CLINICAL

# Multiple Chronic Conditions in Type 2 Diabetes Mellitus: Prevalence and Consequences

Pei-Jung Lin, PhD; David M. Kent, MD, MSc; Aaron N. Winn, MPP; Joshua T. Cohen, PhD; and Peter J. Neumann, ScD


## ABSTRACT

### Objectives

Multiple chronic comorbidities (MCCs) are an issue of growing significance in diabetes because they are highly prevalent and can increase disease burden and costs. We examined MCC patterns among patients with type 2 diabetes mellitus and identified specific comorbidity clusters associated with poor patient outcomes.

### Study Design and Methods

We conducted a cross-sectional analysis of 161,174 patients with diabetes using electronic health record data supplied by US providers in the 2008 to 2012 Humedica data sets. We examined prevalence of MCC clusters in younger and older patients. For each of the 15 most common MCC clusters, we reported predicted probabilities for diabetes face-to-face visits, reaching glycated hemoglobin <8%; emergency department (ED) visits; and 30-day hospital readmissions, based on logistic regression results.

### Results

The leading MCC combination was the presence of hypertension-hyperlipidemia-obesity and no other diagnosed comorbidities (19% of the sample). The most notable difference, by age, was a higher prevalence of obesity in the younger cohort. MCC clusters were more diverse among the older population: the top 10 MCC clusters accounted for 66% of older patients, compared with 78% of younger patients. Patients with certain comorbidity profiles, such as those with obesity only, were less likely to have diabetes-related face-to-face visits and to meet A1C treatment goals, and more likely to have ED visits and 30-day readmissions.

### Conclusions

Patients with diabetes have substantial comorbidities, but the patterns vary considerably across patients and by age. Diabetes care remained suboptimal among many types of MCC patients, and patient outcomes varied by MCC profile. Specific management strategies should be developed for common MCC clusters, such as hypertension-hyperlipidemia-obesity.


*Am J Manag Care. 2015;21(1):e23-e34*

Most adults with diabetes have at least 1 coexisting chronic condition,[1] and approximately 40% have 3 or more.[2] As the number of comorbidities increases, the risks of poor patient outcomes (eg, unnecessary hospitalizations, adverse drug events, mortality) and healthcare costs also increase.[2-6] Further, the types of comorbidities impact diabetes care.[7,8] In a retrospective cohort study of 42,826 veterans with new-onset diabetes, individuals with "concordant conditions" (illnesses that overlap with diabetes in their pathogenesis or management plans; eg, hypertension and coronary artery disease) were more likely to receive recommended diabetes care, including glycated hemoglobin (A1C) testing, low-density lipoprotein cholesterol (LDL-C) testing, and diabetes-related visits, compared with individuals with no concordant comorbidities.[9] In contrast, "discordant conditions" (illness with unrelated pathogenesis or management plans [eg, musculoskeletal diseases]) were associated with decreased diabetes care.[9]



Although previous studies have shown that the type and severity of comorbidities matter, not just the number of conditions,[7-13] less attention has been paid to multiple chronic comorbidities (MCCs) and how they impact diabetes care. Patients with MCCs constitute a majority of the diabetes population, and are known to require high levels of healthcare and to account for a significant proportion of healthcare costs.[2,14-16] However, it is unclear which MCC clusters in diabetes are most prevalent, or how MCC patterns vary by age.

To address these gaps, this study sought to identify specific MCC combinations associated with high morbidity. Unlike previous research that focused on 2-way[17,18] or 3-way[19] combinations between and among comorbidities, this is the first study to our knowledge to examine a large number of the most common MCC combinations for diabetes and to compare these clusters in younger and older patients. Additionally, most diabetes outcomes research that considered MCCs focused on the impact on disease-specific measures (eg, A1C,

cholesterol, blood pressure [BP]), but ignored how MCCs affect broader health outcomes. This study identified specific comorbidity profiles associated with emergency department (ED) visits and 30-day hospital readmissions in addition to diabetes-specific outcomes.

This fresh look at comorbidities is important for 2 reasons. First, MCC outcomes exhibit substantial heterogeneity. Focusing on a limited set of "pairs" (or "triplets") misses many combinations, including those consisting of more than 3 conditions. Second, to date, disease-focused guidelines (including those for diabetes) tend to underplay MCCs, and more importantly, do not describe how comorbidities may affect treatment plans and patient outcomes.[15,19-21] Our analysis of mutually exclusive clusters may suggest a more useful set of patient subgroup definitions for use in clinical guidelines.

## METHODS

### Data and Sample

We used the 2008 to 2012 data sets from the healthcare informatics company Optum Humedica (www.humedica.com), which link de-identified electronic health records (EHRs), encounter files, prescribed medications, and lab values to provide clinical details typically not available in administrative claims files. These data files were supplied by US providers, including ambulatory groups, hospital systems, and integrated delivery networks (IDNs). Information for services acquired from outside of Humedica's provider networks was not available.

From the 2008 to 2012 Humedica data sets (n = 7,247,143), we retained "integrated patients" (n = 4,025,581), defined as those with both ambulatory and institutional data available from IDN providers (**Figure 1**). After excluding individuals younger than 18 years (n = 655,638), we identified 398,377 subjects with any evidence of diabetes, including: type 1 (n = 12,778), type 2 (n = 212,160), prediabetes (*International Classification of Diseases, Ninth Revision, Clinical Modification* [*ICD-9-CM*] = 790.2X for "abnormal glucose"; n = 60,563), other diabetes (eg, gestational diabetes and secondary diabetes, n = 7249), and individuals with an unknown diabetes type (n = 105,627). Unknown type was defined as subjects who had lab evidence of diabetes or received medications for diabetes, but no diabetes diagnosis or abnormal glucose diagnosis.

Our analysis focused on patients with type 2 diabetes mellitus (T2DM) and therefore excluded individuals with type 1, prediabetes, and other diabetes. We classified subjects as having T2DM if they had any *ICD-9-CM* diagnosis codes of 250.X0 or 250.X2 on their ambulatory evaluation and management and/or procedure encounters (n = 212,160). Patients without a last visit at least 2 years apart from their first visit were excluded (n = 50,986). Finally, our analytic sample included 161,174 patients with T2DM with at least 24 months of data available to ensure that they maintained contact with the provider networks. In sensitivity analyses, we included patients with less than 24 months of data and patients with an unknown type of diabetes to examine the robustness of our results.

### Comorbidities of Interest

We derived a list of comorbidities of interest by reviewing previous studies[8,18,22,23] and the 2012 American Diabetes Association (ADA) guidelines,[24] and identified the following conditions that have been determined to be important—clinically or economically—for adults with T2DM: hyperlipidemia, hypertension, obesity, depression, chronic obstructive pulmonary disease (COPD)/asthma, coronary artery disease (CAD), chronic kidney disease (CKD), arthritis, cancers, neuropathy, heart failure, fractures, peripheral arterial disease, and retinopathy. We identified individuals with these conditions by using the Clinical Classifications Software, a tool developed at the Agency for Healthcare Research and Quality for clustering *ICD-9-CM* diagnosis codes of conditions into clinically meaningful categories.[19,25]

We also used prescription records, lab values, and vital signs data to identify certain comorbidities in order to minimize potential underdiagnosis and undercoding. Specifically, individuals were classified as having hypertension if they had 2 or more BP readings on different days in which their diastolic BP reading was over 80, if their systolic BP was over 130 during the study period, or if they received any antihypertensive medications (see **eAppendix** [available at **www.ajmc.com**] for list of drugs). Individuals were classified as having hyperlipidemia if they had 2 or more readings on different days in which their total cholesterol levels were over 200, LDL-C levels were over 130, triglyceride levels were over 150, or high-density lipoprotein cholesterol levels were under 60; or if they received any lipid-lowering medications (eAppendix). Finally, individuals were classified as obese if they had at least 1 obesity diagnosis (*ICD-9-CM* = 278.XX) or had a body mass index of ≥30 kg/m$^2$.[24]

### Patient Outcome Measures

We assessed 2 guideline-recommended diabetes care measures and 2 broader health outcomes. Diabetes care

measures included a diabetes-related face-to-face visit at least once every 6 months and the attainment of A1C <8%—the treatment goal. These measures were chosen based on the 2012 ADA guidelines[24] and the Diabetes Quality Improvement Project.[9,26] We used each patient's last A1C test results in primary analysis and each patient's average A1C values in sensitivity analysis. The analysis of A1C was limited to a subset of 135,357 diabetes patients with available glucose data (84% of the overall sample). For broader health outcomes, we assessed all-cause ED visits and all-cause 30-day hospital readmissions during a year because these measures may signal poor patient outcomes. Readmissions were defined as inpatient hospital admissions that occurred within 30 days of discharge from a previous hospital admission. The analysis of 30-day readmissions was limited to a subset of 21,765 patients with at least 1 admission to the hospital (13.5% of the sample).

### Statistical Analysis

We constructed a 2-year panel of 161,174 adults with T2DM, examined their comorbidity profiles and patient characteristics at the baseline year, and analyzed the 4 patient outcomes at the subsequent year. First, we examined the prevalence rate of each comorbid condition by itself and used *t* tests to compare the prevalence between patients aged <65 years and patients aged ≥65 years. Second, for analysis of MCCs, we limited our attention to the most prevalent comorbidities that affected ≥5% of the sample; these were hyperlipidemia, hypertension, obesity, CAD, COPD/asthma, CKD, arthritis, depression, cancers, and heart failure. Each MCC cluster was mutually exclusive. We analyzed the frequency and clustering of MCCs, and used $\chi^2$ tests to compare overall difference in MCC prevalence rates among older and younger patients.

Using logistic regression, we examined associations between MCC clusters and the 4 binary patient outcomes: at least 1 diabetes face-to-face visit every 6 months, A1C <8%, any ED visits, and any 30-day hospital readmissions. We included binary indicators for each of the top 15 most common MCC clusters, and classified the rest of the comorbidity combinations as "other" in our regression models. We started with a parsimonious model, adjusting for age, sex, race, neighborhood income, and insurance status. The fully adjusted model incorporated 3 additional covariates: Diabetes Complications Severity Index,[27] number of evaluation and management visits, and number of medications prescribed to the patient (measured as unique classes of drugs). Finally, we used the model to estimate probabilities for each patient outcome.

## RESULTS

The **Table** summarizes the characteristics of our sample. Eighty-eight percent of the patients with diabetes had at least 1 of the 14 comorbidities of interest, while 51% had 3 or more. Compared with younger adults, older adults had more comorbidities (mean = 2.3 vs 2.7, $P$ <.001) and were more likely to have hyperlipidemia, hypertension, CAD, COPD/asthma, CKD, arthritis, cancer, and heart failure, and less likely to have obesity and depression.

### Patterns of MCCs

**Figure 2** displays the 15 most common MCC clusters, representing 75% of patients in our sample. The most common pattern was the presence of hypertension, hyperlipidemia, and obesity—roughly 1 in 5 patients (19%) had this combination. Five of the 6 most common clusters, corresponding to 51% of the sample, included some combination of hypertension, hyperlipidemia, and obesity. CAD plus hypertension and hyperlipidemia, either with or without obesity, was also common (5%). Other common clusters included the combination of hypertension-hyperlipidemia-obesity plus 1 other condition, such as COPD/asthma, arthritis, or depression.

MCCs were highly prevalent in both nonelderly and elderly patients with diabetes (Figure 2). The most common MCC clusters for both groups included hypertension, hyperlipidemia, and obesity in combination or in isolation. On the other hand, MCC clusters including obesity were far more common among younger adults: among subjects aged <65 years, the leading MCC cluster was hypertension-hyperlipidemia-obesity (23%), whereas among subjects aged ≥65 years, the most common cluster was hypertension and hyperlipidemia only (20%). Further, obesity alone was the fourth-most common MCC cluster among younger patients, whereas this cluster was seventh-most common among older patients. The higher prevalence of obesity among younger patients may reflect the fact that it is an essential risk factor for early onset T2DM.[28] In addition, older patients exhibited greater MCC cluster heterogeneity: the top 10 MCC clusters accounted for 66% of older patients, compared with 78% of younger patients. Finally, 14% of younger patients had no diagnosed comorbidities, compared with 11% of older patients ($P$ <.001).

### Association Between MCCs and Diabetes Care

Figure 3 shows the predicted probabilities for receiving recommended diabetes care based on the fully adjusted logistic regression models. Predicted diabetes visit probabilities ranged from 18% to 52% among the 15 most common MCC clusters, and exceeded 50% for only 5 clusters: hypertension-hyperlipidemia-obesity only (52%), hypertension-hyperlipidemia-obesity plus depression (51%), arthritis (51%), CKD (51%), and hypertension-hyperlipidemia only (50%). Notably, subjects with no documented comorbidities (18%) and patients with only obesity (24%) were less likely to have a diabetes visit.

Predicted probabilities for achieving the A1C treatment goal ranged from 54% to 76% among the 15 most common MCC clusters and were most likely among patients with co-existing hypertension-hyperlipidemia plus either COPD/asthma (76%), CAD (75%), obesity and COPD/asthma (75%), or obesity and arthritis (75%) (Figure 2). Subjects with no documented comorbidities (54%) and subjects with obesity only (60%) were less likely to meet the A1C goal. Sensitivity analysis using each patient's average A1C values instead of the patient's last A1C test showed similar patterns (results not shown).

### Association Between MCCs and ED Visits and 30-Day Hospital Readmissions

Overall, 18.2% of the diabetes sample had at least 1 ED visit. Adjusted probabilities for ED visits ranged from 13% to 22% in the top 15 MCC clusters (Figure 4). Patients with only obesity were most likely to have ED visits (22%), followed by subjects with no comorbidities (20%). Patients with hypertension-hyperlipidemia only (13%) and hypertension-hyperlipidemia plus obesity and CKD (13%) were less likely to have ED visits.

Among the 21,765 hospitalized patients, 14.5% were readmitted within 30 days of discharge. Adjusted probabilities for readmissions were lower than probabilities for ED visits, ranging from 9% to 15% among the top 15 MCC clusters (Figure 4). Subjects with only obesity (15%) and those with no recorded comorbidities (15%) were more likely to have readmissions, as were patients with hypertension-hyperlipidemia-cancer (15%). Patients with hypertension-hyperlipidemia plus obesity and CAD were less likely to have readmissions (9%).

## DISCUSSION

Our analysis of MCCs showed that 1 in 5 patients with T2DM had the combination of hypertension-hyperlipidemia-obesity and no other diagnosed comorbidities. The top 10 MCC clusters accounted for roughly 70% of all patients with T2DM. However, MCC cluster patterns exhibit substantial heterogeneity across patients and by age. Older patients more frequently had hypertension and hyperlipidemia only, whereas younger patients had hypertension and hyperlipidemia plus obesity, or had obesity and no other conditions. We also found greater MCC cluster heterogeneity among older diabetes patients, reflecting the more complex health needs of this group. In addition, patients with certain comorbidity profiles, such as those with obesity only, had poorer diabetes outcomes and more ED visits and 30-day readmissions.

MCCs are an issue of growing significance not only because of their prevalence, but because they can complicate treatment and increase disease burden and costs.[15,21,29,30] Previous studies have suggested aggressive multifactorial management of hypertension-hyperlipidemia-obesity (commonly referred to as metabolic syndrome[31,32]) in diabetes[33,34]—the leading MCC combination in our data—but less attention has been paid to other comorbidity clusters. In applying the Piette and Kerr framework for understanding the impact of comorbidity on patients with diabetes,[8] we found that diabetes-concordant comorbidities (eg, hypertension, hyperlipidemia, obesity, CAD) co-occurred more frequently than discordant (eg, COPD/asthma, arthritis) or dominant (eg, cancer) conditions. Our findings suggest that diabetes guidelines should explicitly address the co-occurrence of multiple concordant comorbidities and the co-occurrence of concordant and discordant/dominant conditions. Explicit consideration of MCC clusters is important because appropriate management of individual diseases in isolation may not be optimal for patients with MCCs.[21,29]

It should be noted that examining distinct MCC combinations as we have done is only feasible using very large data sets. Even the consideration of 14 comorbid conditions defined more than 16,000 subgroups ($2^{14}$). As a result, many of the most common clusters comprised <1% of the overall population, and many patients had completely unique MCC combinations. While combinations may have unique disease-disease, disease-treatment, and treatment-treatment interactions, the vast combinatorics suggest the need for frameworks and strong hypotheses regarding the most relevant interactions to help reduce the dimensionality of analyses addressing challenges with managing MCCs.[35]

Previous studies showed that certain comorbidities were associated with poor diabetes outcomes (eg, A1C

control[9]) and lower self-management abilities.[7] Our study further demonstrated that diabetes care outcomes remained suboptimal among many types of MCC patients. For example, probabilities for having diabetes-related visits ranged from 18% to 52%, and probabilities for meeting the treatment goal for A1C ranged from 54% to 76% (depending on the MCC cluster).

We also found that many patients with diabetes had ED visits and 30-day readmissions. "Ballpark" estimates suggest that reducing ED visits and 30-day readmissions in the diabetes population could yield substantial savings nationally.[36] To illustrate, costs average $2168 per ED visit[37] and $9700 per hospital stay,[38] and nationwide there are roughly 26 million adults with T2DM. Applying the 18.2% ED admission rate for our sample and assuming only 1 ED visit per person per year yields a national cost of roughly $10 billion annually. Similarly, the total cost of 30-day readmissions is roughly $5 billion based on our sample's 14.5% readmission rate among hospitalized patients.

In contrast with previous studies reporting that patients with diabetes with more comorbidities had poorer outcomes,[3-7] our analysis showed that subjects with obesity alone and individuals with no documented comorbidities performed more poorly across the 4 outcomes we examined. Several factors may contribute to these findings. First, our results may reflect the fact that many patients with diabetes had undiagnosed comorbidities.[24,39] In fact, among patients in our sample without any documented comorbidities in the baseline year, 27.7% had at least 1 recorded comorbidity during the follow-up year. Such underlying conditions could lead to poor patient outcomes such as uncontrolled chronic illnesses,[40] which could trigger more hospital use.

Second, it is possible that patients sought care from out-of-network providers and thus their healthcare utilization records were not fully captured in the Humedica data sets. We found that patients who did not have A1C values in their records were more likely to have other clinical values missing, were less likely to have any diagnosed comorbidities, and had fewer evaluation and management visits, compared with patients with an A1C value recorded. Third, patients with more diagnosed comorbidities may have more frequent contact with their physicians, which may lead to stronger provider-patient relationships, and thus higher adherence to treatment plans and better follow-up.[10,41] Indeed, certain comorbidities have been found to be associated with more resource utilization and better diabetes care.[9,10,18,42] Additionally, providers may be more likely to treat comorbidities in complex patients to reduce adverse outcomes, such as enrolling them in disease management programs that aim to improve overall health.[10]

### Limitations

Our analysis has several limitations. First, we may have underestimated MCC prevalence rates and care outcomes due to unavailable out-of-network utilization data. Second, patients with <24 months of data were excluded (n = 50,986); however, sensitivity analysis including such patients suggested similar results. Third, T2DM and comorbidities may have been under-identified due to coding and practice differences within and across providers that submit data to Humedica. Nevertheless, sensitivity analysis suggested that including the 105,627 patients with an unknown type of diabetes yielded similar results. For comorbidities, we attempted to capture a broader comorbidity profile by utilizing *ICD-9-CM* diagnosis codes, lab data, and prescription records. Future validation study will be helpful in determining if patients classified as having "no comorbidities" in fact have any undiagnosed conditions, and whether they have more access barriers. Fourth, although the Humedica data sets contain detailed utilization and EHR data, they do not contain cost information. Future research should identify the most expensive MCC clusters in order to better target high-cost patients for disease management. Finally, future research into areas related to comorbidity management, such as medication adherence, would help explain why certain MCC clusters are associated with poorer patient outcomes and would highlight areas for quality improvement.

## CONCLUSIONS

Despite these limitations, the current study extended prior work by using considerably more detailed and extensive information about MCCs in T2DM patients. Our findings highlighted important comorbidity clusters, such as co-existing hypertension-hyperlipidemia-obesity, that need to be addressed by diabetes guidelines and disease management programs. Our analysis also showed that many types of MCC patients had poor diabetes outcomes as well as excess ED visits and 30-day hospital readmissions. Determining specific MCC subgroups at increased risk of universal, rather than solely diabetes-specific, outcomes has important policy implications and provides targets for tailored prevention. In addition to improving clinical decisions, such information can be used to refine diabetes risk adjustment measures.[3,43] The

results can help guide payment reforms and improve cost prediction for diabetes patients with MCCs.

*Acknowledgments*

The authors thank Joseph Smith, Michael O'Grady, Paul Bleicher, Allen Kamer, Diane Throop, and Angela Tucker for helpful comments on earlier drafts of this paper.

***Author Affiliations:*** Center for the Evaluation of Value and Risk in Health (P-JL, ANW, JTC, PJN) and Predictive Analytics and Comparative Effectiveness Center (DMK), Institute for Clinical Research and Health Policy Studies, Tufts Medical Center, Boston, MA; Department of Health Policy and Management, Gillings School of Global Public Health, University of North Carolina at Chapel Hill (ANW), Chapel Hill, NC.

***Source of Funding:*** Funding of this research was provided by the West Health Institute, La Jolla, CA.

***Author Disclosures:*** Dr Neumann is a member of the board for Merck, Takeda, Genentech, Novartis, Bayer, Sanofi, and UCB; he is also a consultant for Boston Health Economics. Drs Lin, Kent, and Cohen, and Mr. Winn do not have any conflicts of interest to report.

***Authorship Information:*** Concept and design (JTC, P-JL, DMK, ANW, PJN); acquisition of data (P-JL, PJN); analysis and interpretation of data (P-JL, DMK, ANW, JTC); drafting of the manuscript (P-JL, JTC, ANW, PJN); critical revision of the manuscript for important intellectual content (P-JL, DMK, ANW, JTC); statistical analysis (P-JL, DMK, ANW); administrative, technical, or logistic support (P-JL, JTC); and supervision (P-JL, JTC, DMK).

***Address correspondence to:*** Pei-Jung Lin, PhD, Assistant Professor, Center for the Evaluation of Value and Risk in Health, Institute for Clinical Research and Health Policy Studies, Tufts Medical Center, 800 Washington St, Box 63, Boston, MA 02111. E-mail: plin@tuftsmedicalcenter.org.

## REFERENCES

1. Druss BG, Marcus SC, Olfson M, Tanielian T, Elinson L, Pincus HA. Comparing the national economic burden of five chronic conditions. *Health Aff (Millwood).* 2001;20(6):233-241.

2. Wolff JL, Starfield B, Anderson G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. *Arch Intern Med.* 2002;162(20):2269-2276.

3. Gilmer TP, O'Connor PJ, Rush WA, et al. Predictors of health care costs in adults with diabetes. *Diabetes Care.* 2005;28(1):59-64.

4. Niefeld MR, Braunstein JB, Wu AW, Saudek CD, Weller WE, Anderson GF. Preventable hospitalization among elderly Medicare beneficiaries with Type 2 diabetes. *Diabetes Care.* 2003;26(5):1344-1349.

5. Struijs JN, Baan CA, Schellevis FG, Westert GP, van den Bos GA. Comorbidity in patients with diabetes mellitus: impact on medical health care utilization. *BMC Health Serv Res.* 2006;6:84.

6. Vogeli C, Shields AE, Lee TA, et al. Multiple chronic conditions: prevalence, health consequences, and implications for quality, care management, and costs. *J Gen Intern Med.* 2007;22(Suppl 3):391-395.

7. Kerr EA, Heisler M, Krein SL, et al. Beyond comorbidity counts: how do comorbidity type and severity influence diabetes patients' treatment priorities and self-management? *J Gen Intern Med.* 2007;22(12):1635-1640.

8. Piette JD, Kerr EA. The impact of comorbid chronic conditions on diabetes care. *Diabetes Care.* 2006;29(3):725-731.

9. Pentakota SR, Rajan M, Fincke BG, et al. Does diabetes care differ by type of chronic comorbidity? an evaluation of the Piette and Kerr framework. *Diabetes Care.* 2012;35(6):1285-1292.

10. Woodard LD, Urech T, Landrum CR, Wang D, Petersen LA. Impact of comorbidity type on measures of quality for diabetes care. *Med Care.* 2011;49(6):605-610.

11. Krein SL, Heisler M, Piette JD, Makki F, Kerr EA. The effect of chronic pain on diabetes patients' self-management. *Diabetes Care.* 2005;28(1):65-70.

12. Ciechanowski PS, Katon WJ, Russo JE. Depression and diabetes: impact of depressive symptoms on adherence, function, and costs. *Arch Intern Med.* 2000;160(21):3278-3285.

13. Davydow DS, Katon WJ, Lin EH, et al. Depression and risk of hospitalizations for ambulatory care-sensitive conditions in patients with diabetes. *J Gen Intern Med.* 2013;28(7):921-929.

14. Chronic Conditions Among Medicare Beneficiaries, Chartbook. Baltimore, MD: CMS; 2011.

15. US Department of Health and Human Services. *Multiple Chronic Conditions: A Strategic Framework—Optimum Health and Quality of Life for Individuals with Multiple Chronic Conditions.* Washington, DC: HHS; 2010.

16. Lochner KA, Cox CS. Prevalence of multiple chronic conditions among Medicare beneficiaries, United States, 2010. *Prev Chronic Dis.* 2013;10:E61.

17. Tinetti ME, McAvay GJ, Chang SS, et al. Contribution of multiple chronic conditions to universal health outcomes. *J Am Geriatr Soc.* 2011;59(9):1686-1691.

18. Teljeur C, Smith SM, Paul G, Kelly A, O'Dowd T. Multimorbidity in a cohort of patients with type 2 diabetes. *Eur J Gen Pract.* 2013;19(1):17-22.

19. Steinman MA, Lee SJ, John Boscardin W, et al. Patterns of multimorbidity in elderly veterans. *J Am Geriatr Soc.* 2012;60(10):1872-1880.

20. Barnett K, Mercer SW, Norbury M, Watt G, Wyke S, Guthrie B. Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. *Lancet.* 2012;380(9836):37-43.

21. Boyd CM, Darer J, Boult C, Fried LP, Boult L, Wu AW. Clinical practice guidelines and quality of care for older patients with multiple comorbid diseases: implications for pay for performance. *JAMA.* 2005;294(6):716-724.

22. Suh DC, Choi IS, Plauschinat C, Kwon J, Baron M. Impact of comorbid conditions and race/ethnicity on glycemic control among the US population with type 2 diabetes, 1988-1994 to 1999-2004. *J Diabetes Complications.* 2012;24(6):382-391.

23. Li R, Bilik D, Brown MB, et al. Medical costs associated with type 2 diabetes complications and comorbidities. *Am J Manag Care.* 2013;19(5):421-430.

24. American Diabetes Association. Standards of medical care in diabetes--2012. *Diabetes Care.* 2012;35(Suppl 1):S11-S63.

25. Clinical Classifications Software (CCS) for *ICD-9-CM.* Healthcare Cost and Utilization Project website. http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp. Updated November 17, 2014. Accessed January 20, 2015.

26. Fleming BB, Greenfield S, Engelgau MM, Pogach LM, Clauser SB, Parrott MA. The Diabetes Quality Improvement Project: moving science into health policy to gain an edge on the diabetes epidemic. *Diabetes Care.* 2001;24(10):1815-1820.

27. Young BA, Lin E, Von Korff M, et al. Diabetes complications severity index and risk of mortality, hospitalization, and healthcare utilization. *Am J Manag Care.* 2008;14(1):15-23.

28. The NS, Richardson AS, Gordon-Larsen P. Timing and duration of obesity in relation to diabetes: findings from an ethnically diverse, nationally representative sample. *Diabetes Care.* 2013;36(4):865-872.

29. Tinetti ME, Fried TR, Boyd CM. Designing health care for the most common chronic condition–multimorbidity. *JAMA.* 2012;307(23):2493-2494.

30. Anderson G. Chronic Care: Making the Case for Ongoing Care. Princeton, NJ: Robert Wood Johnson Foundation; 2010.

31. Ford ES. Prevalence of the metabolic syndrome defined by the International Diabetes Federation among adults in the U.S. *Diabetes Care.* 2005;28(11):2745-2749.

32. Riediger ND, Clara I. Prevalence of metabolic syndrome in the Canadian adult population. *CMAJ.* 2011;183(15):E1127-E1134.

33. Gaede P, Lund-Andersen H, Parving HH, Pedersen O. Effect of a multifactorial intervention on mortality in type 2 diabetes. *N Engl J Med.* 2008;358(6):580-591.

34. Gaede P, Vedel P, Larsen N, Jensen GV, Parving HH, Pedersen O. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. *N Eng J Med.* 2003;348(5):383-393.

35. Shippee ND, Shah ND, May CR, Mair FS, Montori VM. Cumulative complexity: a functional, patient-centered model of patient complexity can improve research and practice. *J Clin Epidemiol.* 2012;65(10):1041-1051.

36. AHIP Center for Policy and Research. Using AHRQ's 'Revisit' Data to Estimate 30-Day Readmission Rates in Medicare Advantage and the Traditional Fee-for-Service Program. http://www.ahip.org/AHRQ_revisit_readmission_rates_10-12-10/. Published October 2010. Updated June 2011. Accessed June 1, 2013.

37. Caldwell N, Srebotnjak T, Wang T, Hsia R. "How much will I get charged for this?" patient charges for top ten diagnoses in the emergency department. *PLoS One.* 2013;8(2):e55491.

38. Pfuntner A, Wier LM, Steiner C. Costs for Hospital Stays in the United States, 2010. Healthcare Cost and Utilization Project Statistical Brief #146. Rockville, MD: Agency for Healthcare Research and Quality; 2013.

39. Li C, Ford ES, Zhao G, Ahluwalia IB, Pearson WS, Mokdad AH. Prevalence and correlates of undiagnosed depression among U.S. adults with diabetes: the Behavioral Risk Factor Surveillance System, 2006. *Diabetes Res Clin Pract.* 2009;83(2):268-279.

40. Wilper AP, Woolhandler S, Lasser KE, McCormick D, Bor DH, Himmelstein DU. Hypertension, diabetes, and elevated cholesterol among insured and uninsured U.S. adults. *Health Aff (Millwood).* 2009;28(6):w1151-w1159.

41. Kerse N, Buetow S, Mainous AG 3rd, Young G, Coster G, Arroll B. Physician-patient relationship and medication compliance: a primary care investigation. *Ann Fam Med.* 2004;2(5):455-461.

42. Dixon LB, Kreyenbuhl JA, Dickerson FB, et al. A comparison of type 2 diabetes outcomes among persons with and without severe mental illnesses. *Psychiatr Serv.* 2004;55(8):892-900.

43. Maciejewski ML, Liu CF, Fihn SD. Performance of comorbidity, risk adjustment, and functional status measures in expenditure prediction for patients with diabetes. *Diabetes Care.* 2009;32(1):75-80. ■

### Take-Away Points

This study is the first of which we are aware to examine a large number of the most common multiple chronic comorbidity (MCC) combinations for diabetes and to analyze specific, mutually exclusive MCC clusters associated with poor patient outcomes.

- MCC patterns varied considerably across patients and by age.
- Patients with certain MCC profiles, such as those with obesity only, were less likely to have diabetes-related face-to-face visits and to meet A1C treatment goals, and were more likely to have emergency department visits and 30-day readmissions.
- Specific management strategies should be developed for common MCC clusters, such as hypertension-hyperlipidemia-obesity.

■ **Table.** Characteristics of Adults With Type 2 Diabetes Mellitus

| Characteristic | Overall | Aged <65 Years | Aged ≥65 Years | *P* |
|---|---|---|---|---|
| **N** | 161,174 | 77,973 | 83,201 | -- |
| **Male** | 48% | 48.4% | 47.7% | .011 |
| **Race** | | | | <.001 |
| White | 63.4% | 58.2% | 68.2% | |
| Black | 20.5% | 23.9% | 17.3% | |
| Other | 2.3% | 2.7% | 2.0% | |
| Unknown/not recorded | 13.8% | 15.3% | 12.4% | |
| **Insurance** | | | | <.001 |
| Medicare | 51.9% | 15.0% | 86.3% | |
| Commercial | 40% | 71.6% | 10.2% | |
| Medicaid | 2.4% | 4.6% | 0.4% | |
| Other/unknown | 4.9% | 7.2% | 2.8% | |
| Uninsured | 0.9% | 1.5% | 0.3% | |
| **Annual neighborhood mean household income** | | | | <.001 |
| <$40,000 | 12.3% | 12.9% | 11.7% | |
| $40,000-$60,000 | 43.2% | 43.6% | 42.8% | |
| $60,000-$80,000 | 28.2% | 27.8% | 28.6% | |
| >$80,000 | 13.9% | 13.0% | 14.8% | |
| Unknown | 2.5% | 2.8% | 2.2% | |

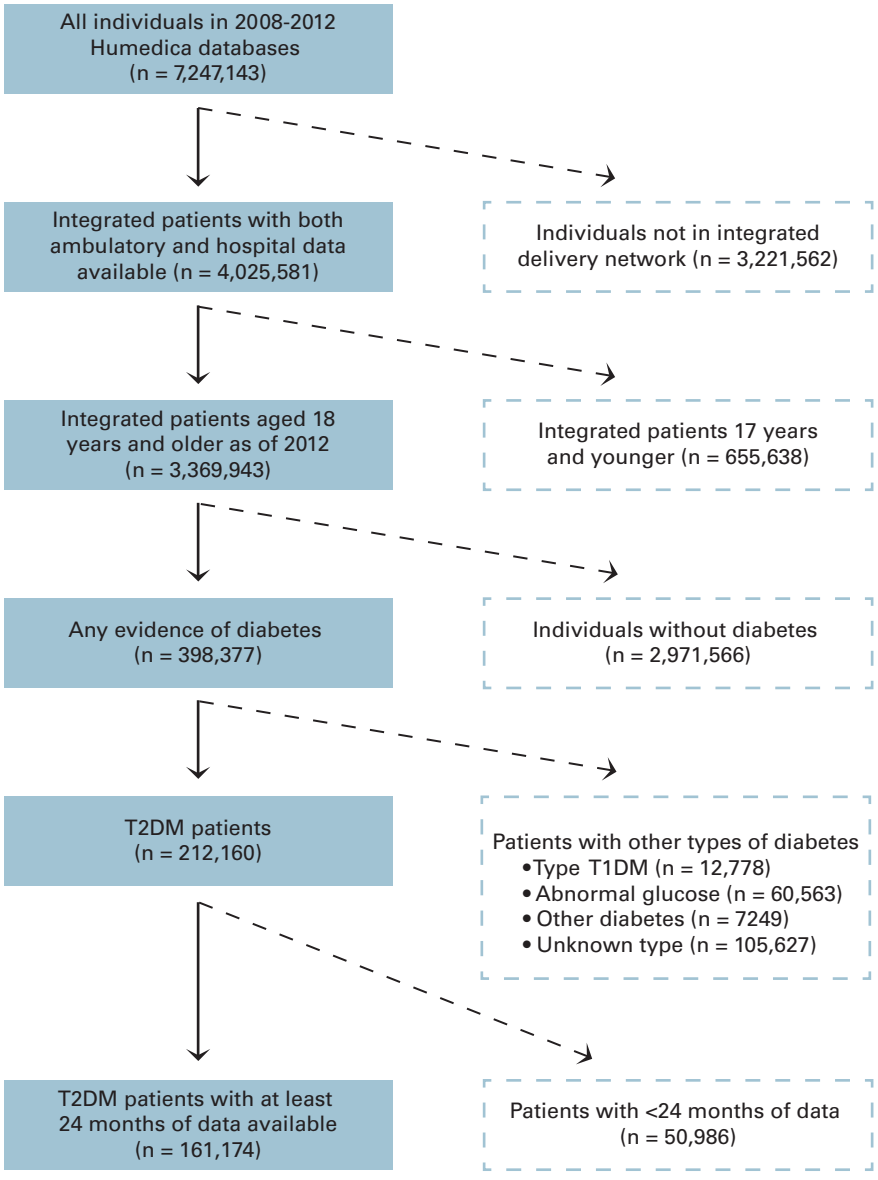
*(continued)*

■ **Table.** Characteristics of Adults With Type 2 Diabetes Mellitus *(continued)*

| Characteristic | Overall | Aged <65 Years | Aged ≥65 Years | *P* |
|---|---|---|---|---|
| **BMI, mean (SD)** | 33.3 (7.5) | 35.4 (7.8) | 31.4 (6.5) | <.001 |
| ≤24 | 5.1% | 3.1% | 7.0% | |
| 25-29 | 21.0% | 15.7% | 26.1% | |
| 30-34 | 20.4% | 20.4% | 20.4% | |
| ≥35 | 25.7% | 34.3% | 17.6% | |
| Missing | 27.8% | 26.6% | 28.9% | |
| **Average A1C value in study period** | | | | <.001 |
| <6.5% | 27.8% | 26.8% | 28.8% | |
| 6.5%-8.0% | 30.2% | 26.5% | 33.7% | |
| ≥8.0% | 27.1% | 29.9% | 24.5% | |
| Missing | 14.9% | 16.8% | 13.1% | |
| **DCSI score (0-13)** | | | | <.001 |
| 0 | 42.8% | 56.1% | 30.3% | |
| 1-2 | 34.1% | 31% | 37% | |
| ≥3 | 23.1% | 12.9% | 32.7% | |
| **Number of evaluation and management visits, mean (SD)** | 8.3 (10.5) | 7.3 (9.4) | 9.2 (11.4) | <.001 |
| **Number of drug classes, mean (SD)** | 5.6 (3.9) | 5.3 (3.8) | 5.9 (4.0) | <.001 |
| **Number of comorbidities, mean (SD)** | 2.5 (1.5) | 2.3 (1.4) | 2.7 (1.5) | <.001 |
| 0 | 11.9% | 13.5% | 10.4% | |
| 1-2 | 36.9% | 39.2% | 34.8% | |
| 3-4 | 43.2% | 42% | 44.3% | |
| ≥5 | 8.0% | 5.3% | 10.5% | |
| **Prevalence rate of comorbidity** | | | | |
| Hyperlipidemia | 77% | 71% | 82% | |
| Hypertension | 65% | 58% | 71% | |
| Obesity | 49% | 58% | 40% | |
| CAD | 11% | 6% | 16% | |
| COPD/asthma | 8% | 7% | 9% | |
| CKD | 7% | 5% | 9% | |
| Arthritis | 7% | 5% | 9% | |
| Depression | 6% | 7% | 5% | |
| Cancers | 6% | 3% | 9% | |
| Heart failure | 5% | 3% | 7% | |
| Neuropathy | 4% | 3% | 4% | |
| Fractures | 2% | 2% | 3% | |
| PAD | 2% | 1% | 3% | |
| Retinopathy | 1% | 1% | 1% | |

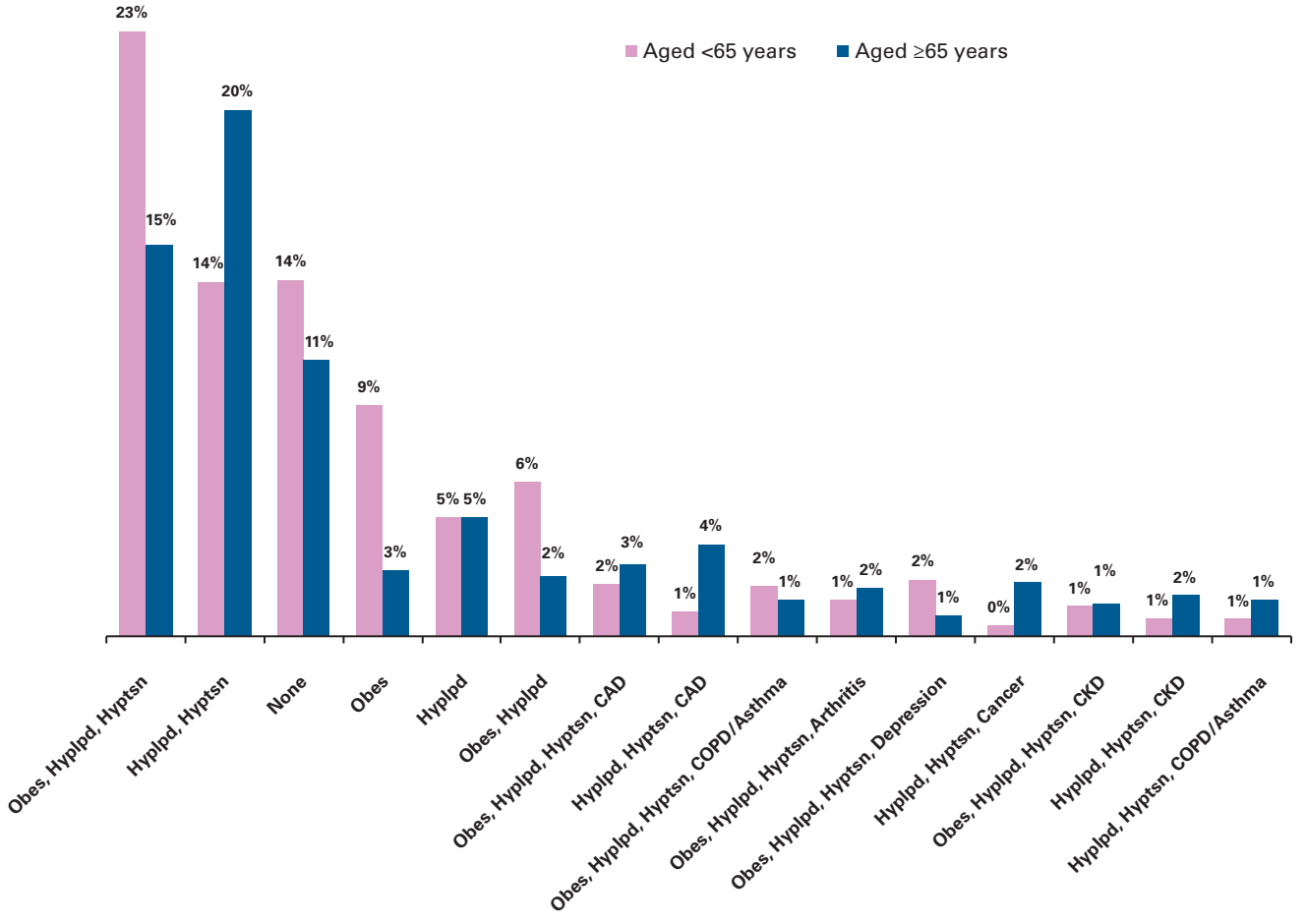
A1C indicates glycated hemoglobin; BMI, body mass index; CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DCSI, Diabetes Complications Severity Index; PAD, peripheral arterial disease.

**Figure 1.** Sample Selection Process



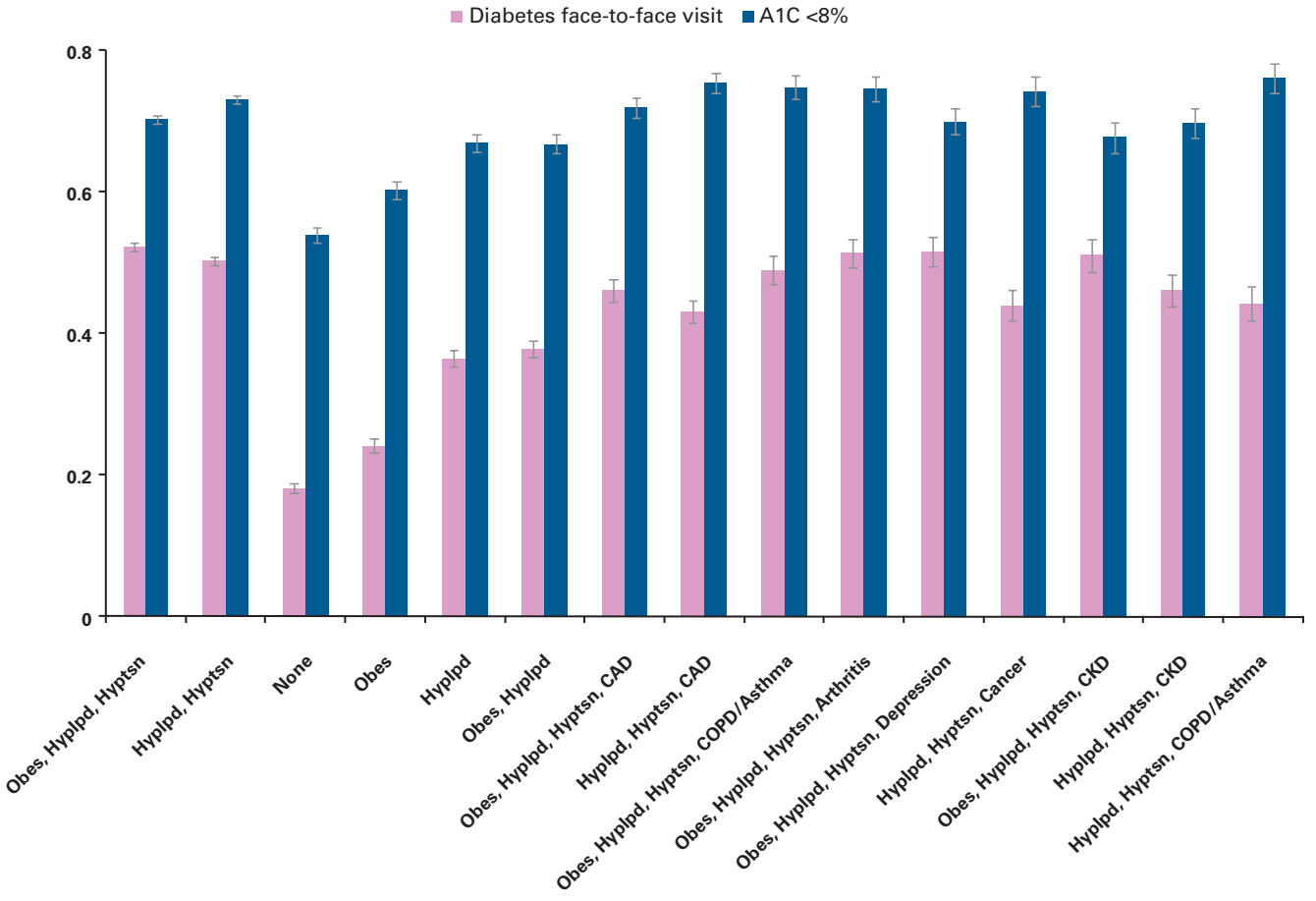

T1DM indicates type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus.

**Figure 2.** Prevalence of the 15 Most Common MCC Clusters, by Age Group



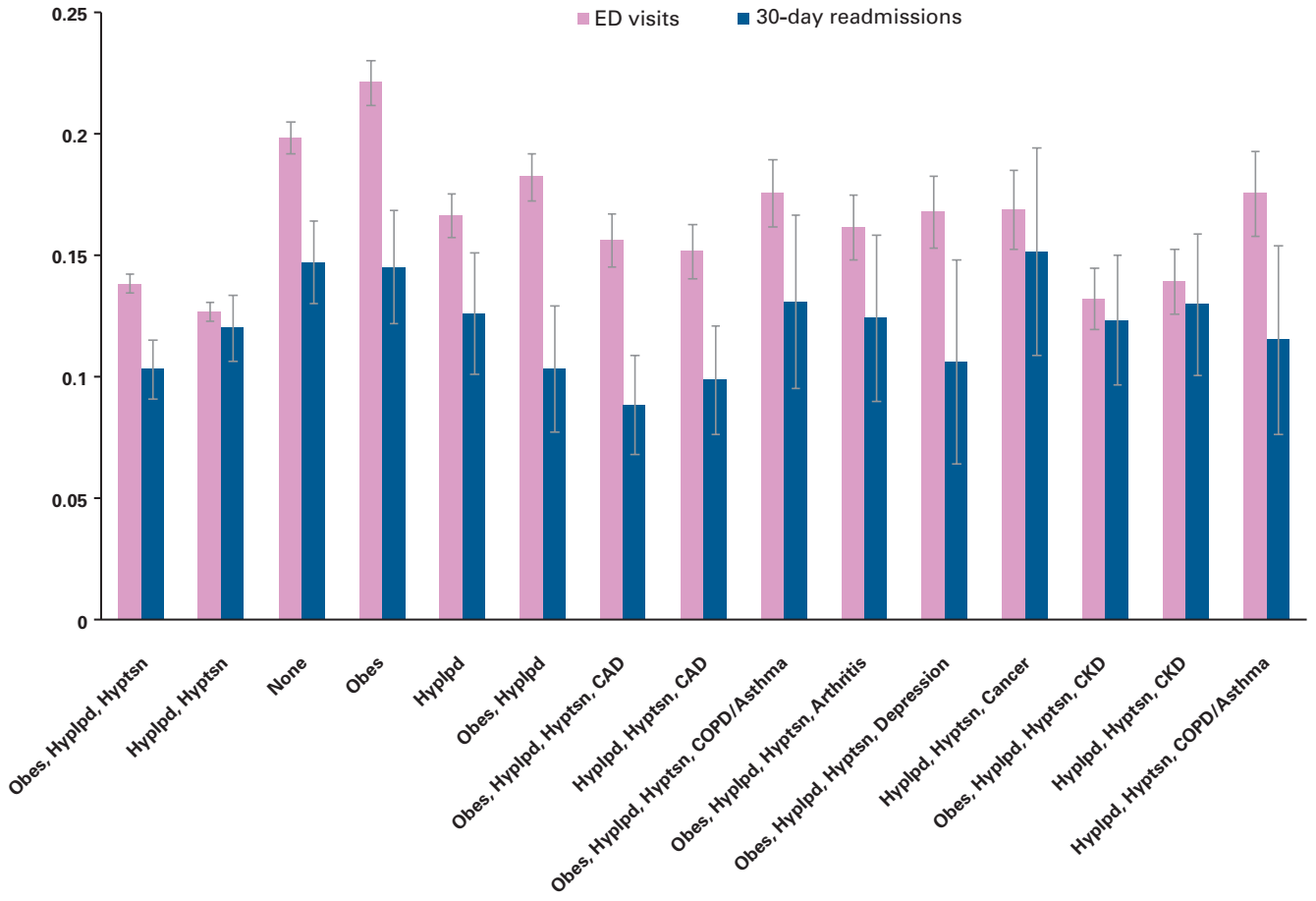

CAD indicates coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disorder; hyplpd, hyperlipidemia; hyptsn, hypertension; MCC, multiple chronic comorbidity; obes, obesity.
Graph shows the 15 most common MCC clusters, representing 75% of the diabetes sample.

■ **Figure 3.** Predicted Probabilities of Having at Least 1 Diabetes Face-to-Face Visit Every 6 Months and Reaching Treatment Goal for A1C <8%, by MCC Cluster




A1C indicates glycated hemoglobin; CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disorder; hyplpd, hyperlipidemia; hyptsn, hypertension; MCC, multiple chronic comorbidity; obes, obesity.
Gray line indicates 95% confidence interval.

**Figure 4.** Predicted Probabilities of All-Cause ED Visits and 30-Day Hospital Readmissions, by MCC Cluster




CAD indicates coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disorder; ED, emergency department; hyplpd, hyperlipidemia; hyptsn, hypertension; MCC cluster, multiple chronic comorbidity cluster; obes, obesity.
Gray line indicates 95% confidence interval.

**eAppendix.** List of Antihypertensive and Lipid-Lowering Medications

| | |
|---|---|
| **Antihypertensive drugs** | Alpha-beta blockers, angiotensin-converting-enzyme inhibitors, angiotensin II receptor antagonists, antiadrenergic antihypertensives, antihypertensive combinations, antihypertensives—miscellaneous, beta-blocker combinations, beta-blockers cardio-selective, beta-blockers non-selective, calcium channel blocker combinations, calcium channel blockers, direct renin inhibitors, diuretic combinations, loop diuretics, nitrates, potassium-sparing diuretics, selective aldosterone receptor antagonists, thiazides and thiazide-like diuretics. |
| **Lipid-lowering drugs** | Bile acid sequestrants, calcium channel blocker and 3-hydroxy-3-methyl-glutaryl-CoA reductase inhibitor [statin] combinations, fibric acid derivatives, intestinal cholesterol absorption inhibitors, intestinal cholesterol absorption inhibitor and statin combinations, niacin, nicotinic acid derivatives, probucol, statin combinations, statins. |