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Can researchers trust ICD-10 coding of medical comorbidities in orthopaedic trauma patients?

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Abstract

Objectives: The 10th revision of the International Classification of Diseases (ICD-10) coding system may prove useful to orthopaedic trauma researchers to identify and document populations based on comorbidities. However, its use for research first necessitates determination of its reliability. The purpose of this study was to assess the reliability of electronic medical record (EMR) ICD-10 coding of nonorthopaedic diagnoses in orthopaedic trauma patients relative to the gold standard of prospective data collection.

Design: Nonexperimental cross-sectional study.

Setting: Level 1 Trauma Center.

Patients/Participants: Two hundred sixty-three orthopaedic trauma patients from 2 prior prospective studies from September 2018 to April 2022.

Intervention: Prospectively collected data were compared with EMR ICD-10 code abstraction for components of the Charlson Comorbidity Index (CCI), obesity, alcohol abuse, and tobacco use (retrospective data).

Main Outcome Measurements: Percent agreement and Cohen's kappa reliability.

Results: Percent agreement ranged from 86.7% to 96.9% for all CCI diagnoses and was as low as 72.6% for the diagnosis "overweight." Only 2 diagnoses, diabetes without end-organ damage (kappa = 0.794) and AIDS (kappa = 0.798) demonstrated Cohen's kappa values to indicate substantial agreement.

Conclusion: EMR diagnostic coding for medical comorbidities in orthopaedic trauma patients demonstrated variable reliability. Researchers may be able to rely on EMR coding to identify patients with diabetes without complications or AIDS. Chart review may still be necessary to confirm diagnoses. Low prevalence of most comorbidities led to high percentage agreement with low reliability.

Level of Evidence: Level 1 diagnostic.

Keywords: ICD-10 reliability, orthopaedic medical comorbidities, orthopaedic trauma diagnostic coding

1. Introduction

The International Classification of Diseases, 10th revision, Clinical Modification (ICD-10-CM) coding system was implemented nationwide in October of 2015 by the Centers for Medicare and Medicaid Services (CMS) and the National Center for Health Statistics (NCHS). As one of the most recent countries to put into effect an adaptation of ICD-10, the base version published by the World Health Organization, the United States transitioned from the previous ninth revision to increase diagnostic code specificity for large-scale research and to share medical data with the rest of the world more efficiently. The goal was to enhance patient care by increasing the capacity to improve tracking of health care statistics including the incidence, prevalence, morbidity, and mortality of disease. However, The ICD-10 system included nearly 5 times as many diagnostic codes as the ICD-9 system, leading to a higher likelihood for inaccurate coding.[1,2]

Through multiple revisions, the ICD coding system has long served as a standard internationally; however, studies assessing its accuracy in administrative databases and electronic medical records have varying results depending on the nature of the diagnoses.[3–12] This is concerning now that the ICD-10 coding system has been implemented because there is evidence suggesting limited improvement in diagnostic coding accuracy after the transition from the ICD-9 system.[13,14] It is reasonable to expect

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further evaluation of ICD-10 coding may identify some utility for valid research. Screening for populations in orthopaedic research is typically driven by common procedural terminology (CPT) codes. This method limits available study populations to those who have undergone procedures, excluding a substantial portion of orthopaedic patients. Some institutions maintain research databases, but available data are limited by funding, and this strategy still excludes many patients. By contrast, all patients have ICD-10 coding data within health care administrative databases that can be searched to screen populations by diagnosis and whose data can be exported to assign diagnoses to established patient populations. Therefore, if certain categories of ICD-10 codes are found to be reliable, then those that are of interest to orthopaedic researchers could greatly enhance research capabilities.

The purposes of this study are to assess the reliability of ICD-10 coding of medical diagnoses in orthopaedic trauma patients and to determine how accurately the Charlson Comorbidity Index (CCI), a measure of the patient's burden of disease and mortality risk, can be calculated based on ICD-10 diagnostic codes. The information gained in this study will be useful to determine whether ICD-10 diagnostic coding can reliably characterize comorbidities of orthopaedic trauma patients and screen electronic health records for populations of interest. We hypothesized that medical comorbidities of interest to orthopaedic researchers can be reliably identified by retrospectively obtained ICD-10 codes and that ICD-10 diagnostic codes can be used to calculate the CCI with sufficient reliability for use in an orthopaedic trauma study population.

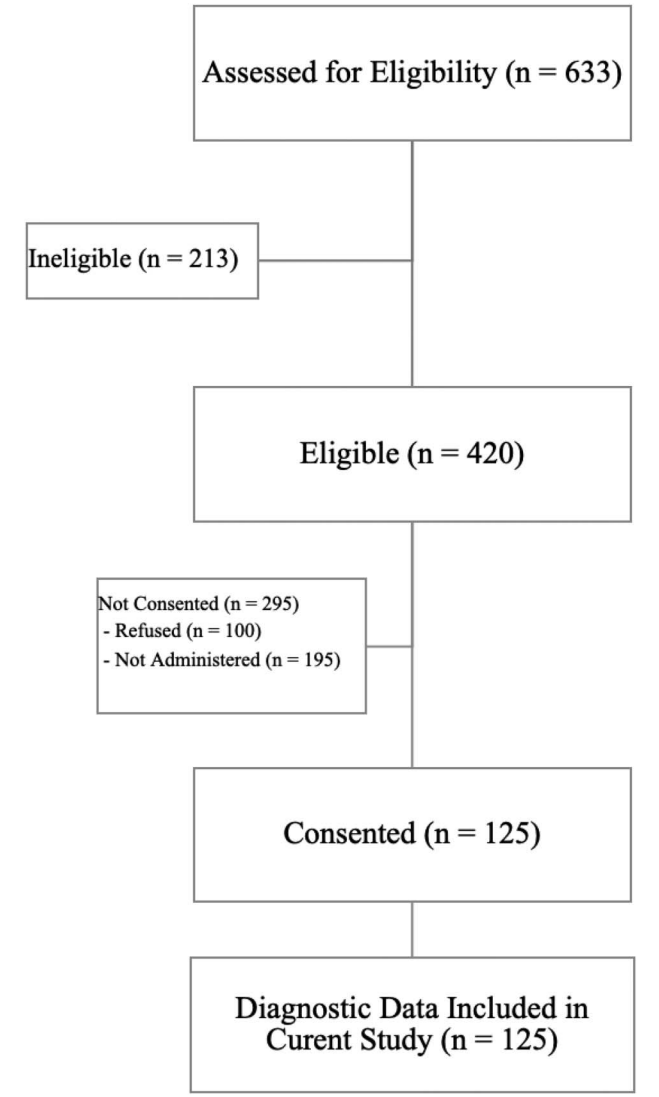

Figure 1. STROBE flowchart of individuals screened, approached for consent, and included in the TENS study from which diagnostic data was obtained.[15]

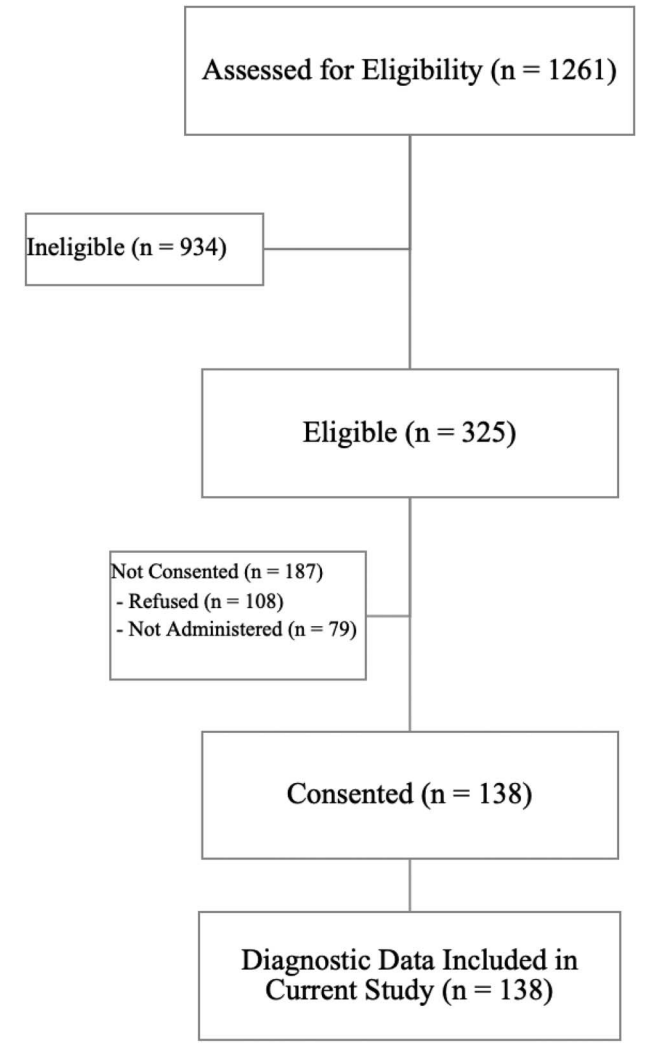

Figure 2. STROBE flowchart of individuals screened, approached for consent, and included in the SDEP study from which diagnostic data was obtained.[16]

2. Materials and Methods

2.1. IRB Approval

IRB approval (Wake Forest School of Medicine Institutional Review Board, IRB00082558, PI: Rachel Seymour, PhD) was obtained for this study, using data from prior prospective studies, which had IRB approval to include retention of data for use in future analyses. Research was conducted in accordance

with the Declaration of the World Medical Association. Informed consent for this specific study was waived due to the retrospective nature.

2.2. Setting

The study site is the orthopaedic department of a metropolitan level 1 trauma center. This was a retrospective analysis including patients from 2 previous prospective studies.

2.3. Study Design

Data were first obtained from 2 prior prospective studies at our institution. Study 1 was a prospective cohort study with enrollment period from January 2020 to April 2022. Patients aged 18 or older with operative lower extremity fracture, nonunion, and deformity correction were included in Study 1. The only exclusion criterion for Study 1 was an inability to provide informed consent.[15] Study 2 was a prospective cohort study with patients enrolled from September 2018 to October 2021 and included patients aged 18–65 with operative femur, tibia, and select ankle fractures. Patients with Injury Severity Score (ISS) greater than 18, bilateral injuries, spine injuries, open fractures, peripheral nerve injuries, skilled nursing facility admission, traumatic brain injury, and pregnant women were excluded from Study 2.[16] Per standard practice to obtain relevant comorbidity data, studies 1 and 2 included abstraction by research coordinators of relevant comorbidities, which in these studies included AIDS, congestive heart failure (CHF), chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD), cerebrovascular accident (CVA), myocardial infarction, peripheral artery disease, peptic ulcer disease, connective tissue disease, dementia, diabetes, hemiplegia, liver disease, tumor, BMI, and tobacco and alcohol use from participants' EMR. Data abstraction included 125 patients from Study 1 and 138 patients from Study 2 for a total sample size of 263 subjects (Figures 1 and 2). Participant demographics can be found in Table 1.

Next, ICD-10 codes were assigned to each of the diagnoses available from the original prospective data. Table 2 shows the ICD-10 codes used to screen for CCI diagnoses based on previous findings from Quan et al.[11] Table 3 demonstrates the ICD-10 codes used for obesity and tobacco and alcohol use. These codes were considered the gold standard for comparison against the ICD-10 codes obtained retrospectively from patient EMRs.

ICD-10 codes assigned by clinicians and hospital coders are saved in our institution's electronic data warehouse (EDW). Business Objects software (BusinessObjects, San Jose, CA) was used to query our EDW to determine ICD-10 code assignments for each of the patients included in the above studies. We included ICD-10 codes for each component of the CCI from the original study enrollment encounter and for any encounter within the prior year. The rationale for this time frame was based on common use of hierarchical condition categories used by health care systems and payors. ICD-10 codes for obesity and tobacco and alcohol use were abstracted from the original study enrollment encounter and 3 months prior because these conditions could possibly change over several months.

TABLE 1

Subject Demographics

Sex	
Male	138
Female	125
Age	
18–29	56
30–49	102
50–64	67
Older than 65	38

TABLE 2

ICD-10 Codes Used for Charlson Comorbidity Index Screening*

Diagnosis	ICD-10 Code
Myocardial infarction	I21, I22, I252
Congestive heart failure	I43, I50, I099, I110, I130, I132, I255, I420, I425, I426, I427, I428, I429, P290
Peripheral vascular disease	I70, I71, I731, I738, I739, I771, I790, I792, K551, K558, K559, Z958, Z959
Cerebrovascular disease	G45, G46, I60, I61, I62, I63, I64, I65, I66, I67, I68, I69, H340
Dementia	F00, F01, F02, F03, G30, F051, G311
Chronic pulmonary disease	J40, J41, J42, J43, J44, J45, J46, J47, J60, J61, J62, J63, J64, J65, J66, J67, I278, I279, J684, J701, J703
Connective tissue disease-rheumatic disease	M05, M32, M33, M34, M06, M315, M351, M353, M360
Peptic ulcer disease	K25, K26, K27, K28
Mild liver disease	B18, K73, K74, K700, K701, K702, K703, K709, K717, K713, K714, K715, K760, K762, K763, K764, K768, K769, Z944
Moderate or severe liver disease	K704, K711, K721, K729, K765, K766, K767, I850, I859, I864, I982
Diabetes without complications	E100, E101, E106, E108, E109, E110, E111, E116, E118, E119, E120, E121, E126, E128, E129, E130, E131, E136, E138, E139, E140, E141, E146, E148, E149
Diabetes with complications	E102, E103, E104, E105, E107, E112, E113, E114, E115, E117, E122, E123, E124, E125, E127, E132, E133, E134, E135, E137, E142, E143, E144, E145, E147
Paraplegia and hemiplegia	G81, G82, G041, G114, G801, G802, G830, G831, G832, G833, G834, G839
Renal disease	N18, N19, N052, N053, N054, N055, N056, N057, N250, I120, I131, N032, N033, N034, N035, N036, N037, Z490, Z491, Z492, Z940, Z992
Cancer	C00, C01, C02, C03, C04, C05, C06, C07, C08, C09, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C30,C31, C32, C33, C34, C37, C38, C39, C40, C41, C43, C45, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C57, C58, C60, C61, C62, C63, C64, C65, C66, C67, C68, C69, C70, C71, C72, C73, C74, C75, C76, C81, C82, C83, C84, C85, C88, C90, C91, C92, C93, C94, C95, C96, C97
Metastatic carcinoma	C77, C78, C79, C80
AIDS/HIV	B20, B21, B22, B24

* All diagnosis code that started with the characters listed was included, even if more characters were added for increased diagnostic specificity.
AIDS/HIV = acquired immunodeficiency syndrome/human immunodeficiency virus

2.4. Data Analysis

Prospectively collected data were considered the "gold standard" set of comorbidities.'[17] Contingency tables, percent agreement, and Cohen's kappa were calculated for each comorbidity to measure agreement and reliability between prospectively

TABLE 3

ICD-10 Codes Used for Obesity and Alcohol and Tobaccos Use Screening*

Diagnosis	ICD-10
Morbidly obese	E66.2, E66.01, Z68.4
Obese	E66.09, E66.1, E66.8, E66.9, Z68.3
Overweight	E66.3, Z68.25, Z68.26, Z68.27, Z67.28, Z68.29
Alcohol abuse	F10
Tobacco use	F17.2, Z72.0, Z71.6, T65.21, T65.22, T65.29

* All diagnosis code that started with the characters listed was included, even if more characters were added for increased diagnostic specificity.

collected diagnoses and EDW data. SAS software version 9.4 (SAS Institute Inc, Cary, NC) was used for all analyses. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of our business objects queries were defined and calculated as follows: Sensitivity was defined as the ability of the EDW to detect patients with the condition (patients identified as positive from both sources divided by the number of patients positive for the condition in the prospective database). Specificity was defined as the ability of the EDW to identify patients correctly as not having the condition (patients identified as negative from both sources divided by the number of patients negative for the condition in the prospective database). Positive predictive value (PPV) was defined as the percentage of patients with the condition in the EDW to be identified as having the condition in the prospective database (patients identified as positive from both sources divided by the number of patients positive for the condition in the EDW). Negative predictive value (NPV) was defined as the percentage of patients without the condition in the EDW to be identified as not having the condition in the prospective database (patients identified as negative from both sources divided by number of patients negative for the condition in the EDW).

TABLE 4

Percent Agreement and Intercoder Reliability Between Prospectively Collected Data and ICD-10 Code Abstraction for Charlson Comorbidity Index–Related Diagnoses

Diagnosis	Percent Agreement (n = 263)	Cohen's Kappa
Dementia	99.6	
AIDS	99.6	0.8
Metastatic tumor	99.2	0.5
Hemiplegia	98.9	
Moderate-severe liver disease	98.5	
Myocardial infarction	97.0	0.2
Peptic ulcer disease	97.0	0.2
Connective tissue disease	96.2	0.0
Moderate-severe chronic kidney disease	95.1	0.6
Diabetes mellitus without end-organ damage	94.7	0.8
Congestive heart failure	94.7	0.4
Cerebrovascular accident/Transient ischemic attack	94.3	0.0
Localized tumor	94.3	0.3
Mild liver disease	93.9	0.4
Peripheral vascular disease	92.0	0.2
Diabetes mellitus with end-organ damage	91.6	0.1
Chronic obstructive pulmonary disease	86.7	0.3
Leukemia		
Lymphoma		

AIDS = acquired immunodeficiency syndrome.

The age-adjusted CCI score was calculated using both the retrospectively collected (EDW-based) ICD-10 codes and the prospectively collected comorbid conditions for each patient. The 2 sets of scores were analyzed with a Wilcoxon sign test and calculation of a Spearman correlation coefficient.

3. Results

ICD-10 codes were assigned to prospectively obtained diagnoses of 263 total patients to include CCI-associated comorbidities, obesity, tobacco, and alcohol use.

Table 4 depicts the percent agreement and intercoder reliability (ICR) between the retrospectively and prospectively gathered CCI-related diagnoses. Percent agreement exceeded 90% for all CCI-related diagnoses except COPD (86.69%). Percent agreement for all other diagnoses ranged from 91.63% for diabetes mellitus with end-organ damage to 99.24% for metastatic tumor.

Table 4 shows Cohen's kappa between the retrospectively and prospectively collected CCI diagnoses. Cohen's kappa ranged from −0.023 for CVA or transient ischemic attack (TIA) to 0.798 for AIDS. Of note, 3 diagnoses (congestive heart failure, moderate-to-severe chronic kidney disease, and metastatic tumor) demonstrated moderate correlation (kappa 0.41–0.60), and 2 diagnoses (diabetes without end-organ damage and AIDS) demonstrated substantial agreement (kappa = 0.61–0.80).

Table 5 depicts percent agreement and ICR between the retrospectively and prospectively gathered ICD-10 codes for obesity, alcohol, and tobacco abuse. Morbid obesity was the only diagnosis with percent agreement exceeding 90%. Cohen's kappa values ranged from −0.001 to 0.477. Morbid obesity demonstrated moderate agreement, and alcohol abuse showed fair reliability. Overweight, obesity, and tobacco abuse diagnoses demonstrated no correlation.

Figure 3A–D shows sensitivity and specificity for CCI and other common diagnoses. Sensitivity exceeded 90% in patients with CHF, CKD, COPD, DM, and metastatic cancer. Specificity exceeded 90% for each comorbidity except COPD, which had a specificity of 86.6%. The highest sensitivity of common diagnoses was tobacco use, with sensitivity equal to 90.41%. Specificity exceeded 90% for morbid obesity, overweight, and alcohol abuse diagnoses. The lowest specificity of these diagnoses was seen in tobacco use, with specificity equal to 82.6%.

Figure 4A–D shows PPV and NPV for CCI and other common diagnoses. PPV exceeded 90% in patients with AIDS only, and NPV was greater than 96% for all CCI-related diagnoses. Among the common diagnoses, PPV did not exceed 75% for any condition. NPV exceeded 95% for morbid obesity and tobacco use diagnoses. The lowest NPV was in overweight patients, with NPV equal to 73.2%.

TABLE 5

Percent Agreement and Intercoder Reliability Between Prospectively Collected Data and ICD-10 Code Abstraction for Other Common Diagnoses

Diagnosis	Percent Agreement (n = 263)	Cohen's Kappa
Morbid obesity	94.3	0.5
Tobacco abuse	84.8	0.1
Obesity	76.8	0.1
Alcohol abuse	74.1	0.3
Overweight	72.6	0.0

ICR = intercoder reliability; ICD = International Classification of Diseases.

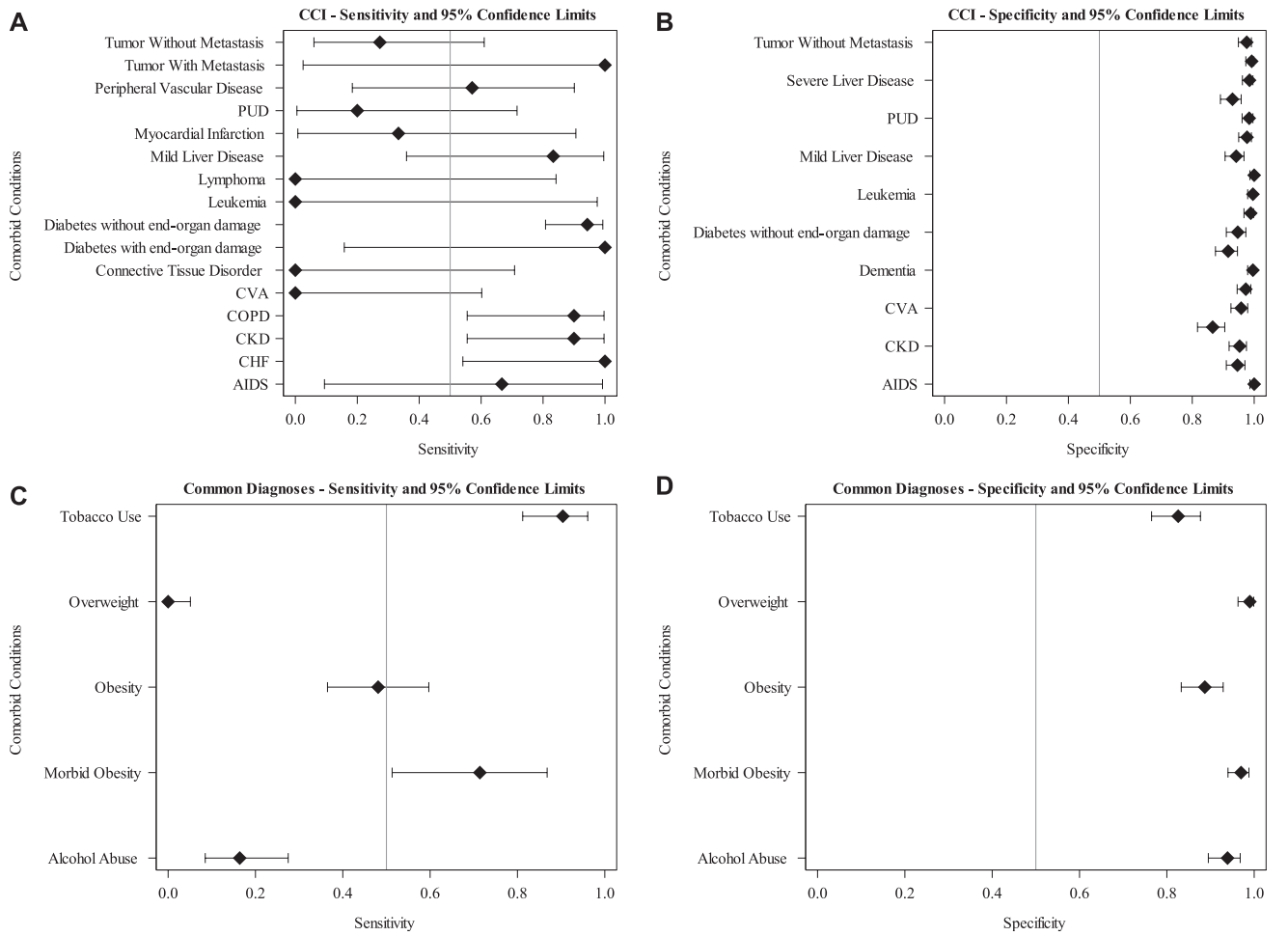

Figure 3. A–D, Sensitivity and specificity of CCI and other common diagnoses.

The median age-adjusted CCI score using the EMR-associated ICD-10 codes was 2 (IQR 1, 5), and the median CCI score using the prospective study–associated comorbid conditions was 1 (IQR 1, 3). The median difference between these 2 CCI scores was 1 point (IQR 0, 3), which was statistically significant ($P < 0.0001$) (Fig. 5). A Spearman correlation coefficient of 0.57 ($P < 0.0001$) indicates a modest relationship between the scores. Compared with the chart abstracted CCI score, ICD-10 CCI score was more variable with a wider IQR.

4. Discussion

This study examined the agreement between retrospectively collected ICD-10 codes from EMR data and prospectively collected data by research coordinators. Although percent agreement for all but one component of the CCI was greater than 90%, Cohen's kappa demonstrated limited reliability for most diagnoses (Table 3) largely because of low prevalence of conditions leading to increased likelihood of agreement by chance. Percent agreement was lower, however, with more common diagnoses of obesity, alcohol use, and tobacco use. This is likely because these conditions are more common than CCI diagnoses and are thus more likely to be absent in documentation reviewed by coders. Cohen's kappa was also low for these diagnoses (ranging from 0.07 to 0.477) with only morbid obesity demonstrating "moderate" agreement.[18]

Sensitivity of data abstracted by ICD-10 diagnoses varied greatly but was low overall for CCI and other common diagnoses. Specificity, on the other hand, was greater than 86% for most CCI and other common diagnoses. As expected, diagnoses with a high prevalence, or pretest probability, have a higher positive predictive value. These diagnoses included obesity, diabetes, alcohol use, and tobacco use. This is demonstrated by high overall NPV found for CCI and lower NPV for the overweight and obesity diagnoses. This suggests if a researcher were using ICD-10 codes to screen for a subset of orthopaedic patients based on comorbidities, they would likely get an incomplete set of patients, but the resulting population would include few incorrectly identified patients.

The disagreement seen between the 2 abstraction methods is likely a product of their different data collection methods. ICD-10 codes are captured in the EMR when a physician, advanced practice provider, or hospital coder submits a code for a diagnosis (regardless of appropriateness/accuracy of the code). Research coordinators, however, through direct review of the EMR and discussion with physicians and patients are able to capture diagnoses that may not have been coded or were coded incorrectly. There is no risk of missing a diagnosis in research because of failure to convert it into an ICD-10 code. Furthermore, ICD-10 code abstraction from the EMR in this study was limited to the recent past (3 months for substance use and obesity diagnoses, 1 year for CCI components) to avoid including past

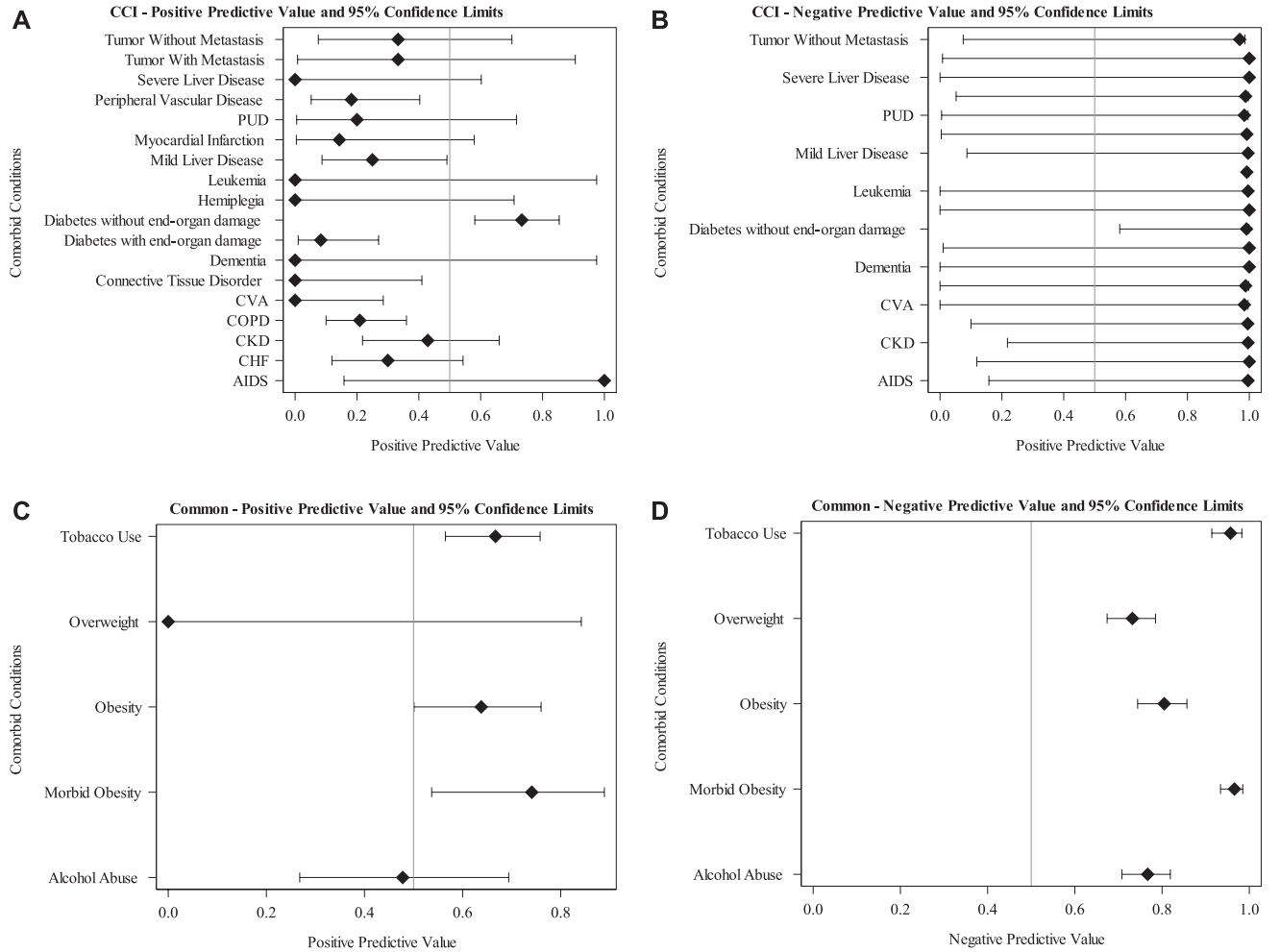

Figure 4. A–D, PPV and NPV of CCI and other common diagnoses.

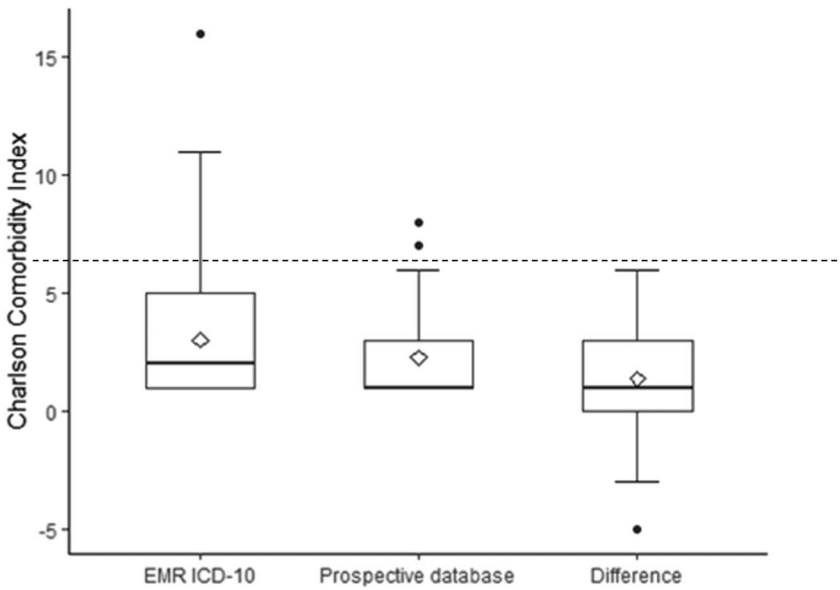

Figure 5. Box and whisker plot depicting CCI scores using EMR ICD-10 coded diagnoses versus prospective database and the media difference between the paired calculations.

diagnoses that are no longer applicable or that were incorrectly assigned in years prior and have since not been included in the EMR. Research coordinator discussions with patients can clarify these issues to improve data accuracy. Based on this explanation, diagnoses with low agreement are likely a result of failure to document these conditions in the EMR when they are in fact present.

Sensitivity of abstraction using ICD-10 codes varied greatly for the different components of the CCI. Although diagnoses like CHF, CKD, COPD, and DM demonstrated a sensitivity greater than 90%, other diagnoses had sensitivities of 0%. Specificity, on the other hand, was greater than 86% for all but one CCI component. Low PPV was calculated for nearly all the CCI components. Low PPV indicates the ICD-10 abstraction method resulted in many false-positive results. By contrast, ICD-10 abstraction demonstrated high NPVs throughout each CCI diagnosis. These high NPVs suggest ICD-10 abstraction can be used to rule out certain diagnoses with a high degree of certainty.

The literature on the reliability of the ICD-10 coding system is relatively sparse, and there are very few studies on its utility as a screening tool, especially in the context of orthopaedic surgery. A review of the ICD-10 coding of 20 common pediatric orthopaedic diagnoses found that ICD-10 codes lacked specificity and laterality was not uniform for some of these common diagnoses.[19] They also found that several unrelated conditions were described by the same code, and one common condition (accessory navicular) had no code. Another study found a 60.38% discordance between existing EMR and surgeon-assigned ICD-10 codes for ankle fractures.[20] The findings in these studies suggest that screening for orthopaedic conditions using ICD-10 diagnostic codes may be inaccurate and database research that relies on ICD-10 coding should be interpreted with caution. In addition, previous studies showed limited reliability of the ICD-9 system in orthopaedic patients.[21–23] Another study comparing ICD-9 and ICD-10 coding for proximal femur fractures revealed both systems were unreliable. Less specific coding improved reliability, but not to a sufficient degree for research purposes.[24] This suggests a lack of improvement between the ICD-9 and ICD-10 codes.

Regarding ICD-10 coding of the CCI comorbidities discussed in this study, the literature has shown more promising results; however, evidence is sparse and may not be representative of the population in the United States. Coding reliability may also differ between a population of patients primarily being treated for orthopaedic conditions and a population being primarily treated for the medical conditions that orthopaedic surgeons see as secondary diagnoses. Researchers using data from a Thai University Hospital database concluded that ICD-10 codes for diabetes mellitus and HIV infection were reliable because they demonstrated good sensitivity and specificity (90% or higher).[25] Codes for cerebrovascular disease, chronic lung disease, cancer, and all infectious conditions also demonstrated good specificity. In addition, Thygesen et al's.[26] examination of the PPV of ICD-10 coding for the 19 Charlson comorbidities resulted in PPVs that ranged from 82% for diabetes with diabetic complications to 100% for congestive heart failure, peripheral vascular disease, chronic pulmonary disease, mild and severe liver disease, hemiplegia, renal disease, leukemia, lymphoma, metastatic tumor, and AIDS. As for the non-CCI comorbidities, the evidence is variable but still sparse. ICD-10 codes for obesity are often missed, but they have also been shown to be accurate when present and can be used to identify patients for epidemiological studies.[27,28] ICD-10 coding of drug and alcohol conditions were found unreliable by researchers in Australian and Thai databases.[29,30] To the best of the authors' knowledge, the validity of ICD-10 coding for tobacco use has not been studied.

It is important that researchers know how ICD-10 codes can be reliably used for data abstraction. This study suggests only 2 diagnoses, diabetes without end-organ disease and AIDS, can be accurately identified in the orthopaedic trauma population through ICD-10 codes alone. Moreover, the other components of the CCI as well as tobacco use, alcohol abuse, and obesity should not be abstracted using ICD-10 codes. By establishing the general lack of validity by this abstraction method, we hope researchers will be cautious in using this method of data abstraction in the future, especially in large administrative database studies in which patient identification by ICD-10 diagnostic codes are common. This continued lack of coding reliability suggests either that the ICD-10 diagnostic coding system needs further updates or that methods of its implementation in the United States need to be revised.

This study has 3 main limitations: unknown degree of external validity, the time frame of included ICD-10 codes, and an unverified gold standard. The data in this study are from one trauma center using a single EMR. Reliability may vary based on different institutional coding procedures, provider documentation, and the EMR used. For example, some EMRs prompt ICD-10 code options for common diagnoses, which could affect coding accuracy. Moreover, this study was limited by the time frame of EMR codes included. Although we believe most codes would be included in the year before surgical encounter for CCI, and the 3 months prior for "other common diagnoses," reliability could change if this time frame was expanded. Finally, errors could still be present in the prospectively collected data. Although prospectively collected data are widely considered superior to chart review, diagnoses can still be missed that EMR codes may have identified.

In conclusion, this study suggests a discrepancy between manual data abstraction and ICD-10 code abstraction for comorbidities in the orthopaedic trauma population. ICD-10 coding should not be used in isolation and without considering its limitations to identify subsets of this population for research. Further research may be able to answer remaining questions of external validity of this study and to determine whether screening by ICD-10 codes in combination with other verification methods can improve research efficiency.

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