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Development and validation of new multimorbidity-weighted index for ICD-10-coded electronic health record and claims data: an observational study

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ABSTRACT

Objective Map multimorbidity-weighted index (MWI) conditions to International Classification of Diseases, 10th Revision (ICD-10), expand the conditions and codes to develop a new ICD-10-coded MWI (MWI-ICD10) and updated MWI-ICD9, and assess their consistency.

Design Population-based retrospective cohort.

Setting Large medical centre between 2013 and 2017.

Participants Adults ≥18 years old with encounters in each of 4 years (2013, 2014, 2016, 2017).

Main outcome measures MWI conditions mapped to ICD-10 codes, and additional conditions and codes added to produce a new MWI-ICD10 and updated MWI-ICD9. We compared the prevalence of ICD-coded MWI conditions within the ICD-9 era (2013–2014), within the ICD-10 era (2016–2017) and across the ICD-9–ICD-10 transition in 2015 (washout period) among adults present in both sets of comparison years. We computed the prevalence and change in prevalence of conditions when using MWI-ICD10 versus MWI-ICD9.

Results 88 175 adults met inclusion criteria. Participants were 60.8% female, 50.5% white, with mean age 54.7±17.3 years and baseline MWI-ICD9 4.47±6.02 (range 0–64.33). Of 94 conditions, 65 had <1% difference across the ICD-9–ICD-10 transition and similar minimal changes within ICD coding eras.

Conclusions MWI-ICD10 captured the prevalence of chronic conditions nearly identically to that of the validated MWI-ICD9, along with notable but explicable changes across the ICD-10 transition. This new comprehensive person-centred index enables quantification of cumulative disease burden and physical functioning in adults as a clinically meaningful measure of multimorbidity in electronic health record and claims data.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study used a comprehensive approach to develop and validate a new, readily available, person-centred measure of multimorbidity for International Classification of Diseases, 10th Revision (ICD-10)-coded electronic health record (EHR) and claims data.
⇒ This study compared within-ICD and across-ICD differences, which enabled us to identify changes due to the new ICD-10 coding compared with expected changes in condition prevalence over time.
⇒ Condition presence was ascertained using ICD-coded encounter diagnoses, but additional EHR data could be incorporated to further confirm or rule out condition diagnoses and characterise disease severity.
⇒ This study used data from a single large, diverse, tertiary and quaternary referral academic healthcare system and should be assessed in additional settings.

INTRODUCTION

Multimorbidity, the coexistence of multiple chronic conditions, is associated with worse health outcomes including decreased physical, cognitive and social functioning, poor health-related quality of life, and increased disability, inappropriate prescribing, hospital readmissions and mortality.[1–8] However, methods to quantify multimorbidity in real-time clinical settings using electronic health record (EHR) data are lacking or limited. In absence of a standardised measure of multimorbidity in the EHR, commonly used measures developed in claims data have been applied. For example, prior measures were developed to predict mortality, healthcare cost and utilisation among hospitalised patients.[9–12] However, such measures may be less well suited for community-dwelling adults with conditions not directly associated with mortality[13 14] but that impact functioning and are prevalent in ambulatory care settings, such as osteoarthritis. In addition, measures that rely on past healthcare utilisation[10] may be inaccurate if limited to recent or isolated encounters, such as elective surgery, rather than long-term consistent care due to insidious chronic disease. Simple (unweighted) disease count is easily computed and may be more broadly applied to community-dwelling adults but does not account for heterogeneity in disease severity, may under-rate single

diseases with high morbidity, and there is no consensus on conditions to include.[15]

Researchers using EHR data lack robust tools to accurately measure multimorbidity. In EHR data, prediction models have been developed such as the EPIC Risk Score.[16] However, the performance and validity of these tools are of limited transparency. A systematic, meaningful multimorbidity measure applicable to clinical settings can be used to risk-stratify patients, allocate resources, or tailor office visit length and frequency to improve practice. A recent hindrance in measuring multimorbidity in modern EHR and claims data was also the mandatory update of the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) to the ICD-10-CM for diagnoses and procedures starting in October 2015. This update was essential to sufficiently incorporate medical advances such as new diagnoses and procedures, since the ICD-9-CM was last expanded in 1977.[17] While the transition to ICD-10 begat a significant improvement over ICD-9, it also introduced complexity due to the vast number and high specificity of new ICD codes and, in some cases, a structural reorganisation. New specifications included aetiology, associated sequela, laterality, and primary versus subsequent encounter for a given condition. The resulting number of diagnostic codes rose from 14 025 ICD-9 to 69 823 ICD-10 codes, and procedure codes rose from 3824 ICD-9 to 71 924 ICD-10 codes.[18] Thus, not all ICD-9 codes directly translate to ICD-10 codes and vice versa. Finally, the update to ICD-10 afforded new opportunities to incorporate additional codes and conditions into multimorbidity measures.

A validated measure of multimorbidity, the multimorbidity-weighted index (MWI), is among the most comprehensive measures for the general population and uses a person-centred approach.[15] The MWI weights conditions by their average impact on the Short Form-36 physical functioning scale using longitudinal data through a typical disease course,[19] unlike prior claims-based measures that lack such repeatedly assessed individual-level outcomes. The original MWI was developed and validated using self-reported physician-diagnosed chronic conditions and was subsequently mapped and validated for use in ICD-9 codes.[20] Its performance has been extensively assessed for individual outcomes and health system utilisation.[4–6 8 20–22] To apply the MWI to modern data, the index must be expanded and refined for use with ICD-10 codes. We thus sought to develop, refine and validate a new ICD-10-coded MWI (MWI-ICD10) for use by providers and researchers to measure multimorbidity in current administrative claims and EHR data.

METHODS

Study population

We created a closed cohort of adults aged ≥18 years old with encounters in primary or specialty care at UCLA Health between 2013–2014 and 2016–2017. UCLA Health is a large, diverse, tertiary and quaternary referral academic health system based at the University of California, Los Angeles and surrounding clinics. For inclusion, participants must have had outpatient encounters in all the following 4 years: 2013, 2014, 2016 and 2017. We considered 2015 to be a washout period during which a rolling transition from ICD-9 to ICD-10 occurred throughout the hospital and outpatient clinics. Chronic condition diagnoses for each adult were assessed using ICD-9 and ICD-10 codes from both outpatient and inpatient encounters. EHR data were queried for available demographic information and ICD-9 and ICD-10 codes from outpatient and inpatient encounters.

Multimorbidity-weighted index

The MWI is a comprehensive person-centred measure of multimorbidity that includes 84 chronic conditions generally considered to require lifelong treatment or lifestyle modification for maintenance and prevention (eg, diabetes, depression). Conditions are assigned weights based on their impact on the standardised Short Form-36 physical functioning scale, and MWI is computed by summing the total physical functioning-weighted conditions for each individual (online supplemental appendix 1).[20] MWI was conveniently calibrated to the Short Form-36, such that each 1-point increase in MWI represents a 1-point decrease in physical functioning, and 3-point changes in the Short Form-36[19] may be considered a clinically meaningful change.[23–25] Thus, MWI is a clinically useful measure of multimorbidity with a twofold interpretation: MWI represents both the cumulative burden of chronic conditions and expected physical functioning decline.

Mapping MWI to ICD-10 codes

MWI conditions were mapped to ICD-10-CM codes using a multistep process. We cross-walked the original ICD-9-CM codes from the MWI-ICD9 to corresponding ICD-10-CM and ICD-10 Procedure System Codes (PCS).[20] We initially applied General Equivalency Mappings (GEM) publicly available from the Centers for Disease Control (CDC) and the Centers for Medicare and Medicaid Services (CMS) (online supplemental appendix 2, tools 1–3). Codes without a corresponding GEM were identified using online codebooks for ICD-9-CM conversions to ICD-10-CM and ICD-10-PCS (online supplemental appendix 2, tools 4–6). To increase the capture of ICD-10 codes relevant to MWI, we cross-referenced these ICD-10 codes derived from the MWI-ICD9 with published studies that compiled ICD-10 codes for serious medical conditions and chronic illnesses among adults, respectively.[26 27] We compiled an initial list of chronic diseases based on mutually exclusive conditions identified by these papers.

From the initial list of chronic diseases and corresponding ICD-10 codes, we performed a systematic review to ensure that the ICD-10 codes accurately matched the corresponding chronic condition in MWI. Three physician reviewers (MYW, AM, TG) separately used the CDC website of ICD-10 codes and searched for each ICD-10

code from the initial list.[28 29] Codes corresponding to pregnancy, family history, screening, annual examinations and paediatric conditions were removed. Parent codes that were overly broad such that they encompassed additional unrelated diseases were narrowed to reflect only the specific chronic condition in MWI. Codes that implied an acute or completely reversible condition without long-term sequelae were removed, as MWI is a measure of chronic conditions. Discrepancies between reviewers were discussed and resolved by MYW. Finally, five MWI post-surgical conditions were included using ICD-10-PCS, along with the corresponding ICD-9 procedure codes for MWI-ICD9. We provide the final list of chronic diseases, their assigned weights, and corresponding ICD-9 and ICD-10 codes in online supplemental table 1.

New changes to MWI-ICD10 and updated MWI-ICD9

In addition to mapping the previously validated MWI-ICD9 (with 84 conditions)[20] to create the new MWI-ICD10 (online supplemental table 1), we expanded the number of included conditions and ICD codes in MWI-ICD10 and updated MWI-ICD9 in parallel (online supplemental table 2). A total of 94 chronic conditions or condition groups are represented in both ICD-based indices, including the original 84 conditions in the MWI based on self-reported physician-diagnosed conditions spanning all organ systems. Key differences from the original MWI include the following three modifications that are described in further detail below:

1. We added new conditions or condition categories.
2. We expanded existing condition categories.
3. We added complex 'duo/trio' ICD codes that simultaneously represent two to three related chronic conditions within a single ICD code.

First, we added 10 new conditions or condition groups to MWI-ICD10 (online supplemental table 2A). These conditions had a related condition in MWI that could be imputed using existing weights (eg, anxiety, paralytic syndrome) or could be a marker of acute disease severity when included at time of multimorbidity assessment (eg, malnutrition, fluid and electrolyte disorders). Second, we expanded existing condition categories to include related conditions (online supplemental table 2B). For example, atrial fibrillation was broadened to include other arrhythmias including atrial flutter; alcohol use disorder was expanded to substance use disorders; and leukaemia, lymphoma was expanded to blood cancers and now includes multiple myeloma. Third, we better integrated into the indices 'combined diseases' from complex 'duo/trio' ICD codes that simultaneously represent two to three related conditions within one ICD code (online supplemental table 2C). These conditions are related and often represent sequelae from the primary condition. The ICD codes for these conditions are intentionally redundantly included in each of the conditions in online supplemental table 1 to avoid undercounting these conditions.

We provide all statistical codes necessary to generate MWI using ICD-9 and ICD-10 codes (online supplemental appendices 3 and 4).

Statistical analysis

MWI-ICD9 and MWI-ICD10 were computed for each participant by identifying ICD-9 and ICD-10 codes, respectively, which were mapped from the original MWI conditions. ICD codes may have originated from inpatient or outpatient encounters, given that the inclusion criteria were met. To compute MWI, we summed the physical functioning-based weights for all conditions present based on their corresponding ICD codes.[20] MWI-ICD9 included ICD-9-coded conditions between 2013 and 2014, and MWI-ICD10 included ICD-10-coded conditions between 2016 and 2017. We examined participant characteristics at baseline in 2013 using MWI-ICD9 tertiles.

We aimed to compare the prevalence and 95% CIs of chronic conditions using the MWI-ICD9 and MWI-ICD10 before, after and across the ICD-9–ICD-10 transition in 2015 (washout period), among participants with encounters in each of the 4 years. To do so, we first computed the change in prevalence within ICD-9 years (2013–2014) and within ICD-10 years (2016–2017) with 95% CIs on the difference.

Next, we computed the overall prevalence of MWI conditions separately for within the ICD-9 (2013 and 2014) and ICD-10 (2016 and 2017) cohort years, in order to compute the change in prevalence and 95% CIs across the ICD-9–ICD-10 transition. Using these values, we then compared the within-ICD coding eras to across the ICD-9–ICD-10 transition. The prevalence of each chronic condition in the MWI was computed as the number of individuals with an ICD code for that condition divided by the total number of individuals in the closed cohort.

As sensitivity analysis to investigate the possibility of an age-related effect, where individuals will have aged over the course of the study period, we examined disease prevalences and patterns standardised by age (18–44, 45–64, ≥65 years) and sex across the transition from ICD-9 to ICD-10 codes. Additionally, to address potential underestimation of severe and fatal conditions due to the exclusion of patients who passed away during the study period (2013–2017), we conducted a sensitivity analysis. This involved comparing disease prevalences and overall MWI values for our study sample with those of our entire UCLA Health sample population and a less restrictive study sample, which required at least one encounter in both the ICD-9 period (2013–2014) and the ICD-10 period (2016–2017) rather than an encounter in all 4 years. The 95% CIs and two-sided p values were computed using Pearson's X^2 test. All analyses were conducted using SAS V.9.4 (SAS Institute).

Patient and public involvement

Patients and the public were not involved in any way in the research.

Table 1 Characteristics of participants by tertile of the multimorbidity-weighted index (MWI-ICD9) in 2013

		Multimorbidity-weighted index, ICD-9 coded (MWI-ICD9)		
	Total N=88 175	Tertile 1 MWI range (0–0.81) N=29 767	Tertile 2 MWI range (0.82–4.54) N=28 864	Tertile 3 MWI range (4.54–64.33) N=29 544
Age, years	54.72 (17.30)	46.94 (15.86)	52.94 (15.87)	64.29 (15.42)
Sex, female	53 618 (60.81%)	18 951 (63.66%)	17 527 (60.72%)	17 140 (58.02%)
Race				
White	44 552 (50.53%)	14 825 (49.8%)	14 474 (50.15%)	15 253 (51.63%)
Black	5513 (6.25%)	1289 (4.33%)	1628 (5.64%)	2596 (8.79%)
Asian	9948 (11.28%)	3497 (11.75%)	3275 (11.35%)	3176 (10.75%)
Other	28 162 (31.94%)	10 156 (34.12%)	9487 (32.87%)	8519 (28.83%)
Ethnicity, Hispanic	10 931 (12.4%)	3344 (11.23%)	3486 (12.08%)	4101 (13.88%)
MWI-ICD9	4.47 (6.02)	0.10 (0.22)	2.44 (1.07)	10.86 (6.54)

Data are presented as mean (SD) or frequency (column %) as appropriate.
ICD-9, International Classification of Diseases, Ninth Revision.

RESULTS

Participant characteristics

We identified 236 979 adults with an encounter in 2013; among these patients, 173 436 had an outpatient encounter. The final sample included 88 175 adults with outpatient encounters in 2013 and all subsequent years of interest (2014, 2016, 2017). Participants had a mean age of 54.7 years (SD 17.3) in 2013 and half self-identified as white (table 1). At baseline in 2013, the mean age was lowest in the first tertile of MWI-ICD9 (mean 46.9, SD 15.9) and highest in the third tertile of MWI-ICD9 (mean 64.3, SD 15.4). There were no significant differences in race or ethnicity by MWI tertile.

Prevalence of chronic conditions in EHR

The 15 most prevalent chronic conditions in 2013 are shown in table 2 and similar to the top prevalent conditions in nationally sampled data.[15] The top five most

Table 2 Prevalence of top 15 most prevalent chronic conditions by year using the ICD-9-coded multimorbidity-weighted index during the ICD-9 coding era (2013, 2014), and ICD-10-coded multimorbidity-weighted index during the ICD-10 coding era (2016, 2017); N=88 175

Prevalence order*		Year, N (%†)			
		2013	2014	2016	2017
1	High blood pressure, hypertension	24 613 (27.9)	26 459 (30.0)	28 718 (32.6)	29 103 (33.0)
2	Elevated cholesterol, hyperlipidaemia	22 659 (25.7)	24 366 (27.6)	27 691 (31.4)	28 175 (32.0)
3	Depression and related psychiatric conditions	9884 (11.2)	10 772 (12.2)	8158 (9.25)	9072 (10.3)
4	Osteoporosis	9661 (11.0)	10 543 (12.0)	6156 (6.98)	6453 (7.32)
5	Hypothyroidism	9640 (10.9)	10 688 (12.1)	12 105 (13.7)	12 033 (13.6)
6	Diabetes mellitus	9237 (10.5)	9830 (11.1)	11 040 (12.5)	11 115 (12.6)
7	Chronic kidney disease, other chronic renal diseases	9082 (10.3)	6328 (7.18)	7279 (8.26)	7632 (8.66)
8	Osteoarthritis	9042 (10.3)	8893 (10.1)	11 692 (13.3)	11 426 (13.0)
9	Anxiety	7978 (9.05)	9186 (10.4)	10 862 (12.3)	11 000 (12.5)
10	Arrhythmias (including atrial fibrillation, atrial flutter)	6604 (7.49)	6945 (7.88)	8089 (9.17)	8569 (9.72)
11	Herniated disc	6134 (6.96)	5582 (6.33)	5719 (6.49)	5621 (6.37)
12	Asthma	5787 (6.56)	5907 (6.70)	6544 (7.42)	6684 (7.58)
13	Cataract	4757 (5.39)	10 186 (11.6)	8871 (10.1)	8428 (9.56)
14	Coronary artery disease	4746 (5.38)	5103 (5.79)	6418 (7.28)	6706 (7.61)
15	Benign prostatic hyperplasia	4010 (4.55)	4313 (4.89)	4715 (5.35)	4759 (5.40)

*Based on condition prevalence at baseline in 2013.
†The denominator for the percentages is constant across the years, at N=88 175. Conditions are not mutually exclusive.
ICD-9, International Classification of Diseases, Ninth Revision; ICD-10, International Classification of Diseases, 10th Revision.

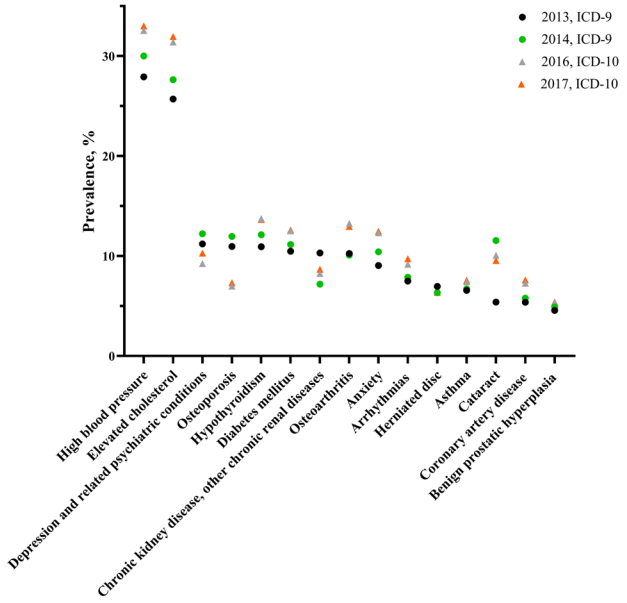

Figure 1 Dot plot of prevalences for the top 15 most prevalent chronic conditions by year using MWI-ICD9 during ICD-9 (2013, 2014) and MWI-ICD10 during ICD-10 (2016, 2017). ICD, International Classification of Diseases; MWI, multimorbidity-weighted index.

prevalent diagnoses were high blood pressure (27.9%), elevated cholesterol (25.7%), depression and related psychiatric conditions (11.2%), osteoporosis (11.0%) and hypothyroidism (10.9%). Rare conditions with <0.1% prevalence in 2013 included ectopic and molar pregnancy, amyotrophic lateral sclerosis and cervical cancer (online supplemental table 3). The distribution of prevalence for the top prevalent conditions by each study year is shown in table 2 and figure 1.

Change in prevalence of ICD-coded MWI conditions within ICD-9 years (2013 vs 2014) and within ICD-10 years (2016 vs 2017)

We assessed for differences in condition prevalences for MWI ICD-9-coded conditions between 2013 and 2014. The average absolute difference in the per cent prevalence for ICD-9-coded chronic conditions from 2013 to 2014 was 0.39% (SD 0.83%; online supplemental table 4). Following a washout period in 2015, we assessed for differences in condition prevalences for MWI-ICD10-coded conditions between 2016 and 2017. The average absolute difference in per cent prevalence for ICD-10-coded conditions from 2016 to 2017 was 0.13% (SD 0.17%). We report the absolute difference for all condition prevalences within ICD-9 years and within ICD-10 years in online supplemental table 4.

Change in prevalence of ICD-coded MWI conditions across the ICD-9–ICD-10 transition (2013–2014 vs 2016–2017)

Comparing the cohort across the ICD-9 (2013–2014) to ICD-10 (2016–2017) coding transition, the average absolute difference in per cent prevalence was 0.85% (SD 1.26%; online supplemental table 4). Of 94 conditions, 65 had <1% difference across the ICD-9–ICD-10 transition, as well as similar small changes within each of the ICD coding eras.

For some conditions, there was a reasonable modest difference in the prevalence when using MWI-ICD10 compared with MWI-ICD9, consistent with larger per cent differences within the ICD years. Six conditions had a >3% prevalence difference across the ICD transition, of which four also had >1% differences within an ICD era. These included anxiety, high blood pressure, elevated cholesterol and osteoporosis (table 3).

For few select conditions, we observed a larger prevalence difference across the ICD-9–ICD-10 transition relative to minimal changes within each of the ICD-9 and ICD-10 coding eras. For example, angina had a 1.04% increase in prevalence across the ICD-9–ICD-10 transition, but was essentially unchanged within ICD-9 (0.02% between 2013 and 2014) and within ICD-10 (0.01% between 2016 and 2017) coding eras.

Sensitivity analysis for potential modification by age, sex and underestimation of severe conditions

When we analysed the sex-standardised differences in prevalence, no differences in disease prevalence patterns were observed between men and women across the ICD-9–ICD-10 transition (online supplemental tables 5 and 6). However, age-standardised prevalences suggested a mild 'age effect' for specific conditions. Changes observed within and across the ICD transition were smaller in younger age groups compared with middle-aged and older adults (online supplemental tables 7 and 8).

We compared disease prevalences and the overall MWI values between the study sample (comprising individuals with encounters in all 4 years) and a less restrictive sample (requiring at least one encounter in both the ICD-9 and ICD-10 periods), as well as our full UCLA Health sample population. As expected, disease prevalences were lower in the less restricted sample, since disease diagnoses are acquired through encounters (online supplemental table 9). This trend persisted across diseases with wide-ranging mortality risk, affirming that our sample, which may have excluded individuals who passed away during the study period, did not selectively underestimate the prevalence of more severe and fatal conditions.

In our study sample, the mean MWI values were higher (11.95, SD 11.87), with an IQR of 3.27–16.86 and full range of 0–94.56. In comparison, the less restrictive sample had a lower mean MWI (8.27, SD 10.07), IQR of 1.45–11.23 and the same range 0–94.56. Our full UCLA Health sample population also displayed a lower mean MWI (5.15, SD 7.75), IQR of 0.14–6.43 and the same range of 0–94.56. Consequently, our findings do not indicate any under-reporting of severe or fatal conditions resulting from the exclusion of patients with these conditions who may have passed away during the study period.

Table 3 Difference in percentage prevalence of top 15* most prevalent chronic conditions within the ICD-9 coding era using MWI-ICD9, within the ICD-10 coding era using MWI-ICD10 and across the ICD-9–ICD-10 transition; N=88 175

Condition/condition category	Absolute difference within ICD-9 coding era (2013–2014), %	95% CI	Absolute difference within ICD-10 coding era (2016–2017), %	95% CI	Absolute difference across ICD-9–ICD-10 transition (2013–2014 to 2016–2017)†, %	95% CI
High blood pressure, hypertension	2.09	1.67 to 2.52	0.44	0.00 to 0.87	3.56	3.12 to 4.01
Elevated cholesterol, hyperlipidaemia	1.94	1.52 to 2.35	0.55	0.11 to 0.98	5.49	5.05 to 5.94
Depression and related psychiatric conditions	1.01	0.71 to 1.31	1.04	0.76 to 1.31	2.21	1.88 to 2.55
Osteoporosis	1.00	0.70 to 1.30	0.34	0.10 to 0.58	6.85	6.54 to 7.16
Hypothyroidism	1.19	0.89 to 1.49	0.08	–0.24 to 0.40	1.96	1.63 to 2.30
Diabetes mellitus	0.67	0.38 to 0.96	0.09	–0.22 to 0.39	1.90	1.58 to 2.22
Chronic kidney disease, other chronic renal diseases	3.12	2.86 to 3.39	0.40	0.14 to 0.66	2.07	1.77 to 2.36
Osteoarthritis	0.17	–0.11 to 0.45	0.30	–0.01 to 0.62	3.95	3.60 to 4.30
Anxiety	1.37	1.09 to 1.65	0.16	–0.15 to 0.46	3.24	2.90 to 3.59
Arrhythmias (including atrial fibrillation, atrial flutter)	0.39	0.14 to 0.64	0.54	0.27 to 0.82	1.94	1.65 to 2.24
Herniated disc	0.63	0.39 to 0.86	0.11	–0.12 to 0.34	0.63	0.35 to 0.91
Asthma	0.14	–0.10 to 0.37	0.16	–0.09 to 0.40	1.16	0.88 to 1.44
Cataract	6.16	5.90 to 6.42	0.50	0.22 to 0.78	0.30	–0.02 to 0.62
Coronary artery disease	0.40	0.19 to 0.62	0.33	0.08 to 0.57	2.14	1.88 to 2.40
Benign prostatic hyperplasia	0.34	0.15 to 0.54	0.05	–0.16 to 0.26	0.79	0.55 to 1.03

*Based on condition prevalence at baseline in 2013.
†The difference in percentage of those who had the condition anytime within the ICD-9 coding era (2013–2014) and the percentage of those who had the condition anytime within the ICD-10 coding era (2016–2017).
ICD, International Classification of Diseases; MWI, multimorbidity-weighted index.

DISCUSSION

Accurate assessment and measurement of multimorbidity are critical for risk adjustment in epidemiological and health services research and have several potential clinical applications such as risk-stratification of patients by multimorbidity. We provide an updated person-centred measure of multimorbidity, the MWI-ICD10, for use in current EHR and claims data. MWI-ICD10 expands upon the previously validated MWI by including more conditions and ICD codes. This timely MWI-ICD10 can be applied to quantify multimorbidity and risk-adjust for comorbidity.

Prior studies of some comorbidity measures report consistent performance for algorithms that cross-walked conditions from ICD-9-CM to ICD-10-CM.[26 30 31] To assess validity of our cross-walk, we examined changes in condition prevalences across the ICD-9–ICD-10 transition relative to changes within a given coding period to distinguish secular changes in prevalence from coding-related differences. We report similar results to prior studies, with many condition prevalences remaining stable across the ICD transition as well as within ICD eras.

However, in contrast to prior studies, we also observed new patterns among certain conditions across the ICD transition, relative to changes within ICD years. First, some conditions such as high blood pressure and elevated cholesterol had modestly large changes across the ICD transition that mirrored dynamic within-ICD prevalence changes. It is possible that such common conditions are neither routinely discussed nor included among encounter diagnoses at a specific encounter, or even several encounters over the course of a year, especially for those with multiple other conditions. This variability is likely more pronounced by the greater prevalence of these conditions. We also observed larger changes in prevalence within and across ICD eras for conditions in acute settings such as malnutrition and fluid and electrolyte disorders. These conditions may be undercoded relative to the primary reason for hospitalisation, which may account for dynamic changes in these condition prevalences. In contrast, severe conditions or conditions that directly impact hospitalisation such as active neurodegenerative diseases and malignancy are more likely to be included in encounter diagnoses, and our data demonstrate this more consistent performance across and within ICD coding years.

Second, we observed few conditions where large across-ICD prevalence changes were accompanied by small within-ICD changes. This is to be expected for some conditions where the severalfold expansion of ICD codes in ICD-10 enabled greater precision in categorising specific condition and combined condition codes. One example is angina. ICD-10 codes newly earmarked angina as a symptom or sequela of other cardiovascular conditions, resulting in more cases of angina in MWI-ICD10. By contrast, ICD-9 codes for symptoms and sequelae of cardiovascular conditions were broader and did not individualise angina. Thus, we excluded unspecified codes from angina in MWI-ICD9 to prevent misdiagnosis and misattribution.

Finally, for some condition mapping to ICD-10, we also had to account for reorganisation of the previous structure. For example, procedure codes for 'prostate surgery for benign prostatic hyperplasia' were greatly expanded and reorganised in ICD-10 owing to new surgical advancements since the last ICD-9 update in 1977.[32]

Our study has several strengths compared with prior studies. First, we used multiple approaches to cross-walk the MWI to ICD-10 codes, including GEM, a literature review, and ultimately, three physician reviewers who independently identified and verified codes using the CDC list to ensure complete and accurate capture of MWI chronic conditions.[29] For each MWI condition, we mapped ICD-9 codes to ICD-10 considering the expansion, redefinition and reorganisation of codes across the ICD transition. Second, we used strict inclusion criteria to examine the change in condition prevalences across a closed, longitudinal cohort spanning both ICD-9 and ICD-10 coding eras. This minimised the chance that external factors could influence the prevalence of MWI conditions, such as an influx of new cases of a specific condition due to new providers or specialty clinics. In addition to applying stringent inclusion criteria to establish a closed cohort, we conducted rigorous sensitivity analyses and found no evidence of bias related to sex or the potential underreporting of more severe conditions resulting from the exclusion of patients who passed away during the study period. An observed mild age effect may in part be attributed to the overall higher prevalence of diseases in older adults. Fourth, we were able to examine both within-ICD and across-ICD differences, which allowed us to compare ordinary prevalence changes through time with changes due to the new ICD coding. Finally, our sample used to validate MWI-ICD10 is a diverse population of community-dwelling adults with inpatient and outpatient encounters.

This study has potential limitations. First, the accurate assessment of condition prevalences depends on the quality and comprehensiveness of both patient and provider reporting of encounter diagnoses. If a condition is not discussed or billed in an outpatient or inpatient encounter, multimorbidity will be underestimated. In longitudinal studies using MWI, this is minimised by carrying forward chronic conditions, but this was not applicable to the present cross-sectional validation study. Further, if a patient is not seen consistently within the same healthcare system, the ability to link outside institutional data is limited. To minimise this, our sample included patients with consistent encounters spanning years. Moreover, while we could create a closed cohort of patients with continuous care, we could not control all factors at the physician and health system levels such as physician turnover (with different clinical and billing practices) and the opening of new clinics. Second, conditions in MWI rely simply on presence of encounter diagnoses, which is beneficial for easy implementation, but

the EHR contains a wealth of data that could be optimised to further substantiate and characterise condition presence and severity. For example, medications, laboratory values, diagnostic procedures and encounter notes could be incorporated to corroborate or rule out condition diagnoses. Future studies are needed to evaluate the added value (and expense of the added complexity) of incorporating ancillary data and advanced methods such as natural language processing to improve the accuracy of provider-documented diagnostic codes. Third, this study is limited to EHR data from one large, diverse academic healthcare system and should be assessed in additional settings. However, we note that the top prevalent and rarest chronic conditions in MWI closely match those observed for MWI conditions using nationally sampled data.[15] Finally, this study did not assess the performance of MWI-ICD10 for long-term outcomes. However, its predecessors MWI and MWI-ICD9, from which it is based, significantly predict key clinical and health systems outcomes in a variety of hospital and population-based settings and data samples.[6 8 20 21 33 34] Further, they confer the broadest distribution and least left censoring of multimorbidity over prior comorbidity measures to more precisely quantify multimorbidity in the general population.[20 22]

Using CDC and CMS ICD-9 and ICD-10 codes and EHR data from a large, diverse, tertiary and quaternary referral academic healthcare system, we developed and assessed the validity of a new MWI-ICD10 as a comprehensive readily available and easily interpretable person-centred measure to quantify multimorbidity in ICD-10-coded EHR and claims data. We provide all statistical codes necessary to implement the new MWI-ICD10 and updated MWI-ICD9. Thus, better quantification of multimorbidity is feasible in a variety of clinical settings.

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