



Validity of the diagnosis of diabetic microvascular complications in Korean national health insurance claim data

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Received: November 6, 2021

Revised: February 4, 2022

Accepted: February 8, 2022

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Background: There is inadequate information on the validation of diabetic microvascular complications in the Korean National Health Insurance Service data set. We aimed to validate the diagnostic algorithms regarding the nephropathy, neuropathy, and retinopathy of diabetes.

Methods: From various secondary and tertiary medical centers, we selected 6,493 patients aged ≥ 40 years who were diagnosed with diabetic microvascular complications more than once based on codes in the 10th version of the International Classification of Diseases (ICD-10). During 2019 and 2020, we randomly selected the diagnoses of 200 patients, 100 from each of two hospitals. The positive predictive value (PPV), negative predictive value, error rate, sensitivity, and specificity were determined for each diabetic microvascular complication according to the ICD-10 codes, laboratory findings, diagnostic studies, and treatment procedure codes.

Results: Among the 200 patients who visited the hospital more than once and had the diagnostic codes of diabetic microvascular complications, 142, 110, and 154 patients were confirmed to have the gold standard of diabetic nephropathy (PPV, 71.0%), diabetic neuropathy (PPV, 55.0%), and diabetic retinopathy (PPV, 77.0%), respectively. The PPV and specificity of diabetic nephropathy (PPV, 71.0–81.4%; specificity, 10.3–53.4%), diabetic neuropathy (PPV, 55.0–81.3%; specificity, 66.7–76.7%) and diabetic retinopathy (PPV, 77.0–96.6%; specificity, 2.2–89.1%) increased after combining them with the laboratory findings, diagnostic studies, and treatment procedures codes. These change trends were observed similarly for both hospitals.

Conclusions: Defining diabetic microvascular complications using ICD-10 codes and their related examination codes may be a feasible method for studying diabetic complications.

Key words: Diabetic nephropathy; Diabetic neuropathy; Diabetic retinopathy

INTRODUCTION

Diabetes is one of the most important risk factors for developing cardiovascular disease worldwide.¹⁻³ The lifespan of patients with diabetes has been prolonged by the recent development of therapeutic drugs and advanced treatment methods.^{4,5} However, the incidence of chronic microvascular complications in patients with diabetes is increasing, including nephropathy, neuropathy, and retinopathy.^{6,7} These diabetic microvascular complications are emerging as an important impediment to determining the prognosis of patients with diabetes.⁸

Recent nationwide population-based research has addressed this issue. Nationwide population-based studies target many different populations, so even when it is difficult to perform a randomized control trial, new prognoses and outcome factors related to specific diseases would be discovered.⁹⁻¹¹ Nationwide population-based studies can also provide real-world practice or evidence.¹² The National Health Insurance Service (NHIS) in Korea covers medical expenses for the entire Korean population. This provides demographic, diagnostic codes, treatment, procedure, and medication prescription data about the entire Korean population, which are also accessible to the public.¹³ The present insurance and population-based study used the International Classification of Diseases (ICD) codes to define specific diseases and clinical outcomes.¹⁴ However, since the ICD codes can be considered for a diagnosis even when a disease is only suspected, it is difficult to accurately confirm whether an actual disease exists or a specific outcome has occurred. Validation for defining diseases based on ICD codes is therefore essential, since this will objectively evaluate the related medical research and the exact disease burden. However, no research has been reported on the validation of diabetic microvascular complications within the Korean NHIS data set.

In this study, we aimed to validate the diagnostic algorithms regarding diabetic microvascular complications, including in diabetic nephropathy, neuropathy, and retinopathy.

MATERIALS AND METHODS

Data sources and study population

Data on discharged patients and outpatient clinic visits were obtained from Ewha Womans University Seoul Hospital (a single secondary medical center) and Ewha Womans University Mokdong Hospital (a single tertiary medical center) in Korea. We selected 6,493 patients aged ≥ 40 years who were diagnosed with diabetic microvascular complications more than once based on the Korean Standard Classification of Disease. These classifications were reorganized from codes in the 10th version of the ICD (ICD-10) between January 2019 and December 2020. We randomly selected the diagnoses of 200 patients, 100 from each hospital (Fig. 1). No patients overlapped between the data of both hospitals. Clinical data for the participants during this period were stored in the Ewha Womans University Hospital electronic medical records (EMR) system and were retrospectively extracted from the hospital case notes. The case notes included information on diabetic microvascular complication diagnoses, medical history, symptom descriptions, neurologic examination findings, blood laboratory tests, urinary laboratory tests, nerve conduction studies, electromyography, fundoscopy, operative recordings, and prescriptions. This study was approved by the Institutional Review Board of Ewha Womans University Seoul Hospital (approval number SEUMC 2021-04-050).

Inclusion and diagnostic criteria

We identified 7,065 patients with diabetic microvascular complication codes. The excluded patients comprised 572 who had only visited the hospital and were diagnosed with one of the relevant codes once or who did not undergo the gold standard tests. We then randomly selected 100 patients from each participating hospital for each disease. Among the 200 patients who visited the hospital more than once and were diagnosed with codes for each diabetic microvascular complication (diabetic nephropathy [E11.2, E12.2, E13.2, E14.2, or N08.3], diabetic neuropathy [E11.4, E12.4, E13.4, E14.4, or G63.2], and diabetic retinopathy [E11.3, E12.3, E13.3, E14.3, or H36.0]), the gold standard of diabetic nephropathy was defined as follows: (1) an estimated glomerular filtration rate of ≤ 60 mL/min/1.73 m² based on the Modification of Diet in Renal Disease study,¹⁵ (2) a urinary albumin-to-cre-

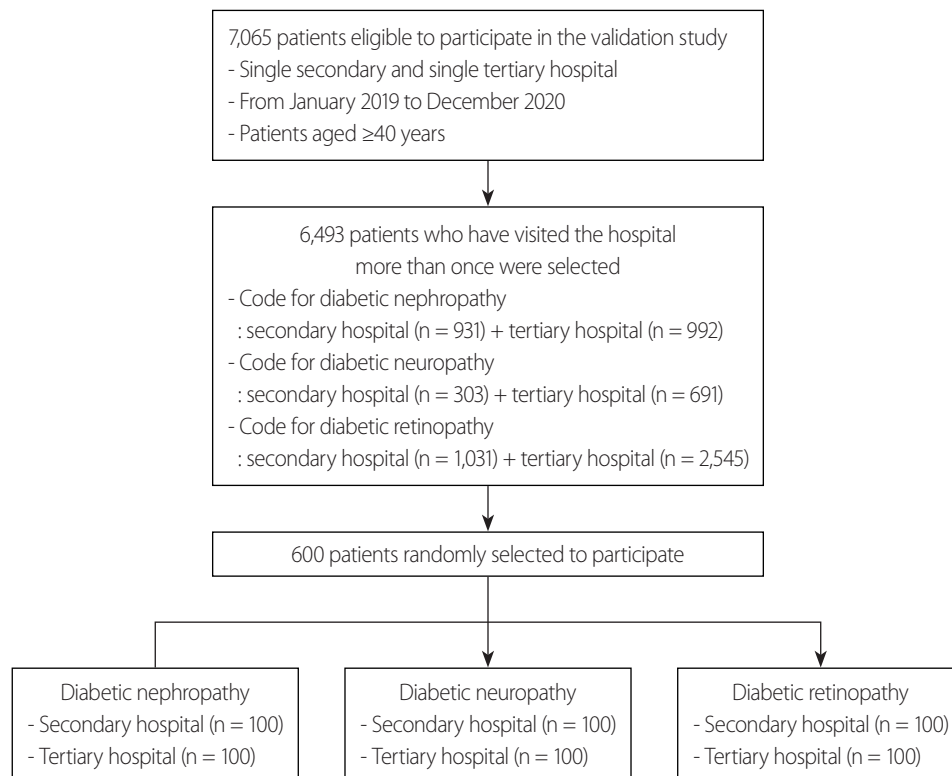


Fig. 1. Flow chart of the study design.

atnine ratio of > 300 mg/g, or (3) end-stage kidney disease with hemodialysis.^{16,17} The gold standard of diabetic neuropathy was defined as follows: (1) abnormal nerve conduction study (NCS) results, with two or more different nerves with abnormal findings more than two standard deviations from the normal range in three or four of the parameters (motor and sensory amplitudes, conduction velocities, F responses, and latencies);¹⁸ (2) abnormal sudomotor test, such as a prolonged sweat response latency, a reduced or absent sweat response, or an elevated sweat volume;¹⁹ or (3) signs and symptoms of peripheral neuropathy, such as decreased sensation (e.g., vibration, proprioception, temperature, or pinprick sensations) in distal limbs in a “stocking and glove” distribution, and a decrease from a proximal to a distal gradient of the deep tendon reflex.^{20,21} Lastly, the gold standard of diabetic retinopathy was defined as cases with proliferative or nonproliferative retinopathy according to an ophthalmologist examination using fundoscopy.^{17,22}

Diagnosis validation for diabetic microvascular complications

Five algorithms were analyzed: (1) only ICD codes (≥ 2 visits with diagnostic code and ≥ 3 visits with diagnostic code; two algorithms) and (2) ICD code and specific tests and/or prescriptions (three algorithms). For diabetic nephropathy, laboratory tests including blood chemistry or urine proteinuria were combined with the diagnostic codes for validation. In each analysis, eight patients who did not receive a blood chemistry test and 54 who did not receive a urine proteinuria test were excluded. For retinopathy, a fundoscopy, an ophthalmologist visit, prescription records for specific agents (ophthalmic solution with 0.1% bromfenac, calcium dobesilate hydrate, sulodexide, vaccinium myrtillus, and bevacizumab), and procedure execution data (retinal photocoagulation) were combined with the diagnostic codes for validation. In each analysis, one patient who did not receive fundoscopy, 15 who did not visit an ophthalmologist, and 38 who did not receive specific treatment were excluded. Lastly, diabetic neuropathy was validated

using electromyography, including an NCS or sudomotor test, and prescription records of specific agents (pathogenic treatments [α -lipoic acid] or symptomatic treatments [γ -aminobutyric acid analogs such as gabapentin or pregabalin, serotonin-norepinephrine reuptake inhibitors such as duloxetine or venlafaxine, and tricyclic agents such as amitriptyline or nortriptyline]). In each analysis, 74 patients who did not receive an NCS test and 44 who did not receive a specific treatment were excluded. Data extraction and classification of each disease were performed by different authors (diabetic retinopathy by T.J.S., diabetic neuropathy by M.S.P., and diabetic nephropathy by H.J.K.). The classification audit was performed by different authors by changing each diagnosis to minimize potential misclassification. M.S.P. and H.J.K. reviewed and discussed uncertain cases to reach a consensus.

Statistical analysis

To assess the percentage of correct diagnostic codes for diabetic microvascular complications, they were compared with the gold standard (in the case notes). The performance parameters included the positive predictive value (PPV), negative predictive value (NPV), error rate, sensitivity, and specificity. The PPV and its 95% confidence interval (CI) are used to quantify the diagnostic accuracy (number of correctly classified cases). PPV refers to the proportion of gold-standard diabetic microvascular complication cases relative to all of those identified with the diagnostic codes for diabetic nephropathy, neuropathy, and retinopathy in the Korean NHIS data. NPV was defined as the ratio of patients truly diagnosed as negative relative to all those who had negative test results. The error rate was defined as the proportion of patients with false results relative to all patients. Sensitivity and specificity analyses assessed the effect of reclassifying diagnoses using a combination of diagnostic codes and cofactors (specific tests and prescriptions for each diagnosis). Simple random sampling was used to select and allocate 100 samples for each disease from each hospital. The kappa coefficient was calculated after being independently investigated and compared by each of the two researchers. Each diabetic microvascular complication had an overall kappa value higher than 0.8, indicating an excellent degree of agreement between the researchers. All statistical analyses were performed using the open-source statistical package R (version 3.6.3; R Project for Statistical Computing, Vienna, Austria).

RESULTS

Diabetic nephropathy

Of the 200 patients who visited the hospital more than once and were diagnosed with a diabetic nephropathy code, 142 had diabetic nephropathy according to the gold standard of diagnostic criteria. Diabetic nephropathy codes predicted the gold standard of diabetic nephropathy in 71.0% (PPV) of cases. Among them, 194 patients visited the hospital and were diagnosed with a diabetic nephropathy code more than twice, and had a slightly increased PPV than did the patients who visited the hospital more than once with a diabetic nephropathy code (71.0% for ≥ 2 hospital visits vs. 71.7% for ≥ 3 hospital visits) (Table 1, Supplementary Table 1). A comparison between blood tests including creatinine and urinary proteinuria examinations with diagnostic codes revealed that the latter had higher PPV (72.9% for diagnostic codes with blood tests vs. 80.8% for diagnostic codes with urinary proteinuria tests) and specificity (10.3% vs. 51.7%), and lower NPV (75.0% vs. 55.6%), error rate (27.0% vs. 26.0%), and sensitivity (98.6% vs. 83.1%). When both factors (blood and urinary proteinuria tests) were combined with the diagnostic codes, PPV (81.4% for diagnostic codes with blood and urinary proteinuria tests vs. 80.8% for diagnostic codes with urinary proteinuria), NPV (56.4% vs. 55.6%) and specificity (53.4% vs. 51.7%) increased slightly, whereas the error rate (25.5% vs. 26.0%) and sensitivity (83.1% vs. 83.1%) decreased compared with combining only one factor with the diagnostic codes. In both the tertiary and secondary hospitals, diagnostic codes in combination with other factors had a PPV of higher than 70% (Table 1).

Diabetic neuropathy

Of the 200 patients who visited the hospital more than once and were diagnosed with a diagnostic code for diabetic neuropathy, 110 had the gold standard of diabetic neuropathy (PPV, 55.0%). Among them, 193 patients visited the hospital more than twice and were diagnosed with a diabetic neuropathy code, and PPV was slightly higher than that for the patients who visited the hospital more than once and were diagnosed with a diabetic neuropathy code (55.0% for ≥ 2 hospital visits vs. 56.0% for ≥ 3 hospital visits) (Table 2, Supplementary Table 2). When the diagnostic codes and NCS were combined, the PPV, NPV, error rate, sensitivity,

and specificity were 76.2%, 81.1%, 22.0%, 87.3%, and 66.7%, respectively. When diagnostic codes and prescriptions were combined, the PPV, NPV, error rate, sensitivity, and specificity were 65.4%, 81.8%, 31.0%, 92.7%, and 40.0%, respectively. After applying the inclusion criteria, the PPV and specificity were maximized by combining primary diagnostic codes

with NCS and prescription records of specific agents (PPV, 81.3%; specificity, 76.7%). In both hospitals, PPV was lower than 70% when only diabetic neuropathy codes were applied. However, including NCS (diagnostic codes with NCS or diagnostic codes with NCS and prescriptions) resulted in PPV increasing to nearly 80% in both hospitals (Table 2).

Table 1. Validation of diagnostic codes for diabetic nephropathy

	Total	True	False	PPV (%)	NPV (%)	Error rate (%)	Sensitivity (%)	Specificity (%)	Kappa value
Secondary hospital									
Diagnostic codes ^a (≥ 2 hospital visits)	100	70	30	70.0 (70.0–70.0)					
Diagnostic codes ^a + blood test	95	69	26	72.6 (62.5–81.3)	80.0 (28.4–99.5)	27.0 (18.6–36.8)	98.6 (92.3–99.9)	13.3 (3.8–30.7)	0.806
Diagnostic codes ^a + urinary proteinuria	75	58	17	77.3 (66.2–86.2)	52.0 (31.3–72.2)	29.0 (20.3–38.9)	82.9 (72.0–90.8)	43.3 (25.5–62.6)	0.865
Diagnostic codes ^a + blood test + urinary proteinuria	75	58	17	77.3 (66.2–86.2)	52.0 (31.3–72.2)	29.0 (20.3–38.9)	82.9 (72.0–90.8)	43.3 (25.5–62.6)	0.896
Tertiary hospital									
Diagnostic codes ^a (≥ 2 hospital visits)	100	72	28	72.0 (72.0–72.0)					
Diagnostic codes ^a + blood test	97	71	26	73.2 (63.2–81.7)	66.7 (9.4–99.2)	27.0 (18.6–36.8)	98.6 (92.5–99.9)	7.1 (0.9–23.5)	0.806
Diagnostic codes ^a + urinary proteinuria	71	60	11	84.5 (74.0–92.0)	58.6 (38.9–76.5)	23.0 (15.2–32.5)	83.3 (72.7–91.1)	60.7 (40.6–78.5)	0.865
Diagnostic codes ^a + blood test + urinary proteinuria	70	60	10	85.7 (75.3–92.9)	60.0 (40.6–77.3)	22.0 (14.3–31.4)	83.3 (72.7–91.1)	64.3 (44.1–81.4)	0.896
Total									
Diagnostic codes ^a (≥ 2 hospital visits)	200	142	58	71.0 (71.0–71.0)					
Diagnostic codes ^a + blood test	192 ^b	140	52	72.9 (66.1–79.1)	75.0 (34.9–96.8)	27.0 (20.9–33.7)	98.6 (95.0–99.8)	10.3 (3.9–21.2)	0.806
Diagnostic codes ^a + urinary proteinuria	146 ^c	118	28	80.8 (73.5–86.9)	55.6 (41.4–69.1)	26.0 (20.1–32.7)	83.1 (75.9–88.9)	51.7 (38.2–65.1)	0.865
Diagnostic codes ^a + blood test + urinary proteinuria	145 ^d	118	27	81.4 (74.1–87.4)	56.4 (42.3–69.7)	25.5 (19.6–32.1)	83.1 (75.9–88.9)	53.4 (39.9–66.7)	0.896

Values are presented as number (95% confidence interval).

PPV, positive predictive value; NPV, negative predictive value.

^aVisited the hospital more than once with all diagnostic codes (hospital admission + outpatient clinic); ^bEight patients who did not undergo blood chemistry tests were excluded; ^cFifty-four patients who did not undergo a urinary proteinuria test were excluded; ^dFifty-five patients who did not undergo both tests were excluded.

Diabetic retinopathy

This study included 200 patients who visited the hospital more than once and were diagnosed with a diagnostic code for diabetic retinopathy from two different hospitals. Among those 200 patients, 154 (77.0%) were identified as having the gold standard of diabetic retinopathy. The patients included 183 who visited the hospital more than twice and were diagnosed with a diabetic retinopathy code, and PPV

was slightly higher than that for the patients who visited the hospital more than once and were diagnosed with a diabetic neuropathy code (77.0% for ≥ 2 hospital visits vs. 79.2% for ≥ 3 hospital visits) (Table 3, Supplementary Table 3). Combining fundoscopy with the diagnostic codes increased PPV slightly, to 77.4%. Combining the ophthalmologist visit history with those results increased the PPV to 81.5%. Lastly, PPV (96.6%) increased the most when the use of specific

Table 2. Validation of diagnostic codes for diabetic neuropathy

	Total	True	False	PPV (%)	NPV (%)	Error rate (%)	Sensitivity (%)	Specificity (%)	Kappa value
Secondary hospital									
Diagnostic codes ^a (≥ 2 hospital visits)	100	59	41	59.0 (59.0–59.0)					
Diagnostic codes ^a + NCS	65	50	15	76.9 (64.8–86.5)	74.3 (56.7–87.5)	24.0 (16.0–33.6)	84.8 (73.0–92.8)	63.4 (46.9–77.9)	0.878
Diagnostic codes ^a + Prescription ^b	86	58	28	67.4 (56.5–77.2)	92.9 (66.1–99.8)	29.0 (20.4–38.9)	98.3 (90.9–99.9)	31.7 (18.1–48.1)	0.912
Diagnostic codes ^a + NCS + prescription ^b	63	50	13	79.4 (67.3–88.5)	75.7 (58.8–88.2)	22.0 (14.3–31.4)	84.8 (73.0–92.8)	68.3 (51.9–81.9)	0.951
Tertiary hospital									
Diagnostic codes ^a (≥ 2 hospital visits)	100	51	49	51.0 (51.0–51.0)					
Diagnostic codes ^a + NCS	61	46	15	75.4 (62.7–85.5)	87.2 (72.6–95.7)	20.0 (12.7–29.2)	90.2 (78.6–96.7)	69.4 (54.6–81.8)	0.878
Diagnostic codes ^a + prescription ^b	70	44	26	62.9 (50.5–74.1)	76.7 (57.7–90.1)	33.0 (23.9–43.1)	86.3 (73.7–94.3)	46.9 (32.5–61.7)	0.912
Diagnostic codes ^a + NCS + prescription ^b	49	41	8	83.7 (70.3–92.7)	80.4 (66.9–90.2)	18.0 (11.0–27.0)	80.4 (66.9–90.2)	83.7 (70.3–92.7)	0.951
Total									
Diagnostic codes ^a (≥ 2 hospital visits)	200	110	90	55.0 (55.0–55.0)					
Diagnostic codes ^a + NCS	126 ^c	96	30	76.2 (67.8–83.3)	81.1 (70.3–89.3)	22.0 (16.5–28.4)	87.3 (79.6–92.9)	66.7 (56.0–76.3)	0.878
Diagnostic codes ^a + prescription ^b	156 ^d	102	54	65.4 (57.4–72.8)	81.8 (67.3–91.8)	31.0 (24.7–37.9)	92.7 (86.2–96.8)	40.0 (29.8–50.9)	0.912
Diagnostic codes ^a + NCS + prescription ^b	112 ^e	91	21	81.3 (72.8–88.0)	78.4 (68.4–86.5)	20.0 (14.7–26.2)	82.7 (74.4–89.3)	76.7 (66.6–84.9)	0.951

Values are presented as number (95% confidence interval).

PPV, positive predictive value; NPV, negative predictive value; NCS, nerve conduction study.

^aVisited the hospital more than once with all diagnostic codes (hospital admission + outpatient clinic); ^bPathogenic treatments (α -lipoic acid) or symptomatic treatment (γ -aminobutyric acid analog, such as gabapentin or pregabalin; serotonin-norepinephrine reuptake inhibitors, such as duloxetine or venlafaxine; and tricyclic agents, such as amitriptyline or nortriptyline); ^cSeventy-four patients who did not undergo an NCS were excluded; ^dForty-four patients who did not receive a prescription were excluded; ^eEighty-eight patients who did not undergo an NCS and receive a prescription were excluded.

Table 3. Validation of diagnostic codes for diabetic retinopathy

	Total	True	False	PPV (%)	NPV (%)	Error rate (%)	Sensitivity (%)	Specificity (%)	Kappa value
Secondary hospital									
Diagnostic codes ^a (≥ 2 hospital visits)	100	83	17	83.0 (74.2–89.7)					
Diagnostic codes ^a + funduscopy	100	83	17	83.0 (74.2–89.7)	0.0 (0.0–0.0)	17.0 (12.6–26.1)	100.0 (100.0–100.0)	0.0 (0.0–0.0)	0.929
Diagnostic codes ^a + visit ophthalmologist + funduscopy	85	79	6	92.9 (85.3–97.4)	73.3 (44.9–92.2)	10.0 (4.9–17.6)	95.2 (88.1–98.7)	64.7 (38.3–85.8)	0.929
Diagnostic codes ^a + visit ophthalmologist + funduscopy + specific treatment ^b	78	77	1	98.7 (93.1–99.9)	72.7 (49.8–89.3)	7.0 (2.9–13.9)	92.8 (84.9–97.3)	94.1 (71.1–99.9)	0.964
Tertiary hospital									
Diagnostic codes ^a (≥ 2 hospital visits)	100	71	29	71.0 (71.0–71.0)					
Diagnostic codes ^a + funduscopy	99	71	28	71.7 (61.4–80.1)	100.0 (100.0–100.0)	28.0 (19.5–37.9)	100.0 (100.0–100.0)	3.4 (0.1–17.8)	0.929
Diagnostic codes ^a + visit ophthalmologist + funduscopy	99	71	28	71.7 (61.4–80.1)	100.0 (100.0–100.0)	28.0 (19.5–37.9)	100.0 (100.0–100.0)	3.4 (0.1–17.8)	0.929
Diagnostic codes ^a + visit ophthalmologist + funduscopy + specific treatment	68	64	4	94.1 (85.6–98.4)	78.1 (60.0–90.7)	11.0 (5.6–18.8)	90.1 (80.7–95.9)	86.2 (68.3–96.1)	0.964
Total									
Diagnostic codes ^a (≥ 2 hospital visits)	200	154	46	77.0 (77.0–77.0)					
Diagnostic codes ^a + funduscopy	199 ^c	154	45	77.4 (70.8–82.9)	100.0 (100.0–100.0)	22.5 (16.5–28.8)	100.0 (100.0–100.0)	2.2 (0.1–11.5)	0.929
Diagnostic codes ^a + visit ophthalmologist + funduscopy	184 ^d	150	34	81.5 (75.2–86.9)	75.0 (47.6–92.7)	19.0 (13.8–25.1)	97.4 (93.5–99.3)	26.1 (14.3–41.1)	0.929
Diagnostic codes ^a + visit ophthalmologist + funduscopy + specific treatment	146 ^e	141	5	96.6 (92.2–98.9)	75.9 (62.4–86.5)	9.0 (5.4–13.9)	91.6 (86.0–95.4)	89.1 (76.4–96.4)	0.964

Values are presented as number (95% confidence interval).

PPV, positive predictive value; NPV, negative predictive value.

^aVisited the hospital more than once with all diagnostic codes (hospital admission + outpatient clinic); ^bPrescription (ophthalmic solution with 0.1% bromfenac, calcium dobesilate hydrate, sulodexide, vaccinium myrtillus, and bevacizumab) or retinal photocoagulation; ^cOne patient who did not undergo funduscopy were excluded; ^dSixteen patients who did not receive an ophthalmologist visit and undergo funduscopy were excluded; ^eFifty-four patients who did not receive an ophthalmologist visit and undergo funduscopy and specific treatment were excluded.

medications for diabetic retinopathy or retinal photocoagulation was combined with ophthalmologist visits, fundoscopy, and diagnostic codes. The sensitivity of all cases exceeded 90.0%, but when all parameters were combined, the specificity significantly increased to 89.1% and the error rate significantly decreased to 9.9%. In each of the two hospitals, PPV was higher than 70.0% in all cases. When specific medications against diabetic retinopathy or retinal photocoagulation, ophthalmologist visits, fundoscopy, and diagnostic codes were combined, the PPV was more than 90.0% in both hospitals (Table 3).

DISCUSSION

This study explored whether ICD-10 codes can be applied to confirm diabetic microvascular complications among the Korean NHIS data. We have demonstrated that combining factors such as laboratory findings, diagnostic test codes, or treatment procedure codes with ICD-10 codes results in reliable diagnoses of diabetic microvascular complications.

Our study found PPV values ranging from 51.0% to 85.6% when using only ICD-10 codes, which depended on the type of complication in diagnosing diabetes microvascular complications. There was no significant increase in PPV for those who visited the hospital more than twice and were diagnosed with diagnostic codes compared with those who visiting the hospital more than once with the diagnostic codes, and previous nationwide cohort studies set the enrollment criteria of more than one visit to the hospital and a diagnosis from the diagnostic codes.²³⁻²⁵ The present study was therefore based on those who visited a hospital more than once and were diagnosed with a diagnostic code. In other diseases, the overall sensitivity of cancer diagnosis using the ICD-10 codes was 92.8%.^{26,27} Moreover, the diagnostic accuracy of the ICD-10 codes for cardiovascular risk factors was 85.0–94.1% in previous studies using the NHIS-Health Screening Cohort data set.^{11,28,29} We cannot clearly explain why the diagnostic accuracy of diabetes microvascular complications using only the ICD-10 codes is lower than that of other diagnosis methods; however, this may be due to differences in study designs or subjects. For diabetic neuropathy cases, neurologists or rehabilitation specialists usually perform an NCS. Physicians in other departments still

do not always perform an NCS to confirm the diagnosis of diabetes microvascular complications. This difference may explain the discrepancy between our study and previous ones.

While the accuracy of the ICD-10 codes for diagnosing diabetes microvascular complications was not poor in this study, it did improve when laboratory findings, functional studies (NCS and fundoscopy), medications, or procedure codes were also considered. Comparing the results of the secondary and tertiary hospitals revealed that the PPV and specificity tended to improve when specific tests or treatments were sequentially combined with the ICD-10 codes. However, the PPV and specificity were higher in the tertiary hospital for diabetic nephropathy and neuropathy, and higher in the secondary hospital for diabetic retinopathy. Diabetic nephropathy and neuropathy have a longer duration of morbidity than diabetic retinopathy.³⁰ There were more patients with critical illnesses in the tertiary hospital than in the secondary hospital, and the morbidity period of diabetes is likely to be longer, which may be related to the higher PPV and specificity of diabetic nephropathy and neuropathy in tertiary hospitals.

It is difficult to determine whether a diagnosis using only the ICD-10 codes is confirmative because a doctor can claim this to insurance providers even when a specific disease is only suspected. A previous study of inflammatory bowel disease (IBD) found that the reference algorithm, which combines the ICD-10 codes, more than one health-care encounter, and more than one pharmaceutical prescription for IBD-specific drugs, achieves excellent performance in identifying patients with IBD (sensitivity, 93.1% [95% CI, 91.0–94.7%]; specificity, 98.1% [95% CI, 96.9–98.8%], and PPV, 97.5% [95% CI, 96.1–98.5%]).²³ A previous study of the diagnosis algorithm for strokes found that the diagnosis accuracy is higher when considering brain imaging and prescriptions together than when only considering primary ICD-10 codes.³¹

This study had some limitations. First, we could not compare the diabetes prevalence with that in previous research because this study was conducted on patients who had already been diagnosed. Second, a bias may have occurred since although we validated patients who visited secondary and tertiary hospitals, the patient groups might not have differed significantly since these two hospitals were adjacent

to each another. Third, depending on the specific situation, the test results may change and the accuracy may decrease; for example, chronic kidney disease can be exacerbated by dehydration, and the sudomotor function test can be affected by drugs.^{32,33} However, the sudomotor test was not performed as a screening test for all diabetic neuropathies,³⁴ and the results did not change significantly even when the sudomotor test was excluded from the diagnosis using the gold standard (Supplementary Table 4). Lastly, missing records may have influenced the study results since the EMR review was conducted retrospectively. There may be some missing data in the symptoms and results of the specific tests on the patients, but there is no possibility of missing data regarding whether specific tests were performed and on ICD codes and prescriptions.

The accuracy of diagnosing diabetic microvascular complications using only ICD-10 codes might be inadequate. However, when ICD-10 codes, laboratory findings, diagnostic studies, and treatment procedure codes are considered in combination, the diagnostic accuracy of diabetic microvascular complications may be reliable. Our study was significant in demonstrating that specific tests and prescriptions should be combined with ICD-10 codes to increase the accuracy of diabetes microvascular complication diagnoses among the Korean NHIS data set.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Funding

This project was supported by a grant from the Basic Science Research Program through the National Research Foundation of Korea, funded by the Ministry of Education (grant number 2021R1F1A1048113). This work was supported by an Ewha Womans University Research Grant awarded in 2018.

Supplementary Material

Supplementary Materials can be found with this article online <https://doi.org/10.14253/acn.2022.24.1.7>.

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