordant conditions compared to those with diabetes-discordant conditions; and it declined with additional comorbid conditions in both groups. Greater continuity of care was associated with lower hospital utilization for older diabetes patients with both concordant and discordant conditions.

Conclusions: There is a need for focusing on improving continuity of care and prioritizing treatment in older adults with diabetes with any multiple conditions, but especially in those with diabetes-discordant conditions (e.g., depression).

Strengths and limitations of this study

- This population-based study included a large sample size to examine the quality of overall care for older adults with four disease combinations representing the most prevalent clusters of concurrent conditions across multimorbidity groupings.
- The study takes advantage of linked patient-level health administrative databases with detailed demographic and clinical information.
- The study used process of care measures for assessing ambulatory care among older adults with selected disease combinations that were developed using a Delphi technique integrating clinical expertise with systematic reviews of each disease combination.
- The study measures were limited to those available in Ontario administrative data.
- Data regarding other covariates (eg, severity of selected conditions, frailty) and health outcomes (eg, quality of life) were not available for this cohort and should be explored in future research.

Introduction

Evidence shows that the majority of care for adults with multiple chronic conditions is provided in ambulatory care settings and primary care, and is an important locus from which to develop approaches of care to better meet the needs of this population (1, 2). Older adults are more likely than younger individuals to have comorbid chronic conditions that can be complex and difficult to manage (3, 4). Recent research has demonstrated that more than 90% of older adults with diabetes in Ontario had at least one comorbid condition (5). In particular, arthritis, other cardiovascular conditions and mood disorders also commonly appear in older adults with diabetes (3, 5). Hypertension consistently appears as a comorbidity in older adults with diabetes (3, 5, 6).

A growing body of evidence shows that people with multiple chronic conditions are more likely to experience negative health outcomes, including increased healthcare utilization, poor quality of life and increased care costs compared to those a with single disease (7-10). Prior research found that Ontarians with three or more diagnoses had 56% more primary care visits, 76% more specialist visits, 256% more inpatient hospital stays, 11% more emergency department visits, and 68% more prescriptions, as compared to those with a single condition (11, 12). Primary care physicians face difficulties in addressing the complex multifaceted needs of older adults with multiple chronic conditions (13). Treatment of people with multiple chronic conditions often requires "trade-off" decisions, because current clinical guidelines may be impractical in the presence of multiple chronic conditions (14).

Treating one condition in older diabetes patients with comorbid conditions may cause undesirable consequences with regard to their other conditions. The optimal approach to treat patients with any combination of co-existing diseases is not the same as the sum of treatments for the separate diseases (15). Meanwhile, a single condition focus in both clinical care and research

persists and limits the assessment of care for the whole person with multiple chronic conditions. There is a need to understand how diabetes treatment and that for co-occurring comorbid chronic conditions varies depending on the specific comorbid conditions and to assess the relationships between specific quality of care measures across combinations of conditions and adverse events such as hospital admission.

To address this knowledge gaps, the objectives of this study were to: 1) explore whether the quality of care for older people with diabetes is differentially affected by types and number of comorbid chronic conditions; and 2) examine the association between quality of care (process) measures and the likelihood of all-cause hospitalizations among older adults with diabetes with selected comorbid conditions.

Methods

Study design and study participants

This was a retrospective cohort study conducted in Ontario, Canada using linked provincial health administrative databases. We identified a cohort of people 65 years of age and older who had diabetes as of April 1, 2010, using the Ontario Diabetes Database (ODD). The ODD is a validated database that identifies all adults aged 20 years and older with diabetes in Ontario from April 1, 1991 (16, 17). The ODD has demonstrated high sensitivity (86%) and specificity (97%) in identifying individuals compared to primary care electronic medical records (16, 18). We also ascertained concurrent diagnoses of hypertension, chronic ischemic heart disease, osteoarthritis and depression. All diagnoses (including diabetes, hypertension, ischemic heart diseases, osteoarthritis and depression) were identified if they had either one hospital admission or two ambulatory physician claims with each respective diagnosis within 2 years.

Depression in this study connotes major depression and dysthymia, since most clinical practice guidelines only address treatment of major depression (19). Each condition was defined with health administrative data from April 1, 2001 to April 1, 2010 (index date). Patients were excluded if they fell under the following criteria: had an invalid health card number, were younger than 65 or older than 105 years old, died before the index date (April 1, 2010), or had no contact with the health care system in the last 5 years before the index date.

The selected five chronic diseases were categorized into two groups by comorbidity type relative to diabetes (20), including: 1) diabetes-concordant conditions that share a common management plan (a) diabetes with comorbid hypertension and without chronic ischemic heart disease, and b) diabetes with comorbid hypertension and chronic ischemic heart disease), and 2) diabetes-discordant conditions that are not directly related in the disease management plan (a)diabetes with comorbid osteoarthritis and without major depression, and b) diabetes with osteoarthritis and major depression). These four disease combinations represented most prevalent clusters of concurrent conditions across multimorbidity groupings based on the prior research results (3).

Data sources

Data sources for this study included: the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) which consists of data on all hospital discharges in Ontario; the OHIP (Ontario Health Insurance Plan) claims database which contains information on patient contact with physicians in both ambulatory and hospital settings; the Registered Persons Database (RPDB) which contains information regarding the demographics of persons eligible for health care coverage in Ontario; the Client Agency Program Enrolment (CAPE) database which

identifies patients belonging to the primary care models; and the Ontario Drug Benefit (ODB) claims database which contains comprehensive records of prescription medications dispensed in outpatient pharmacies to Ontario residents eligible for public drug coverage, specifically those aged 65 and over. Canada census data were also used to derive population estimates by age and sex in each year. All databases were linked using unique, encoded identifiers and analyzed at the Institute of Clinical Evaluative Sciences (ICES) in Toronto, Ontario.

All provinces in Canada hold administrative data for the full population under a universal health care system that is similar to other health systems internationally including diagnoses and utilization from physician, hospital and pharmacy billing data.

The study received approval from the Sunnybrook Health Sciences Research Ethics Board and the University of Toronto (# 32497).

Study outcome

The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. This outcome measure had a value 1 (yes) if any study subject had at least one all-cause hospitalization in each year, and 0 (no) if not.

Process of care measures

This study uses process and outcome measures for diabetes with comorbidities. A specific set of process and outcome measures was developed by means of a Delphi panel (21) for assessing the quality of care for older adults with each particular disease combination in ambulatory care settings (Table 1). Delphi participants purposefully selected a list of indicators

in the context of assessing care of older adults with diabetes and specific comorbid chronic conditions.

Processes of care measures were calculated using the same data sources. The measures included: having 1 or 2 glycated hemoglobin (HbA1c) tests per year, having 3 or more HbA1c tests per year, annual eye examination, use of oral hypoglycemic drugs in each, use of angiotensin-converting-enzyme (ACE) inhibitors in each, use of angiotensin II receptor blockers (ARBs) in each, number of prescribed drugs in each year (22, 23), use of non-steroidal anti-inflammatory drugs (NSAIDs) in each year. There were also a series of "negative" indicators which related to contraindicated processes because they increase the risk of adverse outcomes. Theses included use of tetracyclic antidepressants in each year, use of monoamine oxidase (MAO) inhibitors in each year, use of gaba receptor agonists in each year, and use of benzodiazepines in each year. Continuity of care was measured use the Bice COC (Continuity of Care) index that measures both the dispersion and concentration of care among all providers seen, and can be adapted to capture aspects of the coordination of care by attributing referral visits back to the referring provider (24, 25). To align with the prior research in this population, we categorized COC index as having a high vs. low continuity or concentration of care using the median COC score for each selected disease combination, respectively (26-28).

Covariates

We included patient demographic and clinical factors that could confound the relationship between process of care measures and the study outcomes as covariates in all regression models, including: 1) age (coded as 65-74, 75-84, 85-94, 95 and over), 2) sex (coded

as male/female), 3) geographic location measured by the Rurality Index of Ontario (RIO) (≤40 = non-rural and >40 = rural) (29), 4) neighbourhood income quintile (ranging from Q1 = lowest income to Q5=highest income) (30), 5) level of multimorbidity (i.e., chronic disease burden) as the number of prevalent chronic conditions in addition to the five selected chronic conditions (3, 5), including heart failure, acute myocardial infarction, cardiac arrhythmia, stroke, COPD, asthma, cancer, renal disease, other mood disorders, dementia, psychiatric diseases other than mood disorders and dementia, rheumatoid arthritis, or osteoporosis (Appendix 1) - this was coded as zero, one, two, three, four, or five-plus, as well as 6) the duration of each condition of interest in the particular disease combinations, including diabetes, hypertension, chronic ischemic heart disease, major depression or osteoarthritis (in years). We also included health system factors including 7) patient's primary care model categorized into: a) non-capitated models where physicians largely operate on a fee-for-service basis, b) capitated rostered models, and c) capitated+, including family health teams and other rostered models with additional incentives for interdisciplinary care (31, 32), and 8) number of primary care visits, including office-based visits with a general practitioner or family physician.

Statistical analysis

All analyses were stratified by condition combinations (diabetes with each of hypertension, hypertension with ischemic heart disease, osteoarthritis and osteoarthritis and depression) for which quality indicators were established.

Participant characteristics were described using proportions, means (standard deviation (SD)), and medians (inter-quartile range (IQR)) where appropriate. Marginal logistic models using a generalized estimating equations approach (PROC GENMOD in SAS) were performed

to examine associations between the likelihood of hospitalisations during the follow-up period, from 2011-2014, based on the process of care measures in the year prior, among older adults with each particular disease combination, respectively. Generalized estimating equations were used to make inferences about the mean response in the population, to make inference about differences in quality of care between two groups of patients, to account for within-subject correlation among the repeated responses, to deal with different numbers of observations per patient, and to estimate model parameters, using the available information (33). Risk estimates are presented as adjusted odds ratios (AORs) and corresponding 95 % Confidence Intervals (CIs). All data analyses were performed with SAS package version 9.3 (SAS Institute, Cary, 145 North Carolina). The level of statistical significance was considered p less than 0.05.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination of our research.

Results

Table 2 presents baseline characteristics of the study population. The cohort of older adults with diabetes with comorbid hypertension and without chronic ischemic heart disease included 273,592 patients, while the cohort with comorbid hypertension and chronic ischemic heart disease contained 141,947 patients. The cohort of older adults with diabetes with comorbid osteoarthritis and without depression included 255,214 patients, while the cohort of older adults with diabetes with comorbid osteoarthritis and major depression contained 2,444 individuals.

About 85% of diabetes patients were between 65 and 84 years, and over half were female. Women were more prevalent than men in the cohort of diabetes patients with comorbid osteoarthritis and depression. Nearly half of the people comorbid with hypertension (44.7%) and 76.6% of patients with comorbid osteoarthritis and depression were prescribed 11 or more medications. More than 25% of the latter group were classified as having 5 or more concurrent conditions amongst those measured in this study. The majority of older diabetes patients with comorbid conditions were living in lower income neighborhoods.

Table 3 presents the distribution of process measures and all-cause hospitalizations among older adults with four selected disease combinations. The proportion of patients who met the recommended HbA1c testing goal, had an annual eye examination performed, or were prescribed oral hypoglycemic drugs was lower in older diabetes patients with 2 comorbid conditions compared to those with 1 condition (both concordant and discordant); this decline was more significant in patients with comorbid discordant conditions (with comorbid osteoarthritis and major depression). The median score of continuity of care was greater in older diabetes patients with concordant rather than discordant comorbid conditions (0.57 vs. 0.53 in patients with one concordant vs. discordant condition); however, it declined with additional comorbid conditions, especially in those with discordant conditions (0.36 in patients with comorbid osteoarthritis and major depression).

The proportion of patients who were prescribed ACE inhibitors and ARBs was higher in older adults with comorbid hypertension and chronic ischemic heart disease compared to those without ischemic heart disease. About 14% of older diabetes patients with comorbid osteoarthritis with and without major depression were prescribed tetracyclic antidepressants; 20% were prescribed NSAID therapy; 40% were prescribed benzodiazepines. The incidence of

all-cause hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions.

Table 4 presents results of multivariable association of process of care indicators and all-cause hospitalizations among older adults with four selected disease combinations. Meeting HbA1c testing frequency goals, having an annual eye exam, or oral hypoglycemic drug therapy were significantly associated with reduction in the likelihood of all-cause hospitalizations in older people with diabetes comorbid with both concordant (with comorbid hypertension with or without chronic ischemic heart disease) and discordant conditions (with comorbid osteoarthritis with or without major depression). There was no association between use of ACE inhibitors or ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease.

Antiplatelet therapy was significantly associated with an increase in the likelihood of all-cause hospitalizations among older adults with comorbid hypertension and chronic ischemic heart disease. There was a very marginal though significant association between NSAID therapy and reduction in all-cause hospitalizations in older diabetes patients with comorbid osteoarthritis that was not significant when depression was also present. There was a significant association between use of benzodiazepines and increase in all-cause hospitalizations, while there was no association found between use of tetracyclic antidepressants and all-cause hospitalizations among patients with comorbid osteoarthritis and depression. The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older people with diabetes with comorbid concordant and discordant conditions. The likelihood of all-cause hospitalizations increased by 6% with each additional filled prescription among older adults with comorbid concordant or discordant conditions.

Discussion

The study findings demonstrate that the quality of overall care declined in older adults with diabetes with each additional selected comorbid condition, and was especially low for those with comorbid osteoarthritis and major depression. Therefore, older patients with diabetes with comorbid osteoarthritis with or without major depression need more targeted interventions and collaboration between healthcare providers to improve quality of care and reduce hospitalization. These findings can help inform clinicians and policy makers in developing strategies for subpopulations at-risk. Previous research demonstrates that people with diabetes with 2 or more comorbid conditions were more likely to achieve the target HbA1c testing frequency or have annual eye examination compared to those with no or one comorbid condition (34). However, the authors used diabetes care measures t13o assess the role of number of concordant and discordant conditions on the achievement of diabetes testing goals without specifying individual concordant and discordant conditions, despite the fact that certain conditions may have a greater impact on diabetes care than other conditions.

The study findings support the underlying premise of the framework of Concordance and Discordance proposed by Piette and Kerr that hypothesizes that the effects of comorbidity on patients with diabetes differ depending on the nature of comorbid conditions (20). The literature suggests that physicians may prioritize treatment of concordant conditions over discordant conditions, because a single treatment plan can improve the status of more than one condition (35). Blood pressure and cholesterol targets, increased physical activity, as well as the use of antihypertensive therapy are identical for patients with diabetes and cardiovascular conditions,

including hypertension and ischemic heart disease (36). Thus, for the majority of patients, management of cardiovascular conditions enhances the management of diabetes.

The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older people with diabetes with comorbid concordant and discordant conditions. This finding is consistent with other study results (37-39). Grunier and colleagues (26) found that the risk of hospitalizations was reduced in people with one or more chronic conditions, when visits and referrals are concentrated with a single physician.

We found that older diabetes patients with comorbidities, especially with discordant conditions, are likely to be prescribed a large number of drugs, and the more drugs they are prescribed the higher is the risk of hospitalizations. This study finding is consistent with previous research results (40, 41). The study results demonstrate that the mean number of prescribed drugs increased in older diabetes patients with 2 vs. 1 comorbid condition, especially in those with discordant conditions (17 vs. 12 prescriptions). There was no association observed between use of ACE inhibitors and ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease. The information regarding the benefit of ACE inhibitors or ARBs on vascular protection among older adults with diabetes remains controversial in diabetes patients with comorbidities. The study findings suggest found a negligible association between NSAID therapy and reduction in all-cause hospitalizations in patients with comorbid osteoarthritis that was not significant when depression was also present. Whilst the recent review of evidence from the Osteoarthritis Research Society International (OARSI) suggests that use of NSAID therapy for osteoarthritis management provides better efficacy than acetaminophen for relief of chronic inflammatory pain (42), this was not substantially related to all-cause hospitalizations

The incidence of hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions (diabetes comorbid with osteoarthritis and depression). This study finding is consistent with previous research that found a higher rate of hospital admission among people with diabetes with discordant than concordant comorbid conditions, especially in those with mental conditions (43). A recent study indicated that there is a trend of increasing use of healthcare services, including hospitalizations, emergency department visits and physician visits, with increase in number of comorbid conditions among older adults with diabetes (24).

Strengths and limitations

Our study sheds light on limited research evidence regarding the assessment of the overall quality of care among older adults with diabetes comorbid with specific concordant/discordant comorbid conditions. The study cohort was drawn from the entire Ontario population with a diagnosis of diabetes aged 65 and older. Administrative data have the advantage of being population-based and are relatively inexpensive compared to the other potential sources of data for ambulatory care evaluation. We used validated algorithms to define chronic diagnoses. In our study, multiple databases were used to ascertain the cases, including hospital stay (DAD), physician visits (OHIP), and validated disease cohorts. The specific sets of process of care measures, as judged to be relevant by the Delphi Panel (21), were used for assessing clinical aspects of ambulatory care among older adults with four selected disease combinations. The development of process of care measures integrated clinical expertise with scientific evidence form systematic research.

Nonetheless, the results of the study should be interpreted in light of the following limitations. The study measures identified by the Delphi Panel were purposively limited to those

available in Ontario administrative data. This restricted measurement of important clinical factors such as disease severity, patient disability and frailty, the availability of social supports or caregivers and mobility or aids used to mitigate functional impairment. The study measures were limited to those available in Ontario administrative data. We lacked data related to laboratory tests done in hospitals or paid for privately. Ambulatory prescriptions and tests represent the majority of the care that patients receive over the course of their treatment out of hospital. Several quality measures not measurable in this study, such as blood glucose level control, life style changes, patient education, as well as patient preferences and goals of care and self-management ability, could reveal and explain important aspects of the associations between process of care measures and hospitalizations as reported here. There is a potential for misclassifying people based on their comorbidity profiles.

We were not able to account for severity of selected chronic conditions due to limitation of the administrative data that may lead to biased estimates. We focused on all-cause hospitalizations, without stratifying by reasons for hospitalization that could potentially inform interventions. The common chronic co-existing conditions that were selected for this study do not represent all existing comorbidities in patients with diabetes.

Conclusions

For an older diabetes patient with comorbidities the challenge is to find a way to encourage health care providers to manage all chronic conditions collectively instead of focusing on a single disease treatment. This study highlighted the most prevalent multimoribdity clusters among older adults with diabetes, including both concordant and discordant comorbidities. Explicit consideration of multimorbidity clusters among older adults with diabetes is important because appropriate management of individual diseases in isolation may not be optimal for

patients with multimorbidity due to unique disease-disease or disease-treatment interactions. Furthermore, determining specific multimorbidity subgroups among patients with diabetes at increased risk of adverse health outcomes has important policy implications and provides targets for tailored prevention.

Our study showed that the number of conditions was the strongest predictor of hospitalization but higher achievement on diabetes quality of care measures and physician continuity of care along with fewer prescribed medications were also protective with all-cause hospitalizations. These findings represent opportunities to improve ambulatory care that should lead to reductions in hospital use. Research should focus on the evaluation of quality of care for diabetes patients with comorbidities whilst developing more robust measurement of health outcomes beyond hospitalization.

Authors' contributions

All coauthors fulfill the criteria required for authorship. WPW was the lead for the creation of the cohort. YP and WPW substantially contributed to the conception, analysis, and interpretation of the data for the work and to the drafting of the work. JB, KK, and BL substantially contributed to the analysis and interpretation of the data for the work. YP drafted the manuscript. YP and WPW revised the drafting of the work critically for important intellectual content. All authors contributed to the final approval of the version to be published and are in agreement to be accountable for all aspects of the work and in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

No researcher or panel member involved in this study had any declared or otherwise known conflicts of interest.

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Data sharing statement

The data from this study are held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS.

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Table 1. Process of care measures

Measure	Concordant conditions		Discordant conditions	
	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Process measures				
*HbA1c testing	✓	✓	✓	✓
Eye examination	✓	✓	✓	✓

Use of oral hypoglycemic drugs	✓	✓	✓	✓
Use of angiotensin-converting enzyme (ACE) inhibitors	✓	✓		
Use of angiotensin II receptor blockers (ARBs)	✓	✓		
Us of antiplatelet drugs		✓		
Use of statins		✓		
Use of *NSAIDs-*** "negative" indicator			✓	✓
Use of tetracyclic antidepressant – "negative indicator"				✓
Use of monoamine oxidase inhibitors (MAO) – "negative indicator"				✓
Use of benzodiazepines – "negative indicator"				✓
Use of gaba receptor agonists – "negative indicator"				✓

*HbA1c=glycated hemoglobin
**NSAIDs=non-steroidal anti-inflammatory drugs
*** "Negative" indicators related to contraindicated processes because they increase the risk of adverse outcomes

Table 2. Baseline characteristics

Characteristic	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Number of individuals	273,592	141,947	255,214	2,444
Age in years, mean (SD)	76.2 (7.18)	77.4 (7.12)	76.6 (7.24)	75.7 (7.12)
Age in groups, n (%)				
65 – 74	127,469 (46.6)	54,593 (38.4)	112,046 (43.9)	1,194 (48.9)
75 – 84	106,336 (38.9)	61.883 (43.6)	102,717 (40.2)	906 (37.1)
85 – 94	37,194 (13.6)	23,950 (16.9)	37,900 (14.9)	333 (13.6)

95+	2,593 (0.9)	1,521 (1.1)	2,551 (1.0)	11 (0.4)
Sex, n (%)				
Female	154,565 (56.5)	81,987 (57.8)	139,951 (54.8)	1,545 (63.2)
Male	119,027 (43.5)	59,960 (42.2)	115,263 (45.2)	899 (36.8)
Number of drugs, mean (SD)	10.6 (5.89)	13.4 (6.52)	12.1 (6.42)	17.1 (7.6)
Number of drugs, n (%)				
≤5 drugs	48,210 (17.6%)	10,924 (7.7%)	33,768 (13.2%)	136 (5.7%)
6-10 drugs	103,032 (37.7%)	39,583 (27.9%)	80,695 (31.6%)	433 (17.7%)
≥11 drugs	122,350 (44.7%)	91,440 (64.4%)	140,751 (55.2%)	1,875 (76.6%)
Income quintiles, n (%)				
Q1 lowest income	57,053 (21.7)	29,478 (22.0)	53,174 (21.6)	589 (26.1)
Q2	58,237 (22.1)	29,496 (22.0)	53,884 (22.0)	504 (22.3)
Q3	52,967 (20.1)	26,765 (20.0)	48,922 (20.0)	414 (18.4)
Q4	50,668 (19.2)	25,649 (19.1)	47,143 (19.3)	360 (15.0)
Q5 highest income	44,653 (16.9)	22,657 (16.9)	41,855 (17.1)	388 (17.2)
*RIO index, n (%)				
≤40 (urban)	214,443 (78.4)	131,065 (92.3)	237,312 (93.0)	2,293 (93.8)
>40 (rural)	59,149 (21.6)	10,882 (7.7)	17,.902 (7.0)	151 (6.2)
**Primary care models, n (%)				
Fee-for-service	140,465 (68.3)	120,557 (63.7)	128,522 (69.2)	1450 (67.8)
Capitated+	29,203 (14.2)	26,685 (14.1)	26,930 (14.5)	297 (13.9)
Capitated	35,990 (17.5)	42,015 (22.2)	30,273 (16.3)	391 (18.3)
Comorbidities, n (%)				
0 CC	59,149 (21.6)	15,859 (11.2)	12,061 (4.7%)	77 (3.1%)
1 CC	88,411 (32.3)	33,105 (23.3)	58,547 (22.9%)	335 (13.7%)
2 CC	64,965 (23.7)	34,350 (24.2)	67,635 (26.5%)	495 (20.3%)
3 CC	34,914 (12.8)	26,547 (18.7)	50,641 (19.8%)	490 (20.1%)
4 CC	16,382 (6.0)	16,972 (12.0)	32,778 (12.8%)	428 (17.5%)
5 or more CC	9,771 (3.6)	15,114 (10.7)	33,552 (13.3%)	619 (25.3%)
Number of primary care visits, mean (SD)	6.1 (5.77)	7.6 (6.99)	7.34 (6.60)	7.8 (7.4)
Duration of diabetes in years, mean (SD)	9.90 (5.80)	10.7 (6.02)	10.0 (5.88)	10.3 (6.01)
Duration of hypertension in years, mean (SD)	13.1 (5.65)	13.8 (5.44)	------	------
Duration of chronic ischemic heart disease, mean (SD)	------	7.13 (2.68)	------	-------
Duration of osteoarthritis in years, mean (SD)	------	-------	7.17 (2.57)	7.4 (2.61)
Duration of major depression, mean (SD)	-------	-------	-------	3.3 (1.62)

* Geographic location (≤40=non-rural; >40=rural).

**Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

Table 3. Distribution of process and outcome measures among adults with diabetes with comorbidities

Measure, n (%)	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
Process measures, n (%)				
Having 1 or 2 *HbA1c tests per year	124,336 (45.4)	61,505 (43.3)	114,746 (45.0)	964 (39.4)
Having 3 or more HbA1c tests per year	77,942 (28.5)	42,194 (29.7)	72,469 (28.4)	669 (27.9)
Annual eye examination	177,080 (64.7)	92,623 (65.3)	171,803 (67.3)	1,386 (56.7)
Use of oral hypoglycemic drugs	148,344 (54.2)	72,686 (51.2)	130,599 (51.2)	1,102 (45.1)
Use of **ACE inhibitors	110,641 (40.4)	69,296 (48.8)	-----	-----
Use of ***ARBs	62,169 (22.7)	32,997 (23.3)	-----	-----
Use of antiplatelet drugs	-----	34,868 (24.6)	-----	-----
Use of statins	-----	12,845 (79.5)	-----	-----
Use of ****NSAIDs– “negative”	-----	-----	52,952 (20.8)	452 (18.5)
Use of tetracyclic antidepressants– “negative”	-----	-----	-----	348 (14.2)
Use of benzodiazepines– “negative”	-----	-----	-----	860 (35.2)
Use of gaba receptor agonist– “negative”	-----	-----	-----	<6 (0.2)
Use of *****MAOIs– “negative”	-----	-----	-----	9 (0.4)
****** Continuity of care (COC) index				
Mean, (SD)	0.59 (0.28)	0.51 (0.27)	0.55 (0.26)	0.42 (0.26)
Median, (IQR)	0.57 (0.36-0.82)	0.49 (0.29-0.73)	0.53 (0.32-0.77)	0.36 (0.21-0.59)
Outcome measure, n (%)				
All-cause hospitalizations	45,520 (15.6)	35,157 (24.8)	49,873 (19.5)	536 (29.0)

*HbA1c- glycated hemoglobin

** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index

Table 4. Multivariable associations between process measures and the likelihood of all-cause hospitalizations among older adults with selected disease combinations

Characteristic	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)
Having *HbA1c tests				
No	Ref.	Ref.	Ref.	Ref.
1 or 2 HbA1c tests	0.90 (0.88-0.92)	0.88 (0.85-0.91)	0.88 (0.86-0.90)	0.93 (0.76-1.13)
3 or more HbA1c tests	0.84 (0.82-0.86)	0.86 (0.83-0.88)	0.83 (0.81-0.85)	0.82 (0.69-1.03)
Annual eye examination				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.85 (0.84-0.87)	0.90 (0.88-0.92)	0.89 (0.87-0.91)	0.85 (0.75-0.97)
Use of oral hypoglycemic drugs				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.88 (0.86-0.90)	0.88 (0.86-0.90)	0.92 (0.89-0.93)	0.93 (0.78-1.10)
Use of **ACE-inhibitors				
No	Ref.	Ref.	-----	-----
Yes	1.04 (0.99-1.06)	1.03 (0.98-1.05)	-----	-----
Use of ***ARBs				
No	Ref.	Ref.	-----	-----
Yes	0.93 (0.92-1.02)	0.98 (0.96-1.01)	-----	-----
Use of antiplatelet drugs				
No	------	Ref.	-----	-----
Yes	------	1.08 (1.06-1.11)	-----	-----
Use of statins				
No	------	Ref.	-----	-----
Yes	------	0.89 (0.86-0.92)	-----	------
Use of ****NSAIDs				
No	------	------	Ref.	Ref.
Yes	------	------	0.99 (0.97-0.99)	0.99 (0.88-1.12)
Use of tetracyclic antidepressants				
No	------	------	------	Ref.

Yes	------	------	------	1.14 (0.86-1.32)
Use of benzodiazepines				
No	------	------	------	Ref.
Yes	------	------	------	1.33 (1.20-1.48)
*****Continuity of Care index**				
COC≤ median value	Ref.	Ref.	Ref.	Ref.
COC>median value	0.70 (0.69-0.72)	0.74 (0.72-0.77)	0.73 (0.72-0.74)	0.84 (0.72-0.93)
Number of drugs	1.06 (1.04-1.07)	1.05 (1.02-1.07)	1.06 (1.04-1.08)	1.06 (1.05-1.07)
Age	1.04 (1.03-1.05)	1.03 (1.02-1.04)	1.03 (1.02-1.04)	1.02 (1.01-1.04)
Sex				
Female	Ref.	Ref.	Ref.	Ref.
Male	1.40 (1.36-1.44)	1.15 (1.12-1.18)	1.22 (1.20-1.24)	1.15 (0.97-1.23)
Income quintiles				
Q1 lowest income	Ref.	Ref.	Ref.	Ref.
Q2	0.93 (0.90-0.97)	0.99 (0.97-1.03)	1.02 (0.96-1.05)	1.02 (0.79-1.3)
Q3	0.95 (0.90-0.99)	1.03 (0.99-1.07)	0.97 (0.94-0.99)	0.99 (0.78-1.28)
Q4	0.89 (0.83-0.93)	1.05 (0.98-1.09)	0.97 (0.94-0.99)	1.03 (0.79-1.34)
Q5 highest income	0.87 (0.82-0.92)	1.04 (0.95-1.07)	1.48 (1.40-1.56)	1.05 (0.82-1.35)
******RIO index**				
≤40	Ref.	Ref.	Ref.	Ref.
>40	1.14 (1.09-1.19)	1.16 (1.12-1.20)		1.27 (0.95-1.57)
Duration of diabetes	1.03 (1.01-1.05)	1.02 (1.01-1.03)	1.19 (1.16-1.24)	1.01 (0.99-1.02)
Duration of hypertension	1.02 (1.01-1.03)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	-------
Duration of ischemic heart disease	-----	1.01 (1.00-1.02)	------	-------
Duration of osteoarthritis	-----	-----	0.99 (0.97-1.01)	0.92 (0.97-1.03)
Duration of depression	-----	-----	------	0.95 (0.89-1.01)
Number of primary care visits	1.02 (1.0-1.04)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	1.02 (1.01-1.03)
*******Primary care models**				
Capitated+	Ref.	Ref.	Ref.	Ref.
Fee-for-service	0.77 (0.76-0.79)	0.78 (0.76-0.80)	0.77 (0.76-0.78)	0.83 (0.68-1.02)
Capitated	1.09 (1.02-1.13)	1.08 (0.99-1.13)	1.04 (1.02-1.06)	0.97 (0.51-1.89)
Comorbidities				
0 CC	Ref.	Ref.	Ref.	Ref.
1 CC	1.17 (1.13-1.22)	1.21 (1.16-1.27)	1.10 (1.04-1.15)	0.81 (0.62-1.02)
2 CC	1.37 (1.33-1.40)	1.43 (1.37-1.48)	1.26 (1.19-1.32)	1.05 (0.68-1.21)

3 CC	1.65 (1.58-1.70)	1.69 (1.61-1.75)	1.48 (1.40-1.56)	1.27 (0.71-1.81)
4 CC	2.00 (1.89-2.12)	1.98 (1.89-2.09)	1.77 (1.68-1.86)	1.39 (0.82-1.98)
5 or more CC	2.32 (2.16-2.44)	2.27 (2.15-2.35)	2.12 (1.60-1.46)	1.55 (0.97-2.23)

*HbA1c- glycated hemoglobin
** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index
******* Geographic location (≤40=non-rural; >40=rural).
********* Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

S1 Appendix. Comorbid chronic conditions

S1 Appendix. Comorbid chronic conditions

Condition	ICD 9 / OHIP	ICD 10
Rheumatoid arthritis	714	M05-M06
Osteoporosis	733	M81 M82
Other mood disorders	300, 309	F38—F42, F431, F432, F438, F44, F450, F451, F452, F48, F530, F680, F930, F99
Psychiatric conditions other than mood disorders and dementia	291 292 295 297 298 299 301 302 303 304 305 306 307 313 314 315 319	F04 F050 F058 F059 F060 F061 F062 F063 F064 F07 F08 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F340 F35 F36 F37 F430 F439 F453 F454 F458 F46 F47 F49 F50 F51 F52 F531 F538 F539 F54 F55 F56 F57 F58 F59 F60 F61 F62 F63 F64 F65 F66 F67 F681 F688 F69 F70 F71 F72 F73 F74 F75 F76 F77 F78 F79 F80 F81 F82 F83 F84 F85 F86 F87 F88 F89 F90 F91 F92 F931 F932 F933 F938 F939 F94 F95 F96 F97 F98
Dementia	290, 331 (OHIP) / (DAD: 046.1, 290, 294, 331.0, 331.1, 331.5, 331.82)	F00, F01, F02, F03, G30 ODB subclnam =: 'CHOLINESTERASE INHIBITOR'
Renal failure	403,404,584,585,586,v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Asthma	493	J45
Cancer	140-239 (broad algorithm from ICD table)	C00-C26, C30-C44, C45-C97
Cardiac Arrythmia	427.3 (DAD) / 427 (OHIP)	I48.0, I48.1
CHF	428	I500, I501, I509
COPD	491, 492, 496	J41-J44
Stroke	430, 431, 432, 434, 436	I60-I64

Research checklist

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
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	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	8-9
		(*c*) Explain how missing data were addressed	8-9
		(*d*) If applicable, explain how loss to follow-up was addressed	8-9
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	10-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
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	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Evaluating quality of overall care among older adults with diabetes with comorbidities in Ontario, Canada: a retrospective cohort study

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Evaluating quality of overall care among older adults with diabetes with comorbidities in Ontario, Canada: a retrospective cohort study

Short title: Quality of overall care among older adults with diabetes with comorbidities

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Abstract

Objectives: This study aimed to: 1) explore whether the quality of overall care for older people with diabetes is differentially affected by types and number of comorbid conditions, and 2) examine the association between process of care measures and the likelihood of all-cause hospitalizations.

Design A population-based, retrospective cohort study

Setting The province of Ontario, Canada

Participants: We identified 673,197 Ontarians aged 65 years and older who had diabetes comorbid with hypertension, chronic ischemic heart disease, osteoarthritis or depression on April 1, 2010.

Main outcome measures: The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. Process of care measures specific to older adults with diabetes and these comorbidities, developed by means of a Delphi panel, were used to assess the quality of care. A generalized estimating equations approach was used to examine associations between the process of care measures and the likelihood of hospitalizations.

Results: The study findings suggest that patients are at risk of suboptimal care with each additional comorbid condition, while the incidence of hospitalizations and number of prescribed drugs markedly increased in patients with 2 vs. 1 selected comorbid condition, especially in those with discordant comorbidities. The median continuity of care score was higher among patients with diabetes-concordant conditions compared to those with diabetes-discordant conditions; and it declined with additional comorbid conditions in both groups. Greater continuity of care was associated with lower hospital utilization for older diabetes patients with both concordant and discordant conditions.

Conclusions: There is a need for focusing on improving continuity of care and prioritizing treatment in older adults with diabetes with any multiple conditions, but especially in those with diabetes-discordant conditions (e.g., depression).

Strengths and limitations of this study

- This population-based study included a large sample size to examine the quality of overall care for older adults with four disease combinations representing the most prevalent clusters of concurrent conditions across multimorbidity groupings.
- The study takes advantage of linked patient-level health administrative databases with detailed demographic and clinical information.
- The study used process of care measures for assessing ambulatory care among older adults with selected disease combinations that were developed using a Delphi technique integrating clinical expertise with systematic reviews of each disease combination.
- The study measures were limited to those available in Ontario administrative data.
- Data regarding other covariates (eg, severity of selected conditions, frailty) and health outcomes (eg, quality of life) were not available for this cohort and should be explored in future research.

Introduction

Evidence shows that the majority of care for adults with multiple chronic conditions is provided in ambulatory care settings and primary care, and is an important locus from which to develop approaches of care to better meet the needs of this population (1, 2). Older adults are more likely than younger individuals to have comorbid chronic conditions that can be complex and difficult to manage (3, 4). Recent research has demonstrated that more than 90% of older adults with diabetes in Ontario had at least one comorbid condition (5). In particular, arthritis, other cardiovascular conditions and mood disorders also commonly appear in older adults with diabetes (3, 5). Hypertension consistently appears as a comorbidity in older adults with diabetes (3, 5, 6).

A growing body of evidence shows that people with multiple chronic conditions are more likely to experience negative health outcomes, including increased healthcare utilization, poor quality of life and increased care costs compared to those a with single disease (7-10). Prior research found that Ontarians with three or more diagnoses had 56% more primary care visits, 76% more specialist visits, 256% more inpatient hospital stays, 11% more emergency department visits, and 68% more prescriptions, as compared to those with a single condition (11, 12). Primary care physicians face difficulties in addressing the complex multifaceted needs of older adults with multiple chronic conditions (13). Treatment of people with multiple chronic conditions often requires "trade-off" decisions, because current clinical guidelines may be impractical in the presence of multiple chronic conditions (14).

Treating one condition in older diabetes patients with comorbid conditions may cause undesirable consequences with regard to their other conditions. The optimal approach to treat patients with any combination of co-existing diseases is not the same as the sum of treatments for the separate diseases (15). Meanwhile, a single condition focus in both clinical care and research

persists and limits the assessment of care for the whole person with multiple chronic conditions. There is a need to understand how diabetes treatment and that for co-occurring comorbid chronic conditions varies depending on the specific comorbid conditions and to assess the relationships between specific quality of care measures across combinations of conditions and adverse events such as hospital admission.

To address this knowledge gap, the objectives of this study were to: 1) explore whether the quality of care for older people with diabetes is differentially affected by types and number of comorbid chronic conditions; and 2) examine the association between quality of care (process) measures and the likelihood of all-cause hospitalizations among older adults with diabetes with selected comorbid conditions.

Methods

Study design and study participants

This was a retrospective cohort study conducted in Ontario, Canada using linked provincial health administrative databases. We identified a cohort of people 65 years of age and older who had diabetes as of April 1, 2010, using the Ontario Diabetes Database (ODD). The ODD is a validated database that identifies all adults aged 20 years and older with diabetes in Ontario from April 1, 1991 (16, 17). The ODD has demonstrated high sensitivity (86%) and specificity (97%) in identifying individuals compared to primary care electronic medical records (16, 18). We also ascertained concurrent diagnoses of hypertension, chronic ischemic heart disease, osteoarthritis and depression. All diagnoses (including diabetes, hypertension, ischemic heart diseases, osteoarthritis and depression) were identified if they had either one hospital admission or two ambulatory physician claims with each respective diagnosis within 2 years.

Depression in this study connotes major depression and dysthymia, since most clinical practice guidelines only address treatment of major depression (19). Each condition was defined with health administrative data from April 1, 2001 to April 1, 2010 (index date). Patients were excluded if they fell under the following criteria: had an invalid health card number, were younger than 65 or older than 105 years old, died before the index date (April 1, 2010), or had no contact with the health care system in the last 5 years before the index date.

The selected five chronic diseases were categorized into two groups by comorbidity type relative to diabetes (20), including: 1) diabetes-concordant conditions that share a common management plan (a) diabetes with comorbid hypertension and without chronic ischemic heart disease, and b) diabetes with comorbid hypertension and chronic ischemic heart disease), and 2) diabetes-discordant conditions that are not directly related in the disease management plan (a)diabetes with comorbid osteoarthritis and without major depression, and b) diabetes with osteoarthritis and major depression). These four disease combinations represented most prevalent clusters of concurrent conditions across multimorbidity groupings based on the prior research results (3).

Data sources

Data sources for this study included: the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) which consists of data on all hospital discharges in Ontario; the OHIP (Ontario Health Insurance Plan) claims database which contains information on patient contact with physicians in both ambulatory and hospital settings; the Registered Persons Database (RPDB) which contains information regarding the demographics of persons eligible for health care coverage in Ontario; the Client Agency Program Enrolment (CAPE) database which

identifies patients belonging to the primary care models; and the Ontario Drug Benefit (ODB) claims database which contains comprehensive records of prescription medications dispensed in outpatient pharmacies to Ontario residents eligible for public drug coverage, specifically those aged 65 and over. Canada census data were also used to derive population estimates by age and sex in each year. All databases were linked using unique, encoded identifiers and analyzed at the Institute of Clinical Evaluative Sciences (ICES) in Toronto, Ontario.

All provinces in Canada hold administrative data for the full population under a universal health care system that is similar to other health systems internationally including diagnoses and utilization from physician, hospital and pharmacy billing data.

The study received approval from the Sunnybrook Health Sciences Research Ethics Board and the University of Toronto (# 32497).

Study outcome

The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. This outcome measure had a value 1 (yes) if any study subject had at least one all-cause hospitalization in each year, and 0 (no) if not.

Process of care measures

This study uses process and outcome measures for diabetes with comorbidities. A specific set of process and outcome measures was developed by means of a Delphi panel (21) for assessing the quality of care for older adults with each particular disease combination in ambulatory care settings (Table 1). Delphi participants purposefully selected a list of indicators

in the context of assessing care of older adults with diabetes and specific comorbid chronic conditions.

Processes of care measures were calculated using the same data sources. The measures included: having 1 or 2 glycated hemoglobin (HbA1c) tests per year, having 3 or more HbA1c tests per year, annual eye examination, use of oral hypoglycemic drugs in each, use of angiotensin-converting-enzyme (ACE) inhibitors in each, use of angiotensin II receptor blockers (ARBs) in each, number of prescribed drugs in each year (22, 23), use of non-steroidal anti-inflammatory drugs (NSAIDs) in each year. There were also a series of "negative" indicators which related to contraindicated processes because they increase the risk of adverse outcomes. Theses included use of tetracyclic antidepressants in each year, use of monoamine oxidase (MAO) inhibitors in each year, use of gaba receptor agonists in each year, and use of benzodiazepines in each year. Continuity of care was measured use the Bice COC (Continuity of Care) index that measures both the dispersion and concentration of care among all providers seen, and can be adapted to capture aspects of the coordination of care by attributing referral visits back to the referring provider (24, 25). To align with the prior research in this population, we categorized COC index as having a high vs. low continuity or concentration of care using the median COC score for each selected disease combination, respectively (26-28).

Covariates

We included patient demographic and clinical factors that could confound the relationship between process of care measures and the study outcomes as covariates in all regression models, including: 1) age (coded as 65-74, 75-84, 85-94, 95 and over), 2) sex (coded

as male/female), 3) geographic location measured by the Rurality Index of Ontario (RIO) (≤40 = non-rural and >40 = rural) (29), 4) neighbourhood income quintile (ranging from Q1 = lowest income to Q5=highest income) (30), 5) level of multimorbidity (i.e., chronic disease burden) as the number of prevalent chronic conditions in addition to the five selected chronic conditions (3, 5), including heart failure, acute myocardial infarction, cardiac arrhythmia, stroke, COPD, asthma, cancer, renal disease, other mood disorders, dementia, psychiatric diseases other than mood disorders and dementia, rheumatoid arthritis, or osteoporosis (Appendix 1) - this was coded as zero, one, two, three, four, or five-plus, as well as 6) the duration of each condition of interest in the particular disease combinations, including diabetes, hypertension, chronic ischemic heart disease, major depression or osteoarthritis (in years). We also included health system factors including 7) patient's primary care model categorized into: a) non-capitated models where physicians largely operate on a fee-for-service basis, b) capitated rostered models, and c) capitated+, including family health teams and other rostered models with additional incentives for interdisciplinary care (31, 32), and 8) number of primary care visits, including office-based visits with a general practitioner or family physician.

Statistical analysis

All analyses were stratified by condition combinations (diabetes with each of hypertension, hypertension with ischemic heart disease, osteoarthritis and osteoarthritis and depression) for which quality indicators were established.

Participant characteristics were described using proportions, means (standard deviation (SD)), and medians (inter-quartile range (IQR)) where appropriate. Marginal logistic models using a generalized estimating equations approach (PROC GENMOD in SAS) were performed

to examine associations between the likelihood of hospitalisations during the follow-up period, from 2011-2014, based on the process of care measures in the year prior, among older adults with each particular disease combination, respectively. Generalized estimating equations were used to make inferences about the mean response in the population, to make inference about differences in quality of care between two groups of patients, to account for within-subject correlation among the repeated responses, to deal with different numbers of observations per patient, and to estimate model parameters, using the available information (33). Risk estimates are presented as adjusted odds ratios (AORs) and corresponding 95 % Confidence Intervals (CIs). All data analyses were performed with SAS package version 9.3 (SAS Institute, Cary, 145 North Carolina). The level of statistical significance was considered p less than 0.05.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination of our research.

Results

Table 2 presents baseline characteristics of the study population. The cohort of older adults with diabetes with comorbid hypertension and without chronic ischemic heart disease included 273,592 patients, while the cohort with comorbid hypertension and chronic ischemic heart disease contained 141,947 patients. The cohort of older adults with diabetes with comorbid osteoarthritis and without depression included 255,214 patients, while the cohort of older adults with diabetes with comorbid osteoarthritis and major depression contained 2,444 individuals.

About 85% of diabetes patients were between 65 and 84 years, and over half were female. Women were more prevalent than men in the cohort of diabetes patients with comorbid osteoarthritis and depression. Nearly half of the people comorbid with hypertension (44.7%) and 76.6% of patients with comorbid osteoarthritis and depression were prescribed 11 or more medications. More than 25% of the latter group were classified as having 5 or more concurrent conditions amongst those measured in this study. The majority of older diabetes patients with comorbid conditions were living in lower income neighborhoods.

Table 3 presents the distribution of process measures and all-cause hospitalizations among older adults with four selected disease combinations. The proportion of patients who had at least 2 HbA1c tests per year or were prescribed oral hypoglycemic drugs was lower in diabetes patients with 2 comorbid conditions compared to those with 1 comorbid condition (both concordant and discordant); this decline was more significant in patients with comorbid osteoarthritis and major depression. The proportion of patients who had an annual eye examination performed was slightly higher in diabetes patients with two concordant comorbid conditions than that in diabetes patients with comorbid hypertension only. The median score of continuity of care was greater in older diabetes patients with concordant rather than discordant comorbid conditions (0.57 vs. 0.53 in patients with one concordant vs. discordant condition); however, it declined with additional comorbid conditions, especially in those with discordant conditions (0.36 in patients with comorbid osteoarthritis and major depression).

The proportion of patients who were prescribed ACE inhibitors and ARBs was higher in older adults with comorbid hypertension and chronic ischemic heart disease compared to those without ischemic heart disease. About 14% of older diabetes patients with comorbid osteoarthritis with and without major depression were prescribed tetracyclic antidepressants;

20% were prescribed NSAID therapy; 40% were prescribed benzodiazepines. The incidence of all-cause hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions.

Table 4 presents results of multivariable association of process of care indicators and all-cause hospitalizations among older adults with four selected disease combinations. Meeting HbA1c testing frequency goals, having an annual eye exam, or oral hypoglycemic drug therapy were significantly associated with reduction in the likelihood of all-cause hospitalizations in older people with diabetes comorbid with concordant (with comorbid hypertension with or without chronic ischemic heart disease) and diabetes patients with comorbid osteoarthritis only. In diabetes patients comorbid with osteoarthritis and depression, having an annual eye exam was significantly associated with reduction in the likelihood of all-cause hospitalizations. There was no association between use of ACE inhibitors or ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease.

Antiplatelet therapy was significantly associated with an increase in the likelihood of all-cause hospitalizations among older adults with comorbid hypertension and chronic ischemic heart disease. There was a very marginal though significant association between NSAID therapy and reduction in all-cause hospitalizations in older diabetes patients with comorbid osteoarthritis that was not significant when depression was also present. There was a significant association between use of benzodiazepines and increase in all-cause hospitalizations, while there was no association found between use of tetracyclic antidepressants and all-cause hospitalizations among patients with comorbid osteoarthritis and depression. The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older

people with diabetes with comorbid concordant and discordant conditions. The likelihood of all-cause hospitalizations increased by 6% with each additional filled prescription among older adults with comorbid concordant or discordant conditions.

Discussion

The study findings demonstrate that the quality of overall care declined in older adults with diabetes with each additional selected comorbid condition, and was especially low for those with comorbid osteoarthritis and major depression. Therefore, older patients with diabetes with comorbid osteoarthritis with or without major depression need more targeted interventions and collaboration between healthcare providers to improve quality of care and reduce hospitalization. These findings can help inform clinicians and policy makers in developing strategies for subpopulations at-risk. Previous research demonstrates that people with diabetes with 2 or more comorbid conditions were more likely to achieve the target HbA1c testing frequency or have annual eye examination compared to those with no or one comorbid condition (34). However, the authors used diabetes care measures to assess the role of number of concordant and discordant conditions on the achievement of diabetes testing goals without specifying individual concordant and discordant conditions, despite the fact that certain conditions may have a greater impact on diabetes care than other conditions. Another study demonstrates that as compared with diabetes patients without comorbidities, those with concordant comorbid conditions had an increased likelihood of receiving reviews of medications and blood pressure examinations, while discordant comorbidities do not compete with diabetes care (35).

The study findings support the underlying premise of the framework of Concordance and Discordance proposed by Piette and Kerr that hypothesizes that the effects of comorbidity on

patients with diabetes differ depending on the nature of comorbid conditions (20). The literature suggests that physicians may prioritize treatment of concordant conditions over discordant conditions, because a single treatment plan can improve the status of more than one condition (36). Blood pressure and cholesterol targets, increased physical activity, as well as the use of antihypertensive therapy are identical for patients with diabetes and cardiovascular conditions, including hypertension and ischemic heart disease (37). Thus, for the majority of patients, management of cardiovascular conditions enhances the management of diabetes.

The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older people with diabetes with comorbid concordant and discordant conditions. This finding is consistent with other study results (38-40). Grunier and colleagues (26) found that the risk of hospitalizations was reduced in people with one or more chronic conditions, when visits and referrals are concentrated with a single physician.

We found that older diabetes patients with comorbidities, especially with discordant conditions, are likely to be prescribed a large number of drugs, and the more drugs they are prescribed the higher is the risk of hospitalizations. This study finding is consistent with previous research results (41, 42). The study results demonstrate that the mean number of prescribed drugs increased in older diabetes patients with 2 vs. 1 comorbid condition, especially in those with discordant conditions (17 vs. 12 prescriptions). There was no association observed between use of ACE inhibitors and ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease. The information regarding the benefit of ACE inhibitors or ARBs on vascular protection among older adults with diabetes remains controversial in diabetes patients with comorbidities. The study findings suggest found a negligible association between NSAID therapy and reduction in all-cause

hospitalizations in patients with comorbid osteoarthritis that was not significant when depression was also present. Whilst the recent review of evidence from the Osteoarthritis Research Society International (OARSI) suggests that use of NSAID therapy for osteoarthritis management provides better efficacy than acetaminophen for relief of chronic inflammatory pain (43), this was not substantially related to all-cause hospitalizations

The incidence of hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions (diabetes comorbid with osteoarthritis and depression). This study finding is consistent with previous research that found a higher rate of hospital admission among people with diabetes with discordant than concordant comorbid conditions, especially in those with mental conditions (44). A recent study indicated that there is a trend of increasing use of healthcare services, including hospitalizations, emergency department visits and physician visits, with increase in number of comorbid conditions among older adults with diabetes (24).

Strengths and limitations

Our study sheds light on limited research evidence regarding the assessment of the overall quality of care among older adults with diabetes comorbid with specific concordant/discordant comorbid conditions. The study cohort was drawn from the entire Ontario population with a diagnosis of diabetes aged 65 and older. Administrative data have the advantage of being population-based and are relatively inexpensive compared to the other potential sources of data for ambulatory care evaluation. We used validated algorithms to define chronic diagnoses. In our study, multiple databases were used to ascertain the cases, including hospital stay (DAD), physician visits (OHIP), and validated disease cohorts. The specific sets of process of care measures, as judged to be relevant by the Delphi Panel (21), were used for

assessing clinical aspects of ambulatory care among older adults with four selected disease combinations. The development of process of care measures integrated clinical expertise with scientific evidence form systematic research.

Nonetheless, the results of the study should be interpreted in light of the following limitations. The study measures identified by the Delphi Panel were purposively limited to those available in Ontario administrative data. This restricted measurement of important clinical factors such as disease severity, patient disability and frailty, the availability of social supports or caregivers and mobility or aids used to mitigate functional impairment. We lacked data related to laboratory tests done in hospitals or paid for privately. Ambulatory prescriptions and tests represent the majority of the care that patients receive over the course of their treatment out of hospital. Several quality measures not measurable in this study, such as blood glucose level control, life style changes, patient education, as well as patient preferences and goals of care and self-management ability, could reveal and explain important aspects of the associations between process of care measures and hospitalizations as reported here. There is a potential for misclassifying people based on their comorbidity profiles.

We were not able to account for severity of selected chronic conditions due to limitation of the administrative data that may lead to biased estimates. We focused on all-cause hospitalizations, without stratifying by reasons for hospitalization that could potentially inform interventions. The common chronic co-existing conditions that were selected for this study do not represent all existing comorbidities in patients with diabetes.

Conclusions

For an older diabetes patient with comorbidities the challenge is to find a way to encourage health care providers to manage all chronic conditions collectively instead of focusing

on a single disease treatment. This study highlighted the most prevalent multimoribdity clusters among older adults with diabetes, including both concordant and discordant comorbidities. Explicit consideration of multimorbidity clusters among older adults with diabetes is important because appropriate management of individual diseases in isolation may not be optimal for patients with multimorbidity due to unique disease-disease or disease-treatment interactions. Furthermore, determining specific multimorbidity subgroups among patients with diabetes at increased risk of adverse health outcomes has important policy implications and provides targets for tailored prevention.

Our study showed that the number of conditions was the strongest predictor of hospitalization but higher achievement on diabetes quality of care measures and physician continuity of care along with fewer prescribed medications were also protective with all-cause hospitalizations. These findings represent opportunities to improve ambulatory care that should lead to reductions in hospital use. Research should focus on the evaluation of quality of care for diabetes patients with comorbidities whilst developing more robust measurement of health outcomes beyond hospitalization.

Authors' contributions

All coauthors fulfill the criteria required for authorship. WPW was the lead for the creation of the cohort. YP and WPW substantially contributed to the conception, analysis, and interpretation of the data for the work and to the drafting of the work. JB, KK, and BL substantially contributed to the analysis and interpretation of the data for the work. YP drafted the manuscript. YP and WPW revised the drafting of the work critically for important intellectual content. All authors contributed to the final approval of the version to be published and are in agreement to be accountable for all aspects of the work and in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

No researcher or panel member involved in this study had any declared or otherwise known conflicts of interest.

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Data sharing statement

The data from this study are held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS.

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Table 1. Process of care measures

Measure	Concordant conditions		Discordant conditions	
	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Process measures				
*HbA1c testing	✓	✓	✓	✓
Eye examination	✓	✓	✓	✓
Use of oral hypoglycemic drugs	✓	✓	✓	✓
Use of angiotensin-converting enzyme (ACE) inhibitors	✓	✓		
Use of angiotensin II receptor blockers (ARBs)	✓	✓		
Us of antiplatelet drugs		✓		
Use of statins		✓		
Use of *NSAIDs-*** "negative" indicator			✓	✓
Use of tetracyclic antidepressant – "negative indicator"				✓
Use of monoamine oxidase inhibitors (MAO) – "negative indicator"				✓
Use of benzodiazepines – "negative indicator"				✓
Use of gaba receptor agonists – "negative indicator"				✓

*HbA1c=glycated hemoglobin
**NSAIDs=non-steroidal anti-inflammatory drugs
*** "Negative" indicators related to contraindicated processes because they increase the risk of adverse outcomes

Table 2. Baseline characteristics

Characteristic	Diabetes with	Diabetes with	Diabetes with	Diabetes with

	comorbid hypertension	comorbid hypertension and chronic ischemic heart disease	comorbid osteoarthritis	comorbid osteoarthritis and major depression
Number of individuals	273,592	141,947	255,214	2,444
Age in years, mean (SD)	76.2 (7.18)	77.4 (7.12)	76.6 (7.24)	75.7 (7.12)
Age in groups, n (%)				
65 – 74	127,469 (46.6)	54,593 (38.4)	112,046 (43.9)	1,194 (48.9)
75 – 84	106,336 (38.9)	61.883 (43.6)	102,717 (40.2)	906 (37.1)
85 – 94	37,194 (13.6)	23,950 (16.9)	37,900 (14.9)	333 (13.6)
95+	2,593 (0.9)	1,521 (1.1)	2,551 (1.0)	11 (0.4)
Sex, n (%)				
Female	154,565 (56.5)	81,987 (57.8)	139,951 (54.8)	1,545 (63.2)
Male	119,027 (43.5)	59,960 (42.2)	115,263 (45.2)	899 (36.8)
Number of drugs, mean (SD)	10.6 (5.89)	13.4 (6.52)	12.1 (6.42)	17.1 (7.6)
Number of drugs, n (%)				
≤5 drugs	48,210 (17.6%)	10,924 (7.7%)	33,768 (13.2%)	136 (5.7%)
6-10 drugs	103,032 (37.7%)	39,583 (27.9%)	80,695 (31.6%)	433 (17.7%)
≥11 drugs	122,350 (44.7%)	91,440 (64.4%)	140,751 (55.2%)	1,875 (76.6%)
Income quintiles, n (%)				
Q1 lowest income	57,053 (21.7)	29,478 (22.0)	53,174 (21.6)	589 (26.1)
Q2	58,237 (22.1)	29,496 (22.0)	53,884 (22.0)	504 (22.3)
Q3	52,967 (20.1)	26,765 (20.0)	48,922 (20.0)	414 (18.4)
Q4	50,668 (19.2)	25,649 (19.1)	47,143 (19.3)	360 (15.0)
Q5 highest income	44,653 (16.9)	22,657 (16.9)	41,855 (17.1)	388 (17.2)
*RIO index, n (%)				
≤40 (urban)	214,443 (78.4)	131,065 (92.3)	237,312 (93.0)	2,293 (93.8)
>40 (rural)	59,149 (21.6)	10,882 (7.7)	17,.902 (7.0)	151 (6.2)
**Primary care models, n (%)				
Fee-for-service	140,465 (68.3)	120,557 (63.7)	128,522 (69.2)	1450 (67.8)
Capitated+	29,203 (14.2)	26,685 (14.1)	26,930 (14.5)	297 (13.9)
Capitated	35,990 (17.5)	42,015 (22.2)	30,273 (16.3)	391 (18.3)
Comorbidities, n (%)				
0 CC	59,149 (21.6)	15,859 (11.2)	12,061 (4.7%)	77 (3.1%)
1 CC	88,411 (32.3)	33,105 (23.3)	58,547 (22.9%)	335 (13.7%)
2 CC	64,965 (23.7)	34,350 (24.2)	67,635 (26.5%)	495 (20.3%)
3 CC	34,914 (12.8)	26,547 (18.7)	50,641 (19.8%)	490 (20.1%)
4 CC	16,382 (6.0)	16,972 (12.0)	32,778 (12.8%)	428 (17.5%)
5 or more CC	9,771 (3.6)	15,114 (10.7)	33,552 (13.3%)	619 (25.3%)
Number of primary care visits, mean (SD)	6.1 (5.77)	7.6 (6.99)	7.34 (6.60)	7.8 (7.4)
Duration of diabetes in years, mean (SD)	9.90 (5.80)	10.7 (6.02)	10.0 (5.88)	10.3 (6.01)
Duration of hypertension in years, mean (SD)	13.1 (5.65)	13.8 (5.44)	------	------
Duration of chronic	------		------	-------

ischemic heart disease, mean (SD)		7.13 (2.68)		
Duration of osteoarthritis in years, mean (SD)	------	-------	7.17 (2.57)	7.4 (2.61)
Duration of major depression, mean (SD)	-------	-------	-------	3.3 (1.62)

* Geographic location (≤40=non-rural; >40=rural).

**Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

Table 3. Distribution of process and outcome measures among adults with diabetes with comorbidities

Measure, n (%)	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
Process measures, n (%)				
Having 1 or 2 *HbA1c tests per year	124,336 (45.4)	61,505 (43.3)	114,746 (45.0)	964 (39.4)
Having 3 or more HbA1c tests per year	77,942 (28.5)	42,194 (29.7)	72,469 (28.4)	669 (27.9)
Annual eye examination	177,080 (64.7)	92,623 (65.3)	171,803 (67.3)	1,386 (56.7)
Use of oral hypoglycemic drugs	148,344 (54.2)	72,686 (51.2)	130,599 (51.2)	1,102 (45.1)
Use of **ACE inhibitors	110,641 (40.4)	69,296 (48.8)	-----	-----
Use of ***ARBs	62,169 (22.7)	32,997 (23.3)	-----	-----
Use of antiplatelet drugs	-----	34,868 (24.6)	-----	-----
Use of statins	-----	12,845 (79.5)	-----	-----
Use of ****NSAIDs– “negative”	-----	-----	52,952 (20.8)	452 (18.5)
Use of tetracyclic antidepressants– “negative”	-----	-----	-----	348 (14.2)
Use of benzodiazepines– “negative”	-----	-----	-----	860 (35.2)
Use of gaba receptor agonist– “negative”	-----	-----	-----	<6 (0.2)

Use of *****MAOIs– "negative"	-----	-----	-----	9 (0.4)
****** Continuity of care (COC) index				
Mean, (SD)	0.59 (0.28)	0.51 (0.27)	0.55 (0.26)	0.42 (0.26)
Median, (IQR)	0.57 (0.36-0.82)	0.49 (0.29-0.73)	0.53 (0.32-0.77)	0.36 (0.21-0.59)
Outcome measure, n (%)				
All-cause hospitalizations	45,520 (15.6)	35,157 (24.8)	49,873 (19.5)	536 (29.0)

*HbA1c- glycated hemoglobin
** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index

Table 4. Multivariable associations between process measures and the likelihood of all-cause hospitalizations among older adults with selected disease combinations

Characteristic	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)
Having *HbA1c tests				
No	Ref.	Ref.	Ref.	Ref.
1 or 2 HbA1c tests	0.90 (0.88-0.92)	0.88 (0.85-0.91)	0.88 (0.86-0.90)	0.93 (0.76-1.13)
3 or more HbA1c tests	0.84 (0.82-0.86)	0.86 (0.83-0.88)	0.83 (0.81-0.85)	0.82 (0.69-1.03)
Annual eye examination				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.85 (0.84-0.87)	0.90 (0.88-0.92)	0.89 (0.87-0.91)	0.85 (0.75-0.97)
Use of oral hypoglycemic drugs				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.88 (0.86-0.90)	0.88 (0.86-0.90)	0.92 (0.89-0.93)	0.93 (0.78-1.10)
Use of **ACE-inhibitors				
No	Ref.	Ref.	-----	-----
Yes	1.04 (0.99-1.06)	1.03 (0.98-1.05)	-----	-----
Use of ***ARBs				
No	Ref.	Ref.	-----	-----

Yes	0.93 (0.92-1.02)	0.98 (0.96-1.01)	-----	-----
Use of antiplatelet drugs				
No	------	Ref.	-----	-----
Yes	------	1.08 (1.06-1.11)	-----	-----
Use of statins				
No	------	Ref.	-----	-----
Yes	------	0.89 (0.86-0.92)	-----	------
Use of ****NSAIDs				
No	------	------	Ref.	Ref.
Yes	------	------	0.99 (0.97-0.99)	0.99 (0.88-1.12)
Use of tetracyclic antidepressants				
No	------	------	------	Ref.
Yes	------	------	------	1.14 (0.86-1.32)
Use of benzodiazepines				
No	------	------	------	Ref.
Yes	------	------	------	1.33 (1.20-1.48)
*****Continuity of Care index**				
COC≤ median value	Ref.	Ref.	Ref.	Ref.
COC>median value	0.70 (0.69-0.72)	0.74 (0.72-0.77)	0.73 (0.72-0.74)	0.84 (0.72-0.93)
Number of drugs	1.06 (1.04-1.07)	1.05 (1.02-1.07)	1.06 (1.04-1.08)	1.06 (1.05-1.07)
Age	1.04 (1.03-1.05)	1.03 (1.02-1.04)	1.03 (1.02-1.04)	1.02 (1.01-1.04)
Sex				
Female	Ref.	Ref.	Ref.	Ref.
Male	1.40 (1.36-1.44)	1.15 (1.12-1.18)	1.22 (1.20-1.24)	1.15 (0.97-1.23)
Income quintiles				
Q1 lowest income	Ref.	Ref.	Ref.	Ref.
Q2	0.93 (0.90-0.97)	0.99 (0.97-1.03)	1.02 (0.96-1.05)	1.02 (0.79-1.3)
Q3	0.95 (0.90-0.99)	1.03 (0.99-1.07)	0.97 (0.94-0.99)	0.99 (0.78-1.28)
Q4	0.89 (0.83-0.93)	1.05 (0.98-1.09)	0.97 (0.94-0.99)	1.03 (0.79-1.34)
Q5 highest income	0.87 (0.82-0.92)	1.04 (0.95-1.07)	1.48 (1.40-1.56)	1.05 (0.82-1.35)
******RIO index**				
≤40	Ref.	Ref.	Ref.	Ref.
>40	1.14 (1.09-1.19)	1.16 (1.12-1.20)		1.27 (0.95-1.57)
Duration of diabetes	1.03 (1.01-1.05)	1.02 (1.01-1.03)	1.19 (1.16-1.24)	1.01 (0.99-1.02)
Duration of hypertension	1.02 (1.01-1.03)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	-------
Duration of ischemic heart disease	-----	1.01 (1.00-1.02)	------	-------
Duration of osteoarthritis	-----	-----	0.99 (0.97-1.01)	0.92 (0.97-1.03)
Duration of depression	-----	-----	------	0.95 (0.89-1.01)

Number of primary care visits	1.02 (1.0-1.04)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	1.02 (1.01-1.03)
*******Primary care models**				
Capitated+	Ref.	Ref.	Ref.	Ref.
Fee-for-service	0.77 (0.76-0.79)	0.78 (0.76-0.80)	0.77 (0.76-0.78)	0.83 (0.68-1.02)
Capitated	1.09 (1.02-1.13)	1.08 (0.99-1.13)	1.04 (1.02-1.06)	0.97 (0.51-1.89)
Comorbidities				
0 CC	Ref.	Ref.	Ref.	Ref.
1 CC	1.17 (1.13-1.22)	1.21 (1.16-1.27)	1.10 (1.04-1.15)	0.81 (0.62-1.02)
2 CC	1.37 (1.33-1.40)	1.43 (1.37-1.48)	1.26 (1.19-1.32)	1.05 (0.68-1.21)
3 CC	1.65 (1.58-1.70)	1.69 (1.61-1.75)	1.48 (1.40-1.56)	1.27 (0.71-1.81)
4 CC	2.00 (1.89-2.12)	1.98 (1.89-2.09)	1.77 (1.68-1.86)	1.39 (0.82-1.98)
5 or more CC	2.32 (2.16-2.44)	2.27 (2.15-2.35)	2.12 (1.60-1.46)	1.55 (0.97-2.23)

*HbA1c- glycated hemoglobin
** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index
******* Geographic location (≤40=non-rural; >40=rural).
********* Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

S1 Appendix. Comorbid chronic conditions

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Condition	ICD 9 / OHIP	ICD 10
Rheumatoid arthritis	714	M05-M06
Osteoporosis	733	M81 M82
Other mood disorders	300, 309	F38—F42, F431, F432, F438, F44, F450, F451, F452, F48, F530, F680, F930, F99
Psychiatric conditions other than mood disorders and dementia	291 292 295 297 298 299 301 302 303 304 305 306 307 313 314 315 319	F04 F050 F058 F059 F060 F061 F062 F063 F064 F07 F08 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F340 F35 F36 F37 F430 F439 F453 F454 F458 F46 F47 F49 F50 F51 F52 F531 F538 F539 F54 F55 F56 F57 F58 F59 F60 F61 F62 F63 F64 F65 F66 F67 F681 F688 F69 F70 F71 F72 F73 F74 F75 F76 F77 F78 F79 F80 F81 F82 F83 F84 F85 F86 F87 F88 F89 F90 F91 F92 F931 F932 F933 F938 F939 F94 F95 F96 F97 F98
Dementia	290, 331 (OHIP) / (DAD: 046.1, 290, 294, 331.0, 331.1, 331.5, 331.82)	F00, F01, F02, F03, G30 ODB subclnam =: 'CHOLINESTERASE INHIBITOR'
Renal failure	403,404,584,585,586,v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Asthma	493	J45
Cancer	140-239 (broad algorithm from ICD table)	C00-C26, C30-C44, C45-C97
Cardiac Arrythmia	427.3 (DAD) / 427 (OHIP)	I48.0, I48.1
CHF	428	I500, I501, I509
COPD	491, 492, 496	J41-J44
Stroke	430, 431, 432, 434, 436	I60-I64

Research checklist

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
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	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	8-9
		(*c*) Explain how missing data were addressed	8-9
		(*d*) If applicable, explain how loss to follow-up was addressed	8-9
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	10-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
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	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Evaluating quality of overall care among older adults with diabetes with comorbidities in Ontario, Canada: a retrospective cohort study

Short title: Quality of overall care among older adults with diabetes with comorbidities

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Abstract

Objectives: This study aimed to: 1) explore whether the quality of overall care for older people with diabetes is differentially affected by types and number of comorbid conditions, and 2) examine the association between process of care measures and the likelihood of all-cause hospitalizations.

Design A population-based, retrospective cohort study

Setting The province of Ontario, Canada

Participants: We identified 673,197 Ontarians aged 65 years and older who had diabetes comorbid with hypertension, chronic ischemic heart disease, osteoarthritis or depression on April 1, 2010.

Main outcome measures: The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. Process of care measures specific to older adults with diabetes and these comorbidities, developed by means of a Delphi panel, were used to assess the quality of care. A generalized estimating equations approach was used to examine associations between the process of care measures and the likelihood of hospitalizations.

Results: The study findings suggest that patients are at risk of suboptimal care with each additional comorbid condition, while the incidence of hospitalizations and number of prescribed drugs markedly increased in patients with 2 vs. 1 selected comorbid condition, especially in those with discordant comorbidities. The median continuity of care score was higher among patients with diabetes-concordant conditions compared to those with diabetes-discordant conditions; and it declined with additional comorbid conditions in both groups. Greater continuity of care was associated with lower hospital utilization for older diabetes patients with both concordant and discordant conditions.

Conclusions: There is a need for focusing on improving continuity of care and prioritizing treatment in older adults with diabetes with any multiple conditions, but especially in those with diabetes-discordant conditions (e.g., depression).

Strengths and limitations of this study

- This population-based study included a large sample size to examine the quality of overall care for older adults with four disease combinations representing the most prevalent clusters of concurrent conditions across multimorbidity groupings.
- The study takes advantage of linked patient-level health administrative databases with detailed demographic and clinical information.
- The study used process of care measures for assessing ambulatory care among older adults with selected disease combinations that were developed using a Delphi technique integrating clinical expertise with systematic reviews of each disease combination.
- The study measures were limited to those available in Ontario administrative data.
- Data regarding other covariates (eg, severity of selected conditions, frailty) and health outcomes (eg, quality of life) were not available for this cohort and should be explored in future research.

Introduction

Evidence shows that the majority of care for adults with multiple chronic conditions is provided in ambulatory care settings and primary care, and is an important locus from which to develop approaches of care to better meet the needs of this population (1, 2). Older adults are more likely than younger individuals to have comorbid chronic conditions that can be complex and difficult to manage (3, 4). Recent research has demonstrated that more than 90% of older adults with diabetes in Ontario had at least one comorbid condition (5). In particular, arthritis, other cardiovascular conditions and mood disorders also commonly appear in older adults with diabetes (3, 5). Hypertension consistently appears as a comorbidity in older adults with diabetes (3, 5, 6).

A growing body of evidence shows that people with multiple chronic conditions are more likely to experience negative health outcomes, including increased healthcare utilization, poor quality of life and increased care costs compared to those a with single disease (7-10). Prior research found that Ontarians with three or more diagnoses had 56% more primary care visits, 76% more specialist visits, 256% more inpatient hospital stays, 11% more emergency department visits, and 68% more prescriptions, as compared to those with a single condition (11, 12). Primary care physicians face difficulties in addressing the complex multifaceted needs of older adults with multiple chronic conditions (13). Treatment of people with multiple chronic conditions often requires "trade-off" decisions, because current clinical guidelines may be impractical in the presence of multiple chronic conditions (14).

Treating one condition in older diabetes patients with comorbid conditions may cause undesirable consequences with regard to their other conditions. The optimal approach to treat patients with any combination of co-existing diseases is not the same as the sum of treatments for the separate diseases (15). Meanwhile, a single condition focus in both clinical care and research

persists and limits the assessment of care for the whole person with multiple chronic conditions. There is a need to understand how diabetes treatment and that for co-occurring comorbid chronic conditions varies depending on the specific comorbid conditions and to assess the relationships between specific quality of care measures across combinations of conditions and adverse events such as hospital admission.

To address this knowledge gap, the objectives of this study were to: 1) explore whether the quality of care for older people with diabetes is differentially affected by types and number of comorbid chronic conditions; and 2) examine the association between quality of care (process) measures and the likelihood of all-cause hospitalizations among older adults with diabetes with selected comorbid conditions.

Methods

Study design and study participants

This was a retrospective cohort study conducted in Ontario, Canada using linked provincial health administrative databases. We identified a cohort of people 65 years of age and older who had diabetes as of April 1, 2010, using the Ontario Diabetes Database (ODD). The ODD is a validated database that identifies all adults aged 20 years and older with diabetes in Ontario from April 1, 1991 (16, 17). The ODD has demonstrated high sensitivity (86%) and specificity (97%) in identifying individuals compared to primary care electronic medical records (16, 18). We also ascertained concurrent diagnoses of hypertension, chronic ischemic heart disease, osteoarthritis and depression. All diagnoses (including diabetes, hypertension, ischemic heart diseases, osteoarthritis and depression) were identified if they had either one hospital admission or two ambulatory physician claims with each respective diagnosis within 2 years.

Depression in this study connotes major depression and dysthymia, since most clinical practice guidelines only address treatment of major depression (19). Each condition was defined with health administrative data from April 1, 2001 to April 1, 2010 (index date). Patients were excluded if they fell under the following criteria: had an invalid health card number, were younger than 65 or older than 105 years old, died before the index date (April 1, 2010), or had no contact with the health care system in the last 5 years before the index date.

The selected five chronic diseases were categorized into two groups by comorbidity type relative to diabetes (20), including: 1) diabetes-concordant conditions that share a common management plan (a) diabetes with comorbid hypertension and without chronic ischemic heart disease, and b) diabetes with comorbid hypertension and chronic ischemic heart disease), and 2) diabetes-discordant conditions that are not directly related in the disease management plan (a)diabetes with comorbid osteoarthritis and without major depression, and b) diabetes with osteoarthritis and major depression). These four disease combinations represented most prevalent clusters of concurrent conditions across multimorbidity groupings based on the prior research results (3).

Data sources

Data sources for this study included: the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) which consists of data on all hospital discharges in Ontario; the OHIP (Ontario Health Insurance Plan) claims database which contains information on patient contact with physicians in both ambulatory and hospital settings; the Registered Persons Database (RPDB) which contains information regarding the demographics of persons eligible for health care coverage in Ontario; the Client Agency Program Enrolment (CAPE) database which

identifies patients belonging to the primary care models; and the Ontario Drug Benefit (ODB) claims database which contains comprehensive records of prescription medications dispensed in outpatient pharmacies to Ontario residents eligible for public drug coverage, specifically those aged 65 and over. Canada census data were also used to derive population estimates by age and sex in each year. All databases were linked using unique, encoded identifiers and analyzed at the Institute of Clinical Evaluative Sciences (ICES) in Toronto, Ontario.

All provinces in Canada hold administrative data for the full population under a universal health care system that is similar to other health systems internationally including diagnoses and utilization from physician, hospital and pharmacy billing data.

The study received approval from the Sunnybrook Health Sciences Research Ethics Board and the University of Toronto (# 32497).

Study outcome

The study outcome was the likelihood of having at least one hospital admission in each year, during the study period, April 1, 2010 to March 3, 2014. This outcome measure had a value 1 (yes) if any study subject had at least one all-cause hospitalization in each year, and 0 (no) if not.

Process of care measures

This study uses process and outcome measures for diabetes with comorbidities. A specific set of process and outcome measures was developed by means of a Delphi panel (21) for assessing the quality of care for older adults with each particular disease combination in ambulatory care settings (Table 1). Delphi participants purposefully selected a list of indicators

in the context of assessing care of older adults with diabetes and specific comorbid chronic conditions.

Processes of care measures were calculated using the same data sources. The measures included: having 1 or 2 glycated hemoglobin (HbA1c) tests per year, having 3 or more HbA1c tests per year, annual eye examination, use of oral hypoglycemic drugs in each, use of angiotensin-converting-enzyme (ACE) inhibitors in each, use of angiotensin II receptor blockers (ARBs) in each, number of prescribed drugs in each year (22, 23), use of non-steroidal anti-inflammatory drugs (NSAIDs) in each year. There were also a series of "negative" indicators which related to contraindicated processes because they increase the risk of adverse outcomes. Theses included use of tetracyclic antidepressants in each year, use of monoamine oxidase (MAO) inhibitors in each year, use of gaba receptor agonists in each year, and use of benzodiazepines in each year. Continuity of care was measured use the Bice COC (Continuity of Care) index that measures both the dispersion and concentration of care among all providers seen, and can be adapted to capture aspects of the coordination of care by attributing referral visits back to the referring provider (24, 25). To align with the prior research in this population, we categorized COC index as having a high vs. low continuity or concentration of care using the median COC score for each selected disease combination, respectively (26-28).

Covariates

We included patient demographic and clinical factors that could confound the relationship between process of care measures and the study outcomes as covariates in all regression models, including: 1) age (coded as 65-74, 75-84, 85-94, 95 and over), 2) sex (coded

as male/female), 3) geographic location measured by the Rurality Index of Ontario (RIO) (≤40 = non-rural and >40 = rural) (29), 4) neighbourhood income quintile (ranging from Q1 = lowest income to Q5=highest income) (30), 5) level of multimorbidity (i.e., chronic disease burden) as the number of prevalent chronic conditions in addition to the five selected chronic conditions (3, 5), including heart failure, acute myocardial infarction, cardiac arrhythmia, stroke, COPD, asthma, cancer, renal disease, other mood disorders, dementia, psychiatric diseases other than mood disorders and dementia, rheumatoid arthritis, or osteoporosis (Appendix 1) - this was coded as zero, one, two, three, four, or five-plus, as well as 6) the duration of each condition of interest in the particular disease combinations, including diabetes, hypertension, chronic ischemic heart disease, major depression or osteoarthritis (in years). We also included health system factors including 7) patient's primary care model categorized into: a) non-capitated models where physicians largely operate on a fee-for-service basis, b) capitated rostered models, and c) capitated+, including family health teams and other rostered models with additional incentives for interdisciplinary care (31, 32), and 8) number of primary care visits, including office-based visits with a general practitioner or family physician.

Statistical analysis

All analyses were stratified by condition combinations (diabetes with each of hypertension, hypertension with ischemic heart disease, osteoarthritis and osteoarthritis and depression) for which quality indicators were established.

Participant characteristics were described using proportions, means (standard deviation (SD)), and medians (inter-quartile range (IQR)) where appropriate. Marginal logistic models using a generalized estimating equations approach (PROC GENMOD in SAS) were performed

to examine associations between the likelihood of hospitalisations during the follow-up period, from 2011-2014, based on the process of care measures in the year prior, among older adults with each particular disease combination, respectively. Generalized estimating equations were used to make inferences about the mean response in the population, to make inference about differences in quality of care between two groups of patients, to account for within-subject correlation among the repeated responses, to deal with different numbers of observations per patient, and to estimate model parameters, using the available information (33). Risk estimates are presented as adjusted odds ratios (AORs) and corresponding 95 % Confidence Intervals (CIs). All data analyses were performed with SAS package version 9.3 (SAS Institute, Cary, 145 North Carolina). The level of statistical significance was considered p less than 0.05.

Patient and Public Involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination of our research.

Results

Table 2 presents baseline characteristics of the study population. The cohort of older adults with diabetes with comorbid hypertension and without chronic ischemic heart disease included 273,592 patients, while the cohort with comorbid hypertension and chronic ischemic heart disease contained 141,947 patients. The cohort of older adults with diabetes with comorbid osteoarthritis and without depression included 255,214 patients, while the cohort of older adults with diabetes with comorbid osteoarthritis and major depression contained 2,444 individuals.

About 85% of diabetes patients were between 65 and 84 years, and over half were female. Women were more prevalent than men in the cohort of diabetes patients with comorbid osteoarthritis and depression. Nearly half of the people comorbid with hypertension (44.7%) and 76.6% of patients with comorbid osteoarthritis and depression were prescribed 11 or more medications. More than 25% of the latter group were classified as having 5 or more concurrent conditions amongst those measured in this study. The majority of older diabetes patients with comorbid conditions were living in lower income neighborhoods.

Table 3 presents the distribution of process measures and all-cause hospitalizations among older adults with four selected disease combinations. The proportion of patients who had 1 or 2 HbA1c tests per year or were prescribed oral hypoglycemic drugs was lower in diabetes patients with 2 comorbid conditions compared to those with 1 comorbid condition (both concordant and discordant); this decline was more significant in patients with comorbid osteoarthritis and major depression. The proportion of patients who had an annual eye examination performed was slightly higher in diabetes patients with two concordant comorbid conditions than that in diabetes patients with comorbid hypertension only. The median score of continuity of care was greater in older diabetes patients with concordant rather than discordant comorbid conditions (0.57 vs. 0.53 in patients with one concordant vs. discordant condition); however, it declined with additional comorbid conditions, especially in those with discordant conditions (0.36 in patients with comorbid osteoarthritis and major depression).

The proportion of patients who were prescribed ACE inhibitors and ARBs was higher in older adults with comorbid hypertension and chronic ischemic heart disease compared to those without ischemic heart disease. About 14% of older diabetes patients with comorbid osteoarthritis with and without major depression were prescribed tetracyclic antidepressants;

20% were prescribed NSAID therapy; 40% were prescribed benzodiazepines. The incidence of all-cause hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions.

Table 4 presents results of multivariable association of process of care indicators and all-cause hospitalizations among older adults with four selected disease combinations. Meeting HbA1c testing frequency goals, having an annual eye exam, or oral hypoglycemic drug therapy were significantly associated with reduction in the likelihood of all-cause hospitalizations in older people with diabetes comorbid with concordant (with comorbid hypertension with or without chronic ischemic heart disease) and diabetes patients with comorbid osteoarthritis only. In diabetes patients comorbid with osteoarthritis and depression, having an annual eye exam was significantly associated with reduction in the likelihood of all-cause hospitalizations. There was no association between use of ACE inhibitors or ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease.

Antiplatelet therapy was significantly associated with an increase in the likelihood of all-cause hospitalizations among older adults with comorbid hypertension and chronic ischemic heart disease. There was a very marginal though significant association between NSAID therapy and reduction in all-cause hospitalizations in older diabetes patients with comorbid osteoarthritis that was not significant when depression was also present. There was a significant association between use of benzodiazepines and increase in all-cause hospitalizations, while there was no association found between use of tetracyclic antidepressants and all-cause hospitalizations among patients with comorbid osteoarthritis and depression. The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older

people with diabetes with comorbid concordant and discordant conditions. The likelihood of all-cause hospitalizations increased by 6% with each additional filled prescription among older adults with comorbid concordant or discordant conditions.

Discussion

The study findings demonstrate that the quality of overall care declined in older adults with diabetes with each additional selected comorbid condition, and was especially low for those with comorbid osteoarthritis and major depression. Therefore, older patients with diabetes with comorbid osteoarthritis with or without major depression need more targeted interventions and collaboration between healthcare providers to improve quality of care and reduce hospitalization. These findings can help inform clinicians and policy makers in developing strategies for subpopulations at-risk. Previous research demonstrates that people with diabetes with 2 or more comorbid conditions were more likely to achieve the target HbA1c testing frequency or have annual eye examination compared to those with no or one comorbid condition (34). However, the authors used diabetes care measures to assess the role of number of concordant and discordant conditions on the achievement of diabetes testing goals without specifying individual concordant and discordant conditions, despite the fact that certain conditions may have a greater impact on diabetes care than other conditions. Another study demonstrates that as compared with diabetes patients without comorbidities, those with concordant comorbid conditions had an increased likelihood of receiving reviews of medications and blood pressure examinations, while discordant comorbidities do not compete with diabetes care (35).

The study findings support the underlying premise of the framework of Concordance and Discordance proposed by Piette and Kerr that hypothesizes that the effects of comorbidity on

patients with diabetes differ depending on the nature of comorbid conditions (20). The literature suggests that physicians may prioritize treatment of concordant conditions over discordant conditions, because a single treatment plan can improve the status of more than one condition (36). Blood pressure and cholesterol targets, increased physical activity, as well as the use of antihypertensive therapy are identical for patients with diabetes and cardiovascular conditions, including hypertension and ischemic heart disease (37). Thus, for the majority of patients, management of cardiovascular conditions enhances the management of diabetes.

The study findings suggest an association between greater continuity of care and reduction in all-cause hospitalizations in older people with diabetes with comorbid concordant and discordant conditions. This finding is consistent with other study results (38-40). Grunier and colleagues (26) found that the risk of hospitalizations was reduced in people with one or more chronic conditions, when visits and referrals are concentrated with a single physician.

We found that older diabetes patients with comorbidities, especially with discordant conditions, are likely to be prescribed a large number of drugs, and the more drugs they are prescribed the higher is the risk of hospitalizations. This study finding is consistent with previous research results (41, 42). The study results demonstrate that the mean number of prescribed drugs increased in older diabetes patients with 2 vs. 1 comorbid condition, especially in those with discordant conditions (17 vs. 12 prescriptions). There was no association observed between use of ACE inhibitors and ARB therapy and the likelihood of hospitalizations in patients with diabetes with comorbid hypertension and chronic ischemic heart disease. The information regarding the benefit of ACE inhibitors or ARBs on vascular protection among older adults with diabetes remains controversial in diabetes patients with comorbidities. The study findings suggest found a negligible association between NSAID therapy and reduction in all-cause

hospitalizations in patients with comorbid osteoarthritis that was not significant when depression was also present. Whilst the recent review of evidence from the Osteoarthritis Research Society International (OARSI) suggests that use of NSAID therapy for osteoarthritis management provides better efficacy than acetaminophen for relief of chronic inflammatory pain (43), this was not substantially related to all-cause hospitalizations

The incidence of hospitalizations markedly increased in older adults with diabetes with 2 vs. 1 selected comorbid condition, especially in those with discordant conditions (diabetes comorbid with osteoarthritis and depression). This study finding is consistent with previous research that found a higher rate of hospital admission among people with diabetes with discordant than concordant comorbid conditions, especially in those with mental conditions (44). A recent study indicated that there is a trend of increasing use of healthcare services, including hospitalizations, emergency department visits and physician visits, with increase in number of comorbid conditions among older adults with diabetes (24).

Strengths and limitations

Our study sheds light on limited research evidence regarding the assessment of the overall quality of care among older adults with diabetes comorbid with specific concordant/discordant comorbid conditions. The study cohort was drawn from the entire Ontario population with a diagnosis of diabetes aged 65 and older. Administrative data have the advantage of being population-based and are relatively inexpensive compared to the other potential sources of data for ambulatory care evaluation. We used validated algorithms to define chronic diagnoses. In our study, multiple databases were used to ascertain the cases, including hospital stay (DAD), physician visits (OHIP), and validated disease cohorts. The specific sets of process of care measures, as judged to be relevant by the Delphi Panel (21), were used for

assessing clinical aspects of ambulatory care among older adults with four selected disease combinations. The development of process of care measures integrated clinical expertise with scientific evidence form systematic research.

Nonetheless, the results of the study should be interpreted in light of the following limitations. The study measures identified by the Delphi Panel were purposively limited to those available in Ontario administrative data. This restricted measurement of important clinical factors such as disease severity, patient disability and frailty, the availability of social supports or caregivers and mobility or aids used to mitigate functional impairment. We lacked data related to laboratory tests done in hospitals or paid for privately. Ambulatory prescriptions and tests represent the majority of the care that patients receive over the course of their treatment out of hospital. Several quality measures not measurable in this study, such as blood glucose level control, life style changes, patient education, as well as patient preferences and goals of care and self-management ability, could reveal and explain important aspects of the associations between process of care measures and hospitalizations as reported here. There is a potential for misclassifying people based on their comorbidity profiles.

We were not able to account for severity of selected chronic conditions due to limitation of the administrative data that may lead to biased estimates. We focused on all-cause hospitalizations, without stratifying by reasons for hospitalization that could potentially inform interventions. The common chronic co-existing conditions that were selected for this study do not represent all existing comorbidities in patients with diabetes.

Conclusions

For an older diabetes patient with comorbidities the challenge is to find a way to encourage health care providers to manage all chronic conditions collectively instead of focusing

on a single disease treatment. This study highlighted the most prevalent multimoribdity clusters among older adults with diabetes, including both concordant and discordant comorbidities. Explicit consideration of multimorbidity clusters among older adults with diabetes is important because appropriate management of individual diseases in isolation may not be optimal for patients with multimorbidity due to unique disease-disease or disease-treatment interactions. Furthermore, determining specific multimorbidity subgroups among patients with diabetes at increased risk of adverse health outcomes has important policy implications and provides targets for tailored prevention.

Our study showed that the number of conditions was the strongest predictor of hospitalization but higher achievement on diabetes quality of care measures and physician continuity of care along with fewer prescribed medications were also protective with all-cause hospitalizations. These findings represent opportunities to improve ambulatory care that should lead to reductions in hospital use. Research should focus on the evaluation of quality of care for diabetes patients with comorbidities whilst developing more robust measurement of health outcomes beyond hospitalization.

Authors' contributions

All coauthors fulfill the criteria required for authorship. WPW was the lead for the creation of the cohort. YP and WPW substantially contributed to the conception, analysis, and interpretation of the data for the work and to the drafting of the work. JB, KK, and BL substantially contributed to the analysis and interpretation of the data for the work. YP drafted the manuscript. YP and WPW revised the drafting of the work critically for important intellectual content. All authors contributed to the final approval of the version to be published and are in agreement to be accountable for all aspects of the work and in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

No researcher or panel member involved in this study had any declared or otherwise known conflicts of interest.

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Data sharing statement

The data from this study are held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS.

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Table 1. Process of care measures

Measure	Concordant conditions		Discordant conditions	
	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Process measures				
*HbA1c testing	✓	✓	✓	✓
Eye examination	✓	✓	✓	✓
Use of oral hypoglycemic drugs	✓	✓	✓	✓
Use of angiotensin-converting enzyme (ACE) inhibitors	✓	✓		
Use of angiotensin II receptor blockers (ARBs)	✓	✓		
Us of antiplatelet drugs		✓		
Use of statins		✓		
Use of *NSAIDs-*** "negative" indicator			✓	✓
Use of tetracyclic antidepressant – "negative indicator"				✓
Use of monoamine oxidase inhibitors (MAO) – "negative indicator"				✓
Use of benzodiazepines – "negative indicator"				✓
Use of gaba receptor agonists – "negative indicator"				✓

*HbA1c=glycated hemoglobin
**NSAIDs=non-steroidal anti-inflammatory drugs
*** "Negative" indicators related to contraindicated processes because they increase the risk of adverse outcomes

Table 2. Baseline characteristics

Characteristic	Diabetes with comorbid hypertension	Diabetes with comorbid hypertension and chronic ischemic heart disease	Diabetes with comorbid osteoarthritis	Diabetes with comorbid osteoarthritis and major depression
Number of individuals	273,592	141,947	255,214	2,444
Age in years, mean (SD)	76.2 (7.18)	77.4 (7.12)	76.6 (7.24)	75.7 (7.12)
Age in groups, n (%)				
65 – 74	127,469 (46.6)	54,593 (38.4)	112,046 (43.9)	1,194 (48.9)
75 – 84	106,336 (38.9)	61.883 (43.6)	102,717 (40.2)	906 (37.1)
85 – 94	37,194 (13.6)	23,950 (16.9)	37,900 (14.9)	333 (13.6)
95+	2,593 (0.9)	1,521 (1.1)	2,551 (1.0)	11 (0.4)
Sex, n (%)				
Female	154,565 (56.5)	81,987 (57.8)	139,951 (54.8)	1,545 (63.2)
Male	119,027 (43.5)	59,960 (42.2)	115,263 (45.2)	899 (36.8)
Number of drugs, mean (SD)	10.6 (5.89)	13.4 (6.52)	12.1 (6.42)	17.1 (7.6)
Number of drugs, n (%)				
≤5 drugs	48,210 (17.6%)	10,924 (7.7%)	33,768 (13.2%)	136 (5.7%)
6-10 drugs	103,032 (37.7%)	39,583 (27.9%)	80,695 (31.6%)	433 (17.7%)
≥11 drugs	122,350 (44.7%)	91,440 (64.4%)	140,751 (55.2%)	1,875 (76.6%)
Income quintiles, n (%)				
Q1 lowest income	57,053 (21.7)	29,478 (22.0)	53,174 (21.6)	589 (26.1)
Q2	58,237 (22.1)	29,496 (22.0)	53,884 (22.0)	504 (22.3)
Q3	52,967 (20.1)	26,765 (20.0)	48,922 (20.0)	414 (18.4)
Q4	50,668 (19.2)	25,649 (19.1)	47,143 (19.3)	360 (15.0)
Q5 highest income	44,653 (16.9)	22,657 (16.9)	41,855 (17.1)	388 (17.2)
*RIO index, n (%)				
≤40 (urban)	214,443 (78.4)	131,065 (92.3)	237,312 (93.0)	2,293 (93.8)
>40 (rural)	59,149 (21.6)	10,882 (7.7)	17,.902 (7.0)	151 (6.2)
**Primary care models, n (%)				
Fee-for-service	140,465 (68.3)	120,557 (63.7)	128,522 (69.2)	1450 (67.8)
Capitated+	29,203 (14.2)	26,685 (14.1)	26,930 (14.5)	297 (13.9)
Capitated	35,990 (17.5)	42,015 (22.2)	30,273 (16.3)	391 (18.3)
Comorbidities, n (%)				
0 CC	59,149 (21.6)	15,859 (11.2)	12,061 (4.7%)	77 (3.1%)
1 CC	88,411 (32.3)	33,105 (23.3)	58,547 (22.9%)	335 (13.7%)
2 CC	64,965 (23.7)	34,350 (24.2)	67,635 (26.5%)	495 (20.3%)
3 CC	34,914 (12.8)	26,547 (18.7)	50,641 (19.8%)	490 (20.1%)
4 CC	16,382 (6.0)	16,972 (12.0)	32,778 (12.8%)	428 (17.5%)
5 or more CC	9,771 (3.6)	15,114 (10.7)	33,552 (13.3%)	619 (25.3%)
Number of primary care visits, mean (SD)	6.1 (5.77)	7.6 (6.99)	7.34 (6.60)	7.8 (7.4)
Duration of diabetes in years, mean (SD)	9.90 (5.80)	10.7 (6.02)	10.0 (5.88)	10.3 (6.01)

Duration of hypertension in years, mean (SD)	13.1 (5.65)	13.8 (5.44)	------	------
Duration of chronic ischemic heart disease, mean (SD)	------	7.13 (2.68)	------	-------
Duration of osteoarthritis in years, mean (SD)	------	-------	7.17 (2.57)	7.4 (2.61)
Duration of major depression, mean (SD)	-------	-------	-------	3.3 (1.62)

* Geographic location (≤40=non-rural; >40=rural).
**Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

Table 3. Distribution of process and outcome measures among adults with diabetes with comorbidities

Measure, n (%)	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
Process measures, n (%)				
Having 1 or 2 *HbA1c tests per year	124,336 (45.4)	61,505 (43.3)	114,746 (45.0)	964 (39.4)
Having 3 or more HbA1c tests per year	77,942 (28.5)	42,194 (29.7)	72,469 (28.4)	669 (27.9)
Annual eye examination	177,080 (64.7)	92,623 (65.3)	171,803 (67.3)	1,386 (56.7)
Use of oral hypoglycemic drugs	148,344 (54.2)	72,686 (51.2)	130,599 (51.2)	1,102 (45.1)
Use of **ACE inhibitors	110,641 (40.4)	69,296 (48.8)	-----	-----
Use of ***ARBs	62,169 (22.7)	32,997 (23.3)	-----	-----
Use of antiplatelet drugs	-----	34,868 (24.6)	-----	-----
Use of statins	-----	12,845 (79.5)	-----	-----
Use of ****NSAIDs– “negative”	-----	-----	52,952 (20.8)	452 (18.5)
Use of tetracyclic antidepressants– “negative”	-----	-----	-----	348 (14.2)
Use of benzodiazepines– “negative”	-----	-----	-----	860 (35.2)

Use of gaba receptor agonist– "negative"	-----	-----	-----	<6 (0.2)
Use of *****MAOIs– "negative"	-----	-----	-----	9 (0.4)
****** Continuity of care (COC) index				
Mean, (SD)	0.59 (0.28)	0.51 (0.27)	0.55 (0.26)	0.42 (0.26)
Median, (IQR)	0.57 (0.36-0.82)	0.49 (0.29-0.73)	0.53 (0.32-0.77)	0.36 (0.21-0.59)
Outcome measure, n (%)				
All-cause hospitalizations	45,520 (15.6)	35,157 (24.8)	49,873 (19.5)	536 (29.0)

*HbA1c- glycated hemoglobin
** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index

Table 4. Multivariable associations between process measures and the likelihood of all-cause hospitalizations among older adults with selected disease combinations

Characteristic	Diabetes with comorbid hypertension n=273,592	Diabetes with comorbid hypertension and chronic ischemic heart disease n=141,947	Diabetes with comorbid osteoarthritis n=255,214	Diabetes with comorbid osteoarthritis and major depression n=2,444
	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)	All-cause hospitalisations AOR (95% CI)
Having *HbA1c tests				
No	Ref.	Ref.	Ref.	Ref.
1 or 2 HbA1c tests	0.90 (0.88-0.92)	0.88 (0.85-0.91)	0.88 (0.86-0.90)	0.93 (0.76-1.13)
3 or more HbA1c tests	0.84 (0.82-0.86)	0.86 (0.83-0.88)	0.83 (0.81-0.85)	0.82 (0.69-1.03)
Annual eye examination				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.85 (0.84-0.87)	0.90 (0.88-0.92)	0.89 (0.87-0.91)	0.85 (0.75-0.97)
Use of oral hypoglycemic drugs				
No	Ref.	Ref.	Ref.	Ref.
Yes	0.88 (0.86-0.90)	0.88 (0.86-0.90)	0.92 (0.89-0.93)	0.93 (0.78-1.10)
Use of **ACE-inhibitors				
No	Ref.	Ref.	-----	-----
Yes	1.04 (0.99-1.06)	1.03 (0.98-1.05)	-----	-----

Use of ***ARBs				
No	Ref.	Ref.	-----	-----
Yes	0.93 (0.92-1.02)	0.98 (0.96-1.01)	-----	-----
Use of antiplatelet drugs				
No	------	Ref.	-----	-----
Yes	------	1.08 (1.06-1.11)	-----	-----
Use of statins				
No	------	Ref.	-----	-----
Yes	------	0.89 (0.86-0.92)	-----	------
Use of ****NSAIDs				
No	------	------	Ref.	Ref.
Yes	------	------	0.99 (0.97-0.99)	0.99 (0.88-1.12)
Use of tetracyclic antidepressants				
No	------	------	------	Ref.
Yes	------	------	------	1.14 (0.86-1.32)
Use of benzodiazepines				
No	------	------	------	Ref.
Yes	------	------	------	1.33 (1.20-1.48)
*******Continuity of Care index**				
COC≤ median value	Ref.	Ref.	Ref.	Ref.
COC>median value	0.70 (0.69-0.72)	0.74 (0.72-0.77)	0.73 (0.72-0.74)	0.84 (0.72-0.93)
Number of drugs	1.06 (1.04-1.07)	1.05 (1.02-1.07)	1.06 (1.04-1.08)	1.06 (1.05-1.07)
Age	1.04 (1.03-1.05)	1.03 (1.02-1.04)	1.03 (1.02-1.04)	1.02 (1.01-1.04)
Sex				
Female	Ref.	Ref.	Ref.	Ref.
Male	1.40 (1.36-1.44)	1.15 (1.12-1.18)	1.22 (1.20-1.24)	1.15 (0.97-1.23)
Income quintiles				
Q1 lowest income	Ref.	Ref.	Ref.	Ref.
Q2	0.93 (0.90-0.97)	0.99 (0.97-1.03)	1.02 (0.96-1.05)	1.02 (0.79-1.3)
Q3	0.95 (0.90-0.99)	1.03 (0.99-1.07)	0.97 (0.94-0.99)	0.99 (0.78-1.28)
Q4	0.89 (0.83-0.93)	1.05 (0.98-1.09)	0.97 (0.94-0.99)	1.03 (0.79-1.34)
Q5 highest income	0.87 (0.82-0.92)	1.04 (0.95-1.07)	1.48 (1.40-1.56)	1.05 (0.82-1.35)
********RIO index**				
≤40	Ref.	Ref.	Ref.	Ref.
>40	1.14 (1.09-1.19)	1.16 (1.12-1.20)		1.27 (0.95-1.57)
Duration of diabetes	1.03 (1.01-1.05)	1.02 (1.01-1.03)	1.19 (1.16-1.24)	1.01 (0.99-1.02)
Duration of hypertension	1.02 (1.01-1.03)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	-------
Duration of ischemic heart disease	-----	1.01 (1.00-1.02)	------	-------
Duration of osteoarthritis	-----	-----	0.99 (0.97-1.01)	0.92 (0.97-1.03)

Duration of depression	-----	-----	------	0.95 (0.89-1.01)
Number of primary care visits	1.02 (1.0-1.04)	1.01 (1.00-1.03)	1.02 (1.01-1.03)	1.02 (1.01-1.03)
*******Primary care models**				
Capitated+	Ref.	Ref.	Ref.	Ref.
Fee-for-service	0.77 (0.76-0.79)	0.78 (0.76-0.80)	0.77 (0.76-0.78)	0.83 (0.68-1.02)
Capitated	1.09 (1.02-1.13)	1.08 (0.99-1.13)	1.04 (1.02-1.06)	0.97 (0.51-1.89)
Comorbidities				
0 CC	Ref.	Ref.	Ref.	Ref.
1 CC	1.17 (1.13-1.22)	1.21 (1.16-1.27)	1.10 (1.04-1.15)	0.81 (0.62-1.02)
2 CC	1.37 (1.33-1.40)	1.43 (1.37-1.48)	1.26 (1.19-1.32)	1.05 (0.68-1.21)
3 CC	1.65 (1.58-1.70)	1.69 (1.61-1.75)	1.48 (1.40-1.56)	1.27 (0.71-1.81)
4 CC	2.00 (1.89-2.12)	1.98 (1.89-2.09)	1.77 (1.68-1.86)	1.39 (0.82-1.98)
5 or more CC	2.32 (2.16-2.44)	2.27 (2.15-2.35)	2.12 (1.60-1.46)	1.55 (0.97-2.23)

*HbA1c- glycated hemoglobin
** ACE inhibitors – angiotensin-converting enzyme inhibitors
***ARBs- angiotensin II receptor blockers
****MAO inhibitors - monoamine oxidase inhibitors
***** NSAID- non-steroidal anti-inflammatory drugs
****** Calculated using the Bice index
******* Geographic location (≤40=non-rural; >40=rural).
******** Noncapitated models include nonrostered models and those that operate on a fee-for-service basis; capitated models include family health networks and family health organizations operating on a capitation funding scheme; and the capitated+ models include family health teams and other rostered models operating on a capitated funding scheme with additional incentives for interdisciplinary care.

S1 Appendix. Comorbid chronic conditions

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Condition	ICD 9 / OHIP	ICD 10
Rheumatoid arthritis	714	M05-M06
Osteoporosis	733	M81 M82
Other mood disorders	300, 309	F38—F42, F431, F432, F438, F44, F450, F451, F452, F48, F530, F680, F930, F99
Psychiatric conditions other than mood disorders and dementia	291 292 295 297 298 299 301 302 303 304 305 306 307 313 314 315 319	F04 F050 F058 F059 F060 F061 F062 F063 F064 F07 F08 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F340 F35 F36 F37 F430 F439 F453 F454 F458 F46 F47 F49 F50 F51 F52 F531 F538 F539 F54 F55 F56 F57 F58 F59 F60 F61 F62 F63 F64 F65 F66 F67 F681 F688 F69 F70 F71 F72 F73 F74 F75 F76 F77 F78 F79 F80 F81 F82 F83 F84 F85 F86 F87 F88 F89 F90 F91 F92 F931 F932 F933 F938 F939 F94 F95 F96 F97 F98
Dementia	290, 331 (OHIP) / (DAD: 046.1, 290, 294, 331.0, 331.1, 331.5, 331.82)	F00, F01, F02, F03, G30 ODB subclnam =: 'CHOLINESTERASE INHIBITOR'
Renal failure	403,404,584,585,586,v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Asthma	493	J45
Cancer	140-239 (broad algorithm from ICD table)	C00-C26, C30-C44, C45-C97
Cardiac Arrythmia	427.3 (DAD) / 427 (OHIP)	I48.0, I48.1
CHF	428	I500, I501, I509
COPD	491, 492, 496	J41-J44
Stroke	430, 431, 432, 434, 436	I60-I64

Research checklist

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
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	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-8
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	8-9
		(*c*) Explain how missing data were addressed	8-9
		(*d*) If applicable, explain how loss to follow-up was addressed	8-9
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	9
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	10-11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
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	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
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	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.