

Diabetes Complications Severity Index and Risk of Mortality, Hospitalization, and Healthcare Utilization

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Among the 20 million Americans with diabetes, microvascular and macrovascular complications result in enormous morbidity,^{1,4} disability,⁵ and mortality.⁶⁻⁸ Diabetes complications account for more than 35% of the estimated \$91.8 billion in direct medical expenditures for this disease.⁹ Although much research has addressed individual complications, end-organ complications usually develop simultaneously or consecutively in a patient with diabetes rather than independently.¹⁰ Thus, an indicator that captures the severity or type of complications may be more powerful in predicting mortality and hospitalization than a simple count of complications.

Few attempts have been made to quantify the overall severity of diabetes complications in a reproducible fashion for risk assessment, or for prediction of mortality or future treatment needs and costs.¹¹ Risk equations have been developed to predict adverse cardiovascular outcomes^{12,13} and to identify high-risk patients to target for intervention.¹⁴ However, these risk models considered only cardiovascular disease risk factors and not the broader array of diabetes complications that can now be assessed in large populations enrolled in health plans with automated medical records. Because it is well established that diabetes contributes to increased morbidity and mortality in the general population,¹⁵⁻¹⁹ a logical next step is to use information relevant to the degree of progression of the disease to assess the level of risk for adverse outcomes, including hospitalization and mortality.

Given that healthcare organizations have limited resources to invest in creating disease management interventions for high-risk patients with diabetes, it is important to develop models to predict which patients are at highest risk of adverse medical outcomes. In this study, we sought to develop a method of assessing the level of risk for diabetes adverse outcomes, including hospitalization and mortality, from automated medical record data on diabetes complications. To quantify the severity of complications and to potentially better predict the risk of adverse outcomes, we developed and employed the Diabetes Complications Severity Index (DCSI). The DCSI is a 13-point scale scored from automated diagnostic, pharmacy, and laboratory data. We compared the DCSI with a simple count of diabetes complications to assess whether a severity index of diabetes complications based on clinical diagnoses would improve the prediction of adverse diabetes outcomes.

Objective: To determine whether the number and severity of diabetes complications are associated with increased risk of mortality and hospitalizations.

Study Design: Validation sample.

Methods: The Diabetes Complications Severity Index (DCSI) was developed from automated clinical baseline data of a primary care diabetes cohort and compared with a simple count of complications to predict mortality and hospitalizations. Cox proportional hazard and Poisson regression models were used to predict mortality and hospitalizations, respectively.

Results: Of 4229 respondents, 356 deaths occurred during 4 years of follow-up. Those with 1 complication did not have an increased risk of mortality, whereas those with 2 complications (hazard ratio [HR] = 1.90, 95% confidence interval [CI] = 1.27, 2.83), 3 complications (HR = 2.66, 95% CI = 1.77, 4.01), 4 complications (HR = 3.41, 95% CI = 2.18, 5.33), and ≥5 complications (HR = 7.18, 95% CI = 4.39, 11.74) had greater risk of death. Replacing the complications count with the DCSI showed a similar mortality risk. Each level of the continuous DCSI was associated with a 1.34-fold (95% CI = 1.28, 1.41) greater risk of death. Similar results were obtained for the association of the DCSI with risk of hospitalization. Comparison of receiver operating characteristic curves verified that the DCSI was a slightly better predictor of mortality than a count of complications ($P < .0001$).

Conclusion: Compared with the complications count, the DCSI performed slightly better and appears to be a useful tool for prediction of mortality and risk of hospitalization.

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METHODS

Subjects and Study Design

The Pathways Epidemiology Study is a longitudinal, prospective, population-based cohort study designed to determine the adverse impact of depression in patients diagnosed with diabetes in a primary care population.²⁰ The study recruited patients from a large nonprofit health maintenance organization with more than 400 000 enrollees who receive medical care provided by 30 primary care clinics. Of the 30 clinics available, 9 clinics were selected for this study based on the following 3 criteria: (1) geographic location, (2) large diabetes population, and (3) the largest racial and ethnic diversity. Subjects were prospectively followed from the time of recruitment for the baseline survey (March 2001) to death or May 31, 2005.

Sample Recruitment

Enrollees were recruited from 9 primary care clinics as described in previous publications.²¹⁻²³ A total of 9063 baseline surveys were mailed to patients who met the inclusion criteria of the Group Health Diabetes Registry. This registry has been shown to capture all diabetic patients (both type 1 and 2) enrolled in our institution with administrative (hospitalization, clinic visit, laboratory, or pharmacy) evidence of diabetes.²⁴ Of the 9063 patients who received surveys, 1222 were found to be ineligible based on the following criteria: no diabetes present (259), gestational diabetes (8), cognitive impairment (80), too ill to participate (202), deceased (128), disenrolled/moving (444), language/hearing barriers (99), and other (2). Of the 7841 patients eligible, 4839 returned the surveys,²⁵ for a response rate of 62%. Of the patients who returned the surveys, 369 did not give permission to review medical records, and 201 had type 1 diabetes. The study was approved by the Group Health Institutional Review Board.

Predictors

The primary predictor of interest was the number and type of diabetes complications as an indicator of diabetes severity. Other predictors of interest associated with diabetes severity included diabetes type (1 or 2), duration, glycosylated hemoglobin (A1C) level, and insulin treatment. Because of the observational nature of this study, all A1C tests were performed at point-of-care interaction of the patient with the medical system at a single institutional laboratory, which uses the Roche-Boehringer Mannheim Immuno-inhibition assay performed on a Hitachi 917 machine. The test and standardization are methods certified by the Diabetes Control and Complications Trial, and the laboratory has maintained a long-term interassay preci-

sion of approximately 3.5% coefficient of variation at levels of 6.5% and 11.0%. Secondary model adjustment variables included age, race/ethnicity, sex, body mass index (BMI), and current smoking. A count of the complications, as determined by *International Classification of Diseases, Ninth Revision (ICD-9)* codes (Table 1),²⁶ was utilized as 1 measure of the severity of diabetes morbidity and was compared with the DCSI to better represent the spectrum of concurrent complications and to provide a better representation of the diabetes severity case-mix within our patient population.

Development of the Severity Index

The DCSI was developed to model the severity of diabetes complications at any one point in time. The severity index included the following 7 categories of complications: cardiovascular disease, nephropathy, retinopathy, peripheral vascular disease, stroke, neuropathy, and metabolic. Models were based on those proposed by Selby et al¹³ and Rosenzweig et al,²⁷ but were modified to include laboratory data and ICD-9 codes that represent gradations of the severity of the complication (Table 1). The complications severity index was categorized into 2 or 3 levels (no abnormality = 0, some abnormality = 1, and severe abnormality = 2), depending on the presence and severity of the complication. If no abnormalities were present, the patient received no score for that complication. If a patient had any complication classified as some abnormality, a 1 was added to the DCSI. If patients had any complication classified as severe abnormality, a 2 was added. A total score of 13 was possible for the DCSI. Neuropathy is the only complication to have only 2 levels (not present = 0, abnormal = 1). Events were identified by ICD-9 codes from both outpatient and inpatient records, and laboratory and pharmacy data were obtained from automated electronic databases. Categories of the DCSI were developed based on the previous models^{13,27} and by consensus discussion including a diabetologist, an ophthalmologist, nephrologists, primary care physicians, psychiatrists, and epidemiologists. The DCSI was compared with a simple count of complications (the complication count index) based on ICD-9 codes. For counts of complications, each complication, no matter how severe, was categorized into a single category. For example, if a subject had a diagnosis of diabetic retinopathy, diabetic neuropathy, and a neurogenic bladder, that person was deemed to have 2 complications (diabetic retinopathy and diabetic neuropathy) rather than 3.

Outcomes

All-cause mortality was the primary outcome of interest and was determined from March 1, 2001, to May 31, 2005, by

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Table 1. Diabetes Complications Severity Index (DCSI) and List of Complications Developed from ICD-9 Codes and Laboratory Data

Complication	ICD-9 Diagnosis	ICD-9 Code	DCSI Score*	
			1	2
Retinopathy	Diabetic ophthalmologic disease	250.5x	•	
	Background retinopathy	362.01	•	
	Other retinopathy	362.1	•	
	Retinal edema	362.83	•	
	CSME	362.53	•	
	Other retinal disorders	362.81, 362.82	•	
	Proliferative retinopathy	362.02		••
	Retinal detachment	361.xx		••
	Blindness	369.xx .00-.99		••
	Vitreous hemorrhage	379.23		••
Nephropathy	Diabetic nephropathy	250.4	•	
	Acute glomerulonephritis	580	•	
	Nephrotic syndrome	581	•	
	Hypertension, nephrosis	581.81	•	
	Chronic glomerulonephritis	582	•	
	Nephritis/nephropathy	583	•	
	Chronic renal failure	585		••
	Renal failure NOS	586		••
	Renal insufficiency	593.9		••
	Urine protein \geq 30 mg/g of creatinine, or (+) dipstick protein or serum creatinine \geq 1.5 mg/dL		•	
Serum creatinine >2.0 mg/dL			••	
Neuropathy	Diabetic neuropathy	356.9, 250.6	•	
	Amyotrophy	358.1	•	
	Cranial nerve palsy	951.0, 951.1, 951.3	•	
	Mononeuropathy	354.0-355.9	•	
	Charcot's arthropathy	713.5	•	
	Polyneuropathy	357.2	•	
	Neurogenic bladder	596.54	•	
	Autonomic neuropathy	337.0, 337.1	•	
	Gastroparesis/diarrhea	564.5, 536.3	•	
Orthostatic hypotension	458.0	•		
Cerebrovascular	TIA	435	•	
	Stroke	431, 433, 434, 436		••

(Continued)

using automated vital statistics data. These deaths were validated by comparing the current data with those obtained from the Washington State Department of Health Death Index available from January 1999 to December 2003.

During the first 2 years of the study, administrative data recorded 90% of the deaths reported in the Washington State Death Index.²⁵ A secondary outcome of interest was risk of hospitalization. Admission for any hospitalization

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■ **Table 1.** Diabetes Complications Severity Index (DCSI) and List of Complications Developed from *ICD-9* Codes and Laboratory Data (*Continued*)

Complication	ICD-9 Diagnosis	ICD-9 Code	DCSI Score*	
			1	2
Cardiovascular	Atherosclerosis	440.xx	•	
	Other IHD	411	•	
	Angina pectoris	413	•	
	Other chronic IHD	414	•	
	Myocardial infarction	410		••
	Ventricular fibrillation, arrest	427.1, 427.3		••
	Atrial fibrillation, arrest	427.4, 427.5		••
	Other ASCVD	429.2	•	
	Old myocardial infarction	412		••
	Heart failure	428		••
	Atherosclerosis, severe	440.23, 440.24		••
	Aortic aneurysm/dissection	441		••
Peripheral vascular disease	Diabetic PVD	250.7	•	
	Other aneurysm, LE	442.3	•	
	PVD	443.81, 443.9	•	
	Foot wound + complication	892.1	•	
	Claudication, intermittent	443.9	•	
	Embolism/thrombosis (LE)	444.22		••
	Gangrene	785.4		••
	Gas gangrene	0.40		••
	Ulcer of lower limbs	707.1		••
Metabolic	Ketoacidosis	250.1		••
	Hyperosmolar	250.2		••
	Other coma	250.3		••

*Severity index is based on a scale ranging from 0-2 for each complication as follows: 0 = no abnormality, 1 = some abnormality, 2 = severe abnormality. • indicates a count of 1 added to DCSI; •• indicates a count of 2 added to DCSI. *ICD-9* indicates *International Classification of Diseases, Ninth Revision*; CSME, cystoid macular edema/degeneration; NOS, not otherwise specified; TIA, transient ischemic attack; IHD, ischemic heart disease; ASCVD, atherosclerotic cardiovascular disease; PVD, peripheral vascular disease; LE, lower extremity.

was abstracted from automated data from January 1, 2001, to May 31, 2005.

Statistical Analysis

Cox proportional hazards regression models were used to analyze the association between complication severity and mortality, independent of other predictors of survival.²⁸ Patients were considered at risk from baseline (March 1, 2001) and followed longitudinally for 4 years. Patients were censored at the end of the study (May 31, 2005) or for loss to follow-up, as determined by disenrollment from the coopera-

tive. The DCSI was added to models as both a linear term and as a categorical variable from 0 to ≥ 5 . The adjusted relative risk (RR) or hazard ratio (HR) was estimated for each covariate as the proportionate change in the instantaneous probability of death for 2 individuals differing only by a single covariate. Variables used in the multivariate model were chosen a priori (age, sex, A1C, current smoking, duration, race/ethnicity, and type of diabetes), or for the observed magnitude of their relationship with the response and predictor variables (BMI, salary, and insulin use). The proportional hazards assumption of the Cox models was assessed by log

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($-\log$) and cumulative Schoenfeld residual plots. Because estimates did not conform to the proportional hazards assumptions when race and insulin use were included in the models and because longitudinal pharmacy data for an insulin time-varying covariate were not available, robust standard error estimates were used to determine the significance of the mortality models.²⁹ Because race and insulin were selected a priori as potential confounders, it was important to include them in the adjusted model. Though they appeared to violate the proportional hazards assumption, including them allowed us to adjust for their average effect (averaged over time as well as subjects); using the robust standard error estimate ensured that we could still make valid inferences about the variables of primary interest. For the secondary analysis, Poisson regression was used to determine the association between complication severity and number of hospitalizations.³⁰

To determine whether a simple count of complications or the DCSI was a better predictor of mortality, we conducted a series of model comparisons using both the mortality models. Akaike's information criterion was used to determine goodness of fit. In addition, we used logistic regression models to construct receiver operating characteristic (ROC) curves to compare the DCSI with a simple count of complications in

the prediction of 2-year mortality. Area under the curve (AUC) results obtained from the ROC curves were used to determine which measure better predicted 2-year mortality. Two-year mortality was assessed instead of 4-year mortality because of the need to have 100% survival time and follow-up for all subjects included in the model so that AUC curves could be constructed accurately.

RESULTS

Of the 4470 eligible respondents, 4229 had complete data for analysis. Of those, 1356 (32.1%) had no complications, 1334 (31.5%) had 1 complication, and 1539 (36.4%) had 2 or more complications. Compared with patients who had no complications, those with 1 complication were older, more likely to be male, had a longer duration of diabetes, were more likely to be African American, and had a slightly higher mean A1C level. Those with 2 or more complications were older, had a longer duration of diabetes, were even more likely to be African American, were more likely to have an annual household income less than \$20 000, were more likely to have type 1 diabetes, and had higher mean A1C levels than those with no complications or 1 complication (**Table 2**).

■ **Table 2.** Baseline Patient Characteristics

Characteristic	No Complications	1 Complication	≥2 Complications	All Subjects
Total	1356	1334	1539	4229
Mean age, y (SD)	59.00 (13.4)	62.70 (13.0)	67.36 (12.3)	63.21 (13.3)
Male sex, n	658 (48.5%)	696 (52.2%)	835 (54.3%)	2189 (51.8%)
Duration of diabetes, y (SD)	6.44 (6.9)	8.45 (8.5)	13.10 (10.6)	9.50 (9.3)
Race, n				
Caucasian	1039 (76.6%)	1025 (76.8%)	1257 (81.7%)	3321 (78.5%)
African American	97 (7.2%)	105 (7.9%)	137 (8.9%)	339 (8.0%)
Asian American	150 (11.1%)	127 (9.5%)	90 (5.9%)	367 (8.7%)
Hispanic	43 (3.2%)	50 (3.8%)	24 (1.6%)	117 (2.8%)
Hypertension present, n	393 (29.0%)	517 (38.8%)	903 (58.7%)	1813 (42.9%)
Type 1 diabetes, n	150 (11.1%)	141 (10.6%)	201 (13.1%)	492 (11.6%)
Current smoking, n	150 (11.1%)	103 (7.7%)	109 (7.1%)	362 (8.6%)
Salary ≥\$20 000/year, n	757 (55.8%)	648 (48.6%)	566 (36.8%)	1971 (46.6%)
Education beyond high school, n	1066 (78.6%)	1034 (77.5%)	1100 (71.5%)	3200 (75.7%)
Mean glycosylated hemoglobin A1C level, % (SD)	7.52 (1.48)	7.79 (1.56)	7.99 (1.58)	7.78 (1.55)
Mean severity index score, (SD)	0 (0)	1.20 (0.40)	3.73 (1.75)	1.74 (1.92)

■ **Table 3.** Cox Proportional Hazard Models of Mortality*

Characteristic	Unadjusted HR (95% CI)	Adjusted HR [†] (95% CI)
Age	1.08 (1.07, 1.09)	1.09 (1.07, 1.10)
Race (Non-Caucasian)	0.62 (0.45, 0.84)	0.89 (0.65, 1.23)
Insulin use	2.15 (1.73, 2.67)	2.26 (1.76, 2.89)
Duration of diabetes	1.03 (1.02, 1.04)	1.01 (1.00, 1.02)
Smoking	0.83 (0.54, 1.27)	1.57 (1.02, 2.42)
BMI	0.94 (0.92, 0.97)	0.99 (0.97, 1.02)
Salary ≥\$20 000/year	0.59 (0.52, 0.67)	0.83 (0.72, 0.95)
DCSI (linear)	1.46 (1.41, 1.52)	1.34 (1.28, 1.41)
DCSI (categorical)		
0	Reference	Reference
1	1.22 (0.79, 1.89)	1.05 (0.67, 1.62)
2	1.76 (1.14, 2.73)	1.19 (0.77, 1.86)
3	3.29 (2.14, 5.07)	1.95 (1.25, 3.04)
4	6.40 (4.24, 9.66)	3.11 (2.01, 4.81)
5+	10.99 (7.70, 15.68)	5.13 (3.45, 7.64)
No. of complications		
0	Reference	Reference
1	1.47 (0.99, 2.19)	1.15 (0.77, 1.71)
2	3.00 (2.04, 4.40)	1.90 (1.27, 2.83)
3	5.25 (3.55, 7.77)	2.66 (1.77, 4.01)
4	7.56 (5.00, 11.44)	3.41 (2.18, 5.33)
≥5	17.02 (11.04, 26.22)	7.18 (4.39, 11.74)

*Includes 4229 subjects who do not have missing values for any of the adjustment or severity/complications variables.
[†]Adjusted for age, duration of diabetes, race, type of diabetes, sex, current smoking, insulin use, salary, and body mass index.
 HR indicates hazard ratio; CI, confidence interval; DCSI, Diabetes Complications Severity Index.

Mortality Risk

A total of 356 deaths occurred during a total of 14 166 patient-years of risk. Kaplan-Meier curves of mortality stratified by complication count are shown in **Figure 1**. The adjusted HRs of mortality are shown in **Table 3**. Compared with those who had no complications, the adjusted RR of death increased as the number of complications increased. Compared with patients who had no complications, those with 1 complication did not have an increased risk of death; however, those with 2 or more complications had a significantly higher risk of death (2 complications HR = 1.90, 95% confidence interval [CI] = 1.27, 2.83; 3 complications HR = 2.66, 95% CI = 1.77, 4.01; 4 complications HR = 3.41, 95% CI = 2.18, 5.33; ≥5 complications HR = 7.18, 95% CI = 4.39, 11.74) after adjusting for age, sex, race, type and duration of diabetes, current smoking, insulin

use, and BMI. Replacing the count of complications with a categorical variable of DCSI levels showed that risk of mortality increased significantly from baseline, once a score of 3 or more was obtained compared to a score of zero (**Table 3**). Likewise, for each increment of the severity index (added as a linear variable), the adjusted risk of death increased by 1.34-fold (95% CI = 1.28, 1.41).

Risk of Hospitalization

Risk of hospitalization increased with number and severity of complications (**Table 4**). A higher number of complications was associated with a greater risk of hospitalization after adjusting for age, sex, race, diabetes duration, A1C level, BMI, current smoking, and insulin use. Compared with no complications, a greater risk of hospitalization was found in relation to the number of complications as follows: 1 complication HR = 1.48, 95% CI = 1.22, 1.80; 2 complications HR = 2.27, 95% CI = 1.86, 2.77; 3 complications HR = 3.12, 95% CI = 2.52, 3.87; 4 complications HR = 4.13, 95% CI = 3.27, 5.20; and ≥5 complications HR = 6.56, 95% CI = 5.04, 8.53. When the DCSI was used instead of an absolute count of complications, the DCSI achieved similar results, although the magnitude of risk elevation was slightly attenuated. When the DCSI replaced the count of complications as a linear variable, each level of the DCSI was associated with a 29% (HR = 1.29, 95% CI = 1.25, 1.32) increased risk of hospitalization.

Comparison of Diabetes Complications Severity Index with Complications Count

Models of mortality containing the DCSI as a categorical or linear variable, or the count of complications as either a linear or categorical term were compared by using Akaike's information criterion for goodness of fit. We found that for the linear term of the DCSI, Akaike's information criterion was 4927.4; for the categorical term of the DCSI, Akaike's information criterion was 4952.6; and for the complication cate-

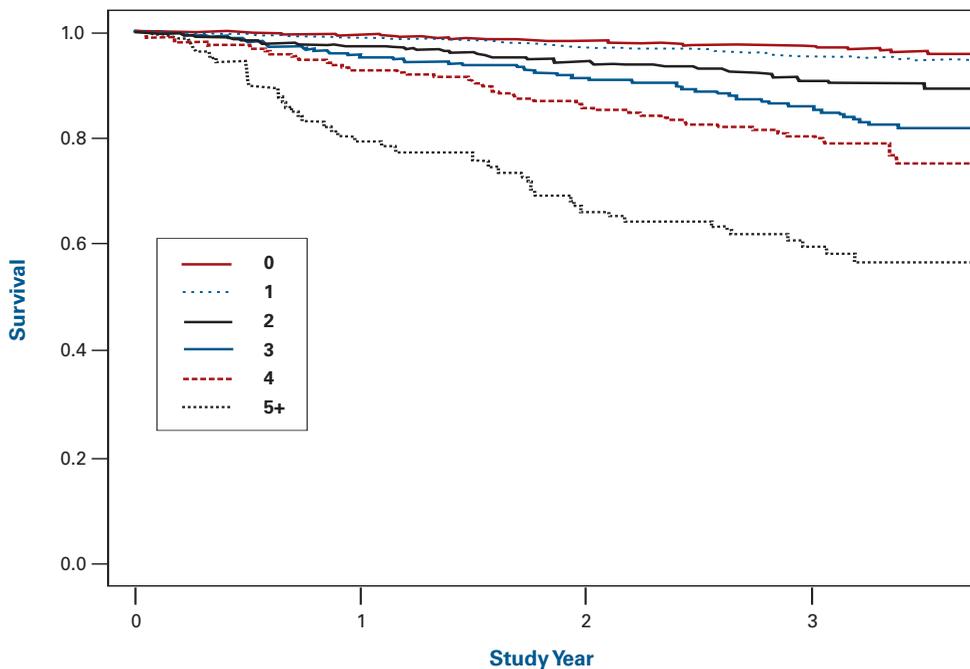
gories variable, Akaike's information criterion was 4979.4. For this determination, lower values for Akaike's information criterion were considered to have a better fit of the data. These criteria suggest that including severity as a linear term provided the best model fit for mortality. In addition, we compared the ROC curve for the DCSI with that of a simple count of complications (Figure 2). The ROC curves show that the DCSI is a slightly better indicator of mortality compared with a simple count of complications. Comparing AUC values between the 2 measures (DCSI = 0.76 vs complications count = 0.74, $P < .0001$) suggests that the DCSI is a slightly better predictor of 2-year mortality than a simple count of complications, although both appear to predict mortality well.

DISCUSSION

The current study showed that number and severity of diabetes complications both are independently associated with increased risk of mortality and hospitalization in a population-based sample of primary care patients with diabetes. When directly compared, the DCSI performed slightly better than a simple count of diabetes complications to predict mortality and hospitalizations, although both the DCSI and the count of complications performed well.

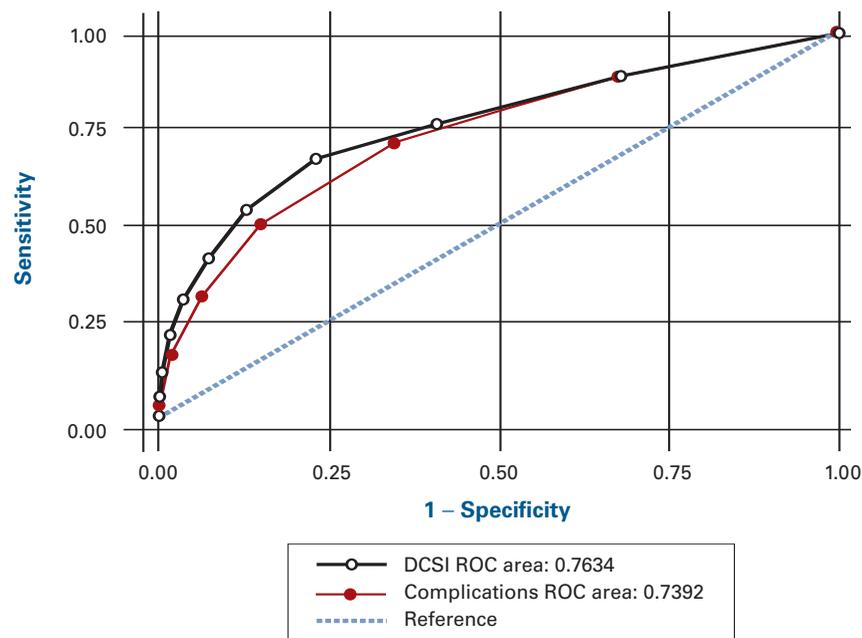
Prior studies of patients with diabetes have used retrospective cohort

■ **Figure 1.** Kaplan-Meier Survival Curves Stratified by Complications Count



Patients with a greater number of complications at baseline had worse mortality.

■ **Figure 2.** Receiver Operating Characteristic (ROC) Curves Comparing the Diabetes Complications Severity Index (DCSI) With the Complications Count



The AUC for the DCSI (0.76) was significantly different from the AUC for the complications count (0.74) ($P < .0001$). AUC indicates area under the curve.

■ **Table 4.** Poisson Regression Model of Risk of Hospitalization

Characteristic	Risk of Hospitalization	
	Unadjusted HR (95% CI)	Adjusted HR (95% CI)*
Age	1.04 (1.03, 1.04)	1.05 (1.04, 1.05)
Race	0.78 (0.67, 0.91)	0.98 (0.84, 1.15)
Insulin use	1.94 (1.72, 2.18)	2.16 (1.89, 2.48)
Duration of diabetes	1.022 (1.016, 1.027)	1.003 (0.997, 1.009)
Smoking	0.92 (0.74, 1.15)	1.45 (1.16, 1.81)
DCSI (linear)	1.36 (1.34, 1.39)	1.29 (1.25, 1.32)
DCSI (categorical)		
0	Reference	Reference
1	1.40 (1.14, 1.72)	1.30 (1.06, 1.61)
2	2.25 (1.84, 2.76)	1.89 (1.54, 2.33)
3	3.36 (2.72, 4.14)	2.55 (2.05, 3.17)
4	5.05 (4.07, 6.26)	3.38 (2.69, 4.25)
≥5	7.70 (6.41, 9.24)	4.96 (4.03, 6.10)
Complications (categorical)		
0	Reference	Reference
1	1.65 (1.36, 2.00)	1.48 (1.22, 1.80)
2	2.81 (2.27, 3.41)	2.27 (1.86, 2.77)
3	4.61 (3.78, 5.63)	3.12 (2.52, 3.87)
4	6.47 (5.24, 8.00)	4.13 (3.27, 5.20)
≥5	10.61 (8.38, 13.42)	6.56 (5.04, 8.53)

*Adjusted for age, sex, race, diabetes duration, glycosylated hemoglobin level, body mass index, current smoking, and insulin use.
HR indicates hazard ratio; CI, confidence interval; DCSI, Diabetes Complications Severity Index.

As several prior epidemiologic studies have shown, diabetes substantially increases the risk of all-cause and cardiovascular mortality for both men and women by 2- to 4-fold.^{15,16,19,32,33} Miettinen and colleagues showed that diabetes increased mortality significantly after the first myocardial infarction.³⁴ In the current study, we found that the DCSI (capturing the type and severity of complications) versus a simple count of complications was more strongly associated with mortality and hospitalization.

The current study expands the existing literature by evaluating concurrent risk of mortality associated with cardiovascular disease, nephropathy, retinopathy, peripheral vascular disease, and neuropathy as indicators of diabetes severity. Several studies have shown that other individual complications such as underlying severe diabetic retinopathy,^{35,36} early and severe diabetic nephropathy, peripheral vascular disease, hyperglycemia, and metabolic abnormalities increase the risk of mortality. In both younger and older diabetic subjects, proliferative diabetic retin-

opathy compared with no diabetic retinopathy was associated with an increased risk of cardiovascular disease³⁵ and mortality.³⁶⁻³⁸ In addition, early (microalbuminuria) and overt diabetic nephropathy have been shown to be risk factors for cardiovascular disease and mortality.³⁹ Patients with later stages of chronic kidney disease and advanced diabetic nephropathy have a greater risk of complications and mortality than patients without renal disease.⁴⁰ In addition, data from the Coronary Artery Surgery Study registry showed that patients with lower extremity arterial disease had a 1.2-fold greater risk of death than patients without baseline lower extremity arterial disease.⁴¹ The current study augments these data by providing an estimation of risk of death and hospitalization in relation to the number and severity of complications, which is useful in actual clinical settings, where more than 1 complication often is present.

analyses to develop prediction rules for incident cardiovascular disease (eg, the Framingham Heart Study³¹ and the United Kingdom Prospective Diabetes Study¹² risk engines), for short-term complications,¹³ for risk management or prediction,¹⁴ and for cost analysis.²⁷ However, to our knowledge, no severity index based on laboratory and automated data has been developed and tested to predict mortality and hospitalizations in patients with diabetes. The DCSI differs from other risk engines in that it is an index to better identify severity and gives researchers or health plan administrators an easy, reliable method to risk-adjust for severity of diabetes when self-reported variables or additional laboratory variables are not available. Given that healthcare plans have limited resources to improve disease management for diabetes, this index should allow healthcare plans to target these resources to the highest risk group of patients.

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Duration of diabetes also has been determined to be an independent risk factor for an increased risk of cardiovascular events¹⁸ and for development of certain complications such as microalbuminuria.⁴² We found that duration was independent of and highly correlated with both the individual count of complications and the severity index. Duration became a less significant predictor of mortality after the addition of either complications count or the severity index to the Cox models. The development of diabetes complications may serve as a surrogate marker for diabetes duration. Because the diagnosis of type 2 diabetes often is not made until years after its onset, the number and severity of complications may better represent biologic markers of duration of diabetes after adjustment for other potential confounding variables.⁴³

This study has several potential limitations. The data obtained at baseline were observational, and as such, not all laboratory data were collected on all patients at entry into the study. However, all prior events were collected by the automated databases and because the categorization of severity was most dependent on prior hospitalizations, this limitation should be minimal. In addition, because the study was based on clinical practice at the time of data ascertainment at a single healthcare system in 1 geographic region of the United States, it may not be representative of populations in other regions of the United States. The study population, however, has been shown to be representative of Washington State population, with the exception of lower representation in the highest income status. A final limitation is that the DCSI is an unweighted index that did not independently test adverse outcomes associated with each complication; however, the advantage of the DCSI is its ease of use by clinicians, researchers, and healthcare plans.

CONCLUSION

We conclude that both the number of diabetes complications and the severity of those complications are associated with a greater risk of mortality and hospitalizations. The DCSI should prove useful as a tool for adjusting for baseline severity of disease in populations with diabetes. Our severity index performed slightly better than a simple count of complications. Because diabetes complications predict risk of death, the DCSI may be a useful tool for case-mix adjustment and for targeting high-risk patients in large populations for which automated medical records data are available.

Take-away Points

The Diabetes Complications Severity Index (DCSI), developed from automated clinical baseline data of a primary care diabetes cohort, was compared with a simple count of diabetes complications to predict mortality and hospitalizations.

- Both the count and severity of complications were associated with an increased risk of mortality and hospitalizations.
- Relative to a count of complications, the DCSI performed slightly better and appears to be a useful tool for prediction of mortality and risk of hospitalization.

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