The Incidence of Diabetes Among 2,777,768 Veterans With and Without Recent SARS-CoV-2 Infection

Pandora L. Wander,[1,2] Elliott Lowy,[1,3] Lauren A. Beste,[1,2] Luis Tulloch-Palomino,[1,2] Anna Korpak,[1] Alexander C. Peterson,[1] Steven E. Kahn,[1,2] and Edward J. Boyko[1,2]

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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

To examine associations of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection/coronavirus disease 2019 with incident diabetes.

RESEARCH DESIGN AND METHODS

We conducted a retrospective cohort study using Veterans Health Administration data. We defined all patients without preexisting diabetes with one or more nasal swabs positive for SARS-CoV-2 (1 March 2020–10 March 2021; *n* = 126,710) as exposed and those with no positive swab and one or more laboratory tests (1 March 2020–31 March 2021; *n* = 2,651,058) as unexposed. The index date for patients exposed was the date of first positive swab and for patients unexposed a random date during the month of the qualifying laboratory test. We fit sex-stratified logistic regression models examining associations of SARS-CoV-2 with incident diabetes within 120 days and all follow-up time through 1 June 2021. A subgroup analysis was performed among hospitalized subjects only to help equalize laboratory surveillance.

RESULTS

SARS-CoV-2 was associated with higher risk of incident diabetes, compared with no positive tests, among men (120 days, odds ratio [OR] 2.56 [95% CI 2.32–2.83]; all time, 1.95 [1.80–2.12]) but not women (120 days, 1.21 [0.88–1.68]; all time, 1.04 [0.82–1.31]). Among hospitalized participants, SARS-CoV-2 was associated with higher risk of diabetes at 120 days and at the end of follow-up in men (OR 1.42 [95% CI 1.22–1.65] and 1.32 [1.16–1.50], respectively) but not women (0.72 [0.34–1.52] and 0.80 [0.44–1.45]). Sex * SARS-CoV-2 interaction *P* values were all <0.1.

CONCLUSIONS

SARS-CoV-2 is associated with higher risk of incident diabetes in men but not in women even after greater surveillance related to hospitalization is accounted for.

Diabetes is a major contributor to health care spending in the U.S., costing over $327 billion in 2017 (1,2). The incidence and prevalence of diabetes continue to rise at startling rates across all age-groups (3), and by 2050, 33% of all U.S. adults could have diabetes (4). Sequelae of infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)/coronavirus disease 2019 (COVID-19) extend far

[1]Veterans Affairs Puget Sound Health Care System, Seattle, WA
[2]Department of Medicine, University of Washington, Seattle, WA
[3]Department of Health Systems and Population Health, University of Washington, Seattle, WA

Corresponding author: Pandora L. Wander, lwander@u.washington.edu

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beyond the acute postviral recovery period (5–7) and appear to involve both pulmonary and extrapulmonary complications, including metabolic diseases. Thus, the COVID-19 pandemic may contribute to a higher diabetes incidence wherever SARS-CoV-2 infection has affected a substantial proportion of the population.

A link between SARS-CoV-2/COVID-19 infection and new-onset diabetes has been postulated (8). Previous reports have estimated the magnitude of the association of SARS-CoV-2 with new-onset diabetes as one of many outcomes (5–7). However, these previous reports may have underestimated the risk of incident diabetes after COVID-19 by defining new-onset diabetes based only on diagnostic codes, potentially missing cases by not examining pharmacy records for glucose-lowering medications or laboratory findings for glucose or hemoglobin A_{1c} (A1C) values. Estimates of the magnitude of the association in these reports may, therefore, be biased by misclassification of diabetes at baseline or follow-up or by surveillance bias due to increased frequency of laboratory testing among individuals diagnosed with and treated for COVID-19 compared with individuals not diagnosed with COVID-19. We sought to extend previous reports by *1*) systematically excluding individuals with preexisting diabetes, *2*) defining diabetes based on not only diagnostic codes but also laboratory measurements of glucose and A1C and use of glucose-lowering medications, and *3*) using sample restriction to evaluate for the presence of surveillance bias.

RESEARCH DESIGN AND METHODS

Study Setting and Study Population

In this analysis we used data from the Corporate Data Warehouse (CDW), a data repository derived from the electronic medical record of the Veterans Health Administration (VHA), the largest integrated health care system in the U.S. (9). VA (Veterans Affairs) Informatics and Computing Infrastructure (VINCI) has extracted CDW data to create the COVID-19 Shared Data Resource containing analytic variables for all patients tested for SARS-CoV-2, which we accessed for this research (10). We defined all patients with one or more nasal swabs positive for SARS-CoV-2 between 1 March 2020 and 10 March 2021 as exposed. Most tests were performed in VA laboratories using U.S. Food and Drug Administration–approved RealTime SARS-CoV-2 Assay (Abbott Laboratories) or Xpert Xpress SARS-CoV-2 assay (Cepheid). A small number was sent to outside laboratories. All laboratories were required to conform to standards for laboratory reporting set out in a VHA operational memo (11 February 2020) from the Deputy Under Secretary for Health for Operations and Management. Only tests performed by the Public Health Reference Laboratory of the VA Palo Alto Health Care System or by state and local health departments were allowed. Veterans receiving VHA care (i.e., with any inpatient or outpatient clinical encounter between 1 June 2019 and 30 May 2021) without a positive nasal swab for SARS-CoV-2 and with any laboratory test performed between 1 March 2020 and 31 March 2021 were chosen as the unexposed comparison group. For SARS-CoV-2–positive individuals, the index date was defined as the date the first positive test result was returned. For individuals without a positive test for SARS-CoV-2, the index date was defined as a random date during a month in which they had any laboratory test performed.

Individuals were excluded if they *1*) had one or more abnormal laboratory values from plasma or serum (random glucose $\geq$200 mg/dL, fasting glucose $\geq$126 mg/dL, 2-h glucose from an oral glucose tolerance test $\geq$200 mg/dL) or whole blood (A1C $\geq$6.5%); *2*) had any single ICD-9, Clinical Modification (ICD-9-CM), or ICD-10, Clinical Modification (ICD-10-CM), codes of 250 or E08–E13; or *3*) received any glucose-lowering medication after 1 January 2000. Further, all participants were required to have at least one laboratory value that did not support a diagnosis of diabetes (random glucose $\leq$199 mg/dL, fasting glucose $\leq$125 mg/dL, 2-h glucose $\leq$199 mg/dL, or A1C $\leq$6.4%) measured during the same time period. Among VHA patients screened for eligibility in the current analysis, the proportion of SARS-CoV-2–positive individuals with preexisting diabetes was 45.2% (n = 104,309). The proportion of individuals without a positive test with preexisting diabetes was 42.0% (n = 1,917,638). The final sample size was n = 126,710 diagnosed with COVID-19 and n = 2,651,058 with no known COVID-19 diagnosis. To address the possibility that individuals diagnosed with COVID-19 might receive closer surveillance after COVID-19 diagnosis, we also identified a subgroup restricted to participants who were hospitalized in the 30 days after the index date: n = 12,418 positive for SARS-CoV-2 and n = 43,323 with no positive swabs for SARS-CoV-2. The study was approved by the institutional review board at VA Puget Sound Health Care System with the requirement for informed consent waived.

Variables

We collected data on age, sex, race/ethnicity, and facility location. BMI was defined as weight in kilograms divided by the square of height in meters. Veterans chose any number of race/ethnicity responses, which were categorized as selected/not selected for each individual response (e.g., White yes/no). Smoking status was classified as current, former, or never based on self-report in VHA's national health factors database. If no smoking code was entered, the participant was classified as never smoked. We classified facility location using Veterans Integrated Service Networks, which comprise 18 regional systems of care within VHA. Participants were followed through 1 June 2021 for the development of diabetes defined as *1*) two or more abnormal laboratory values from plasma or serum (random glucose $\geq$200 mg/dL, fasting glucose $\geq$126 mg/dL, 2-h glucose from an oral glucose tolerance test $\geq$200 mg/dL) or whole blood (A1C $\geq$6.5%) (11); *2*) two outpatient or one inpatient ICD-10 codes of E08–E13; or *3*) receipt of an initial and one refill prescription of a glucose-lowering medication. To avoid capturing transient hyperglycemia related to treatment with systemic corticosteroids, we excluded plasma glucose values collected within 30 days of the index date for all participants. We included diagnostic codes E08 (diabetes due to underlying condition) and E09 (drug- or chemical-induced diabetes mellitus) because we did not want to miss any incident cases of diabetes that were miscoded. We did not include E14 (unspecified diabetes) because it is not used in the CDW to code diabetes. For the full cohort, incident diabetes was defined as diabetes that occurred *1*) up to 120 days after the

index date or *2*) between the index date and 1 June 2021. For hospitalized participants, incident diabetes was defined as diabetes that occurred *1*) between the date of admission and 120 days after the index date or *2*) between the admission date and 1 June 2021.

Statistical Analyses

We used DAGitty (12) for generation of a directed acyclic graph (DAG) to assist in model selection for confounder adjustment. We adjusted for variables thought to be causally associated with both likelihood of testing positive for SARS-CoV-2 and diagnosis of diabetes based on our DAG. By using these criteria, we determined that certain variables (e.g., COVID-19 treatments) would not be confounders. We examined for the presence of multiplicative first-order interactions of sex at birth with SARS-CoV-2 infection in models including all participants and fit sex-stratified logistic regression models assessing associations of COVID-19 diagnosis with incident diabetes in the full cohort and the group restricted to individuals hospitalized within 30 days after the index date. Analyses were adjusted for age, race/ethnicity, BMI, tobacco use, and facility location. We used multiple imputation with 10 sets of imputations for analyses that included BMI due to ∼20% missing values for this variable. Given that the incidence of diabetes in this cohort was <5% overall, the relative odds is expected to be approximately equal to the relative risk. For ease of interpretation, we reported the latter estimate in describing our results.

RESULTS

Mean ± SD age of participants was 59.0 ± 17.1 years, and 14% percent were female (n = 376,274). Five percent (n = 126,710) had one or more positive respiratory swab for SARS-CoV-2 (Table 1). Of individuals without a positive test for SARS-CoV-2, 8.5% (225,935) had a documented negative test for SARS-CoV-2. During the 30 days after the index date, 2% (n = 55,741) were hospitalized. Among SARS-CoV-2–positive individuals, 0.5% (n = 484 of 104,376) developed diabetes by 120 days and 0.6% (n = 748 of 126,710) developed diabetes during available follow-up time through 1 June 2021 (mean 193 days [range 32–456]). Among individuals without a positive test for SARS-CoV-2, 0.2% (n = 4,024 of 2,079,281) developed diabetes by 120 days and 0.3% (n = 8,402 of 2,651,058) developed diabetes during available study follow-up time (mean 239 days [range 32–457]). Among the subgroup of SARS-CoV-2–positive individuals who were hospitalized in the 30 days after the index date, 2.8% (n = 290 of 10,181) developed diabetes by 120 days and 3.2% (n = 400 of 12,418) developed diabetes over all available follow-up time. Among the subgroup of individuals without a positive test for SARS-CoV-2 who were hospitalized in the 30 days after the index date, 1.7% (n = 590 of 33,785) developed diabetes by 120 days and 2.2% (n = 952 of 43,323) developed diabetes over all available follow-up time. Among all participants, a positive respiratory swab for SARS-CoV-2 was associated with higher risk of diabetes at 120 days and over all available follow-up time compared with no positive respiratory swab after adjustment for age, race/ethnicity, BMI, tobacco use, and facility location in men (adjusted odds ratio [2.56] [95% CI 2.32–2.83] and 1.95 [1.80–2.12], respectively) but not women (1.21 [95% CI 0.88–1.68] and 1.04 [0.82–1.31]). Among hospitalized participants, a respiratory swab positive for SARS-CoV-2 was associated with higher risk of diabetes at 120 days and over all available follow-up time compared with no positive respiratory swabs in men (1.42 [1.22–1.65] and 1.32 [95% CI 1.16–1.50]). Among women who were hospitalized in the 30 days after the index date, a respiratory swab positive for SARS-CoV-2 was not associated with higher risk of diabetes at 120 days or over all follow-up time (0.72 [0.34–1.52] and 0.80 [0.44–1.45]) (Tables 2 and 3). P values for sex * SARS-CoV-2 interaction terms were significant at a threshold of <0.1 for all participants ($P_{interaction}$ at 120 days and over all follow-up time both <0.001) and among hospitalized participants ($P_{interaction}$ at 120 days = 0.072, over all follow-up time = 0.089).

In men, among all participants, factors associated with higher risk of incident diabetes at either time point included older age (60–69, 70–79, and ≥80 years compared with the reference category of 50–59 years), Black (vs. non-Black) race, Latinx (vs. non-Latinx) ethnicity, BMI (30–34.9, 35–39.9, and ≥40 kg/m^2 compared with the reference category of 18.5–24.9 kg/m^2), and former or current tobacco use. Among hospitalized participants, additional factors associated with higher risk of incident diabetes at either time point included older age (60–69, 70–79, and ≥80 years compared with the reference category of 50–59 years) and higher BMI (35–39.9, and ≥40 kg/m^2 compared with the reference category of 18.5–24.9 kg/m^2). In women, among all participants, factors associated with higher risk of incident diabetes at either time point included BMI (25–29.9, 30–34.9, 35–39.9, and ≥40 kg/m^2 compared with the reference category of 18.5–24.9 kg/m^2) and current tobacco use. Among hospitalized participants, no additional factors were significantly associated with higher risk of incident diabetes at either time point.

CONCLUSIONS

In this large national cohort of veterans, the presence of a positive respiratory swab for SARS-CoV-2 was associated with a higher risk of diabetes at 120 days and over all study follow-up time, at an average of 237 days of follow-up, in the general VHA population and among individuals requiring hospitalization in the 30 days after enrollment. Associations were present in men but not women. To our knowledge, this is among the largest U.S.-based studies to examine associations of SARS-CoV-2 infection with incident diabetes; is the first study with rigorous exclusion of individuals with undiagnosed diabetes prior to infection on the basis of not only diagnostic codes but also laboratory testing and pharmacy information; and is the first study with examination of sex-specific associations. In addition, we assessed whether diagnostic surveillance bias might have accounted for this association, since patients recently diagnosed with COVID-19 are likely to have more medical encounters that might reveal presence of diabetes. We found that the higher risk of diabetes among individuals with a positive respiratory swab for SARS-CoV-2 persisted when we restricted our analyses to infected and uninfected patients who had recently been hospitalized, with hospitalization as

Table 1—Characteristics of VHA veterans without preexisting diabetes with stratification by presence of one or more respiratory swabs positive for SARS-CoV-2, March 2020–March 2021

	All participants		Participants hospitalized in the 30 days after index date	
	No respiratory swabs positive for SARS-CoV-2	One or more respiratory swabs positive for SARS-CoV-2	No respiratory swabs positive for SARS-CoV-2	One or more respiratory swabs positive for SARS-CoV-2
n	2,651,058	126,710	43,323	12,418
Age, years	59.2 ± 17.1	56.2 ± 17.3	61.1 ± 17.3	65.3 ± 16.7
Age category, years				
19–39	462,954 (17)	28,095 (22)	6,940 (16)	1,238 (10)
40–49	334,553 (13)	19,481 (15)	4,272 (10)	1,038 (8)
50–59	433,812 (16)	23,468 (19)	6,331 (15)	1,755 (14)
60–69	509,529 (19)	21,091 (17)	10,077 (23)	2,528 (20)
70–79	651,650 (25)	23,862 (19)	10,236 (24)	3,542 (29)
≥80	258,560 (10)	10,713 (8)	5,467 (13)	2,317 (19)
Female sex at birth	359,257 (14)	17,017 (13)	3,867 (9)	912 (7)
Race/ethnicity				
White	1,918,484 (72)	87,758 (69)	30,855 (71)	7,972 (64)
Black	439,492 (17)	26,188 (21)	9,236 (21)	3,309 (27)
Latinx	183,487 (7)	13,685 (11)	2,703 (6)	1,204 (10)
Other	257,942 (10)	9,758 (8)	2,889 (7)	881 (7)
BMI, kg/m^2	29.2 ± 5.64	30.3 ± 5.9	27.8 ± 5.91	29.4 ± 6.39
BMI category, kg/m^2				
<18.5	19,390 (1)	715 (1)	962 (3)	185 (2)
18.5–24.9	373,342 (22)	13,946 (16)	10,026 (31)	2,161 (23)
25–29.9	660,558 (38)	30,326 (35)	11,098 (35)	3,210 (34)
30–34.9	438,655 (25)	24,522 (29)	6,491 (20)	2,321 (24)
35–39.9	168,901 (10)	10,930 (13)	2,393 (7)	1,017 (11)
≥40	72,227 (4)	5,309 (6)	1,071 (3)	593 (6)
Tobacco use				
Never	986,657 (37)	49,464 (39)	9,287 (21)	3,719 (30)
Former	878,530 (33)	44,697 (35)	13,049 (30)	4,985 (40)
Current	785,871 (30)	32,549 (26)	20,987	3,714 (30)
Proportion with diabetes at 120 days*	4,024 (0.19)	484 (0.46)	590 (1.75)	290 (2.85)
Proportion with diabetes over available follow-up time	8,402 (0.32)	748 (0.60)	952 (2.20)	400 (3.22)

Data are presented as mean ± SD for continuous variables and *n* (%) for categorical variables. *P* values for comparisons of participants who were SARS-CoV-2 positive with participants without a positive test for SARS-CoV-2 were all significant at $P < 0.001$. *All participants: *n* followed for diabetes until 120 days = 2,183,657 (*n* = 2,079,281 without a positive test for SARS-CoV-2 and *n* = 104,376 with a positive test). Hospitalized participants: *n* followed for diabetes until 120 days = 43,966 (*n* = 33,785 without a positive test for SARS-CoV-2 and *n* = 10,181 with a positive test).

a proxy for opportunities for diagnostic surveillance.

Other infections (e.g., *Helicobacter pylori*, *Mycobacterium tuberculosis*, and hepatitis C) have previously been implicated in the development of type 2 diabetes (13). Reports of increased hyperglycemia and ketoacidosis among individuals acutely ill with COVID-19 suggest that SARS-CoV-2 might play a causal role in new-onset postviral diabetes (14). Mechanisms hypothesized to contribute to loss of β-cell function after COVID-19 include *1*) direct β-cell injury, *2*) "bystander" effects on β-cells due to infection of other cells in the islet, exocrine pancreas, or microvasculature; or *3*) systemic effects on insulin resistance or the inflammatory milieu due to glucocorticoid treatment or SARS-CoV-2 infection itself (15). At this writing, however, the primary mechanism remains unclear. Future studies quantifying insulin secretion and sensitivity after COVID-19 are urgently needed to clarify mechanisms and guide therapy.

Existing research has in general shown an association between COVID-19 infection and higher prevalence and incidence of type 2 diabetes but has many important limitations, including lack of adjustment for BMI or other measures of body composition and lack of use of glucose and pharmacy data to identify diabetes, leading to inclusion of undiagnosed cases at onset of infection and underascertainment of cases during follow-up. A meta-analysis (eight studies, $n = 3{,}711$ COVID-19 patients, 492 cases of diabetes) reported a pooled prevalence of new or undiagnosed diabetes of 14.4% (95% CI 5.9–25.8) among hospitalized individuals (16) compared with 7.4% among hospitalized individuals in the current report; however, because

Table 2—Adjusted ORs (95% CI) for incident diabetes at 120 days in comparisons of veterans with and veterans without a respiratory swab positive for SARS-CoV-2, March 2020–March 2021

	All participants				Participants who were hospitalized in the 30 days after index date			
	Men, *n* = 1,887,188		Women, *n* = 296,469		Men, *n* = 40,260		Women, *n* = 3,453	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
SARS-CoV-2 positive	2.56	2.32–2.83	1.21	0.88–1.68	1.42	1.22–1.65	0.72	0.34–1.52
Age category, years								
19–39	0.31	0.26–0.36	0.95	0.77–1.18	0.25	0.16–0.40	0.47	0.20–1.12
40–49	0.70	0.62–0.80	0.96	0.76–1.20	0.77	0.54–1.10	0.37	0.14–1.03
50–59	ref		ref		ref		ref	
60–69	1.21	1.10–1.34	1.01	0.79–1.29	1.46	1.15–1.87	0.86	0.41–1.83
70–79	1.16	1.05–1.27	0.62	0.37–1.04	1.77	1.39–2.25	1.77	0.72–4.36
≥80	1.12	0.98–1.27	1.09	0.51–2.34	1.88	1.43–2.46	0.83	0.18–3.89
Race/ethnicity								
White (vs. non-White)	1.09	0.85–1.40	1.31	0.75–2.29	0.72	0.42–1.25	3.43	0.50–23.39
Black (vs. non-Black)	1.61	1.25–2.09	1.44	0.82–2.55	0.92	0.52–1.60	4.41	0.66–29.33
Latinx (vs. non-Latinx)	1.49	1.31–1.70	1.06	0.77–1.48	1.21	0.90–1.64	0.74	0.17–3.21
Other	1.33	1.01–1.75	0.72	0.39–1.33	0.94	0.51–1.71	5.35	0.59–48.14
BMI category, kg/m^2								
<18.5	1.25	0.95–1.64	1.30	0.46–3.64	0.87	0.531.45	1.79	0.39–8.27
18.5–24.9	ref		ref		ref		ref	
25–29.9	0.94	0.85–1.04	1.49	1.03–2.17	1.02	0.84–1.25	0.79	0.28–2.22
30–34.9	1.25	1.12–1.40	2.31	1.62–3.28	1.25	0.99–1.57	1.16	0.48–2.79
35–39.9	1.82	1.61–2.07	3.40	2.33–4.96	1.55	1.15–2.09	0.79	0.24–2.63
≥40	3.65	3.21–4.16	7.56	5.32–10.73	2.43	1.75–3.36	2.07	0.73–5.82
Tobacco use								
Never	ref		ref		ref		ref	
Former	1.20	1.11–1.31	1.06	0.86–1.32	0.90	0.74–1.09	1.70	0.85–3.43
Current	1.61	1.49–1.75	1.43	1.18–1.73	1.00	0.83–1.21	0.93	0.45–1.91

Models additionally adjusted for geographic location by Veterans Integrated Service Networks location.

the meta-analysis included estimates of both new-onset and previously undiagnosed diabetes, the estimates cannot be interpreted as incidence estimates, which might account for the differences seen. Among enrollees aged 18–65 years in the UnitedHealth Group Clinical Discovery Database (*n* = 193,113), the hazard ratio (HR) for diabetes was 2.47 (95% CI 1.14–5.38) in comparison of individuals with COVID-19 with a propensity score–matched comparator cohort with viral lower respiratory tract illness (5). Study individuals with COVID-19 were younger on average (41.7 vs. 56.2 years) and among individuals with COVID-19 there was a higher proportion of female patients (52.4% vs. 13.4%) compared with the current cohort. Importantly, this study did not adjust for BMI, a potentially important confounder in the association of SARS-CoV-2 infection with incident diabetes, and glucose concentration, A1C, and pharmacy data were not included in the diabetes case definition. These differences in methodology and populations—or surveillance bias due to increased screening among post–COVID-19 patients—may contribute to the higher magnitude of the association reported in the previous study.

In a study conducted with use of VHA data earlier in the pandemic (*n* = 73,435 individuals with COVID-19) (6), HRs for the following diabetes-related diagnostic codes were higher for individuals diagnosed with COVID-19 compared with nonhospitalized VHA users who were not diagnosed with COVID-19 in the interval between 30 days and 6 months after infection: diabetes without complication (HR 1.39 [95% CI 1.28–1.52]), diabetes with complication (1.36 [1.24–1.49]), type 2 diabetes (1.44 [1.30–1.60]), and diabetes due to underlying conditions, drug- or chemical-induced diabetes, or other unspecified diabetes type (1.25 [1.03–1.52]) (6). Risk of type 1 diabetes was not significantly increased. These HRs are similar in magnitude to the OR among hospitalized men in our study. In an analysis of individuals hospitalized with COVID-19 in England (*n* = 47,780) and control subjects taken from the general population, the incidence rate ratio of new-onset type 1 or type 2 diabetes identified by diagnostic codes in comparisons of individuals with COVID-19 and control subjects was 1.5 (95% CI 1.4–1.6) (7)—very similar to previously reported estimates (6) and findings among men in the current report.

We also found that associations were present among men but not women. Female sex is associated with a lower risk of COVID-19 mortality (17). Some authors have hypothesized that this may be due to sex differences in immune responses (18). A similar phenomenon may underlie the results we found in the current analysis. This is an area deserving of future study with potential to inform novel prevention strategies.

Our study has several strengths, most importantly, the large, well-characterized national sample. We used ICD codes, laboratory values, and/or glucose-lowering medication use to define diabetes—a more sensitive approach than strategies that rely entirely on diagnostic codes (19).

Table 3—Adjusted ORs (95% CI) for incident diabetes for all available follow-up time in comparisons of veterans with and without a respiratory swab positive for SARS-CoV-2, March 2020–March 2021

	All participants				Participants who were hospitalized in the 30 days after the index date			
	Men, *n* = 2,401,494		Women, *n* = 376,274		Men, *n* = 50,962		Women, *n* = 4,643	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
SARS-CoV-2 positive	1.95	1.80–2.12	1.04	0.82–1.31	1.32	1.16–1.50	0.80	0.44–1.45
Age category, years								
19–39	0.31	0.28–0.34	0.85	0.74–0.99	0.27	0.19–0.38	0.53	0.28–1.01
40–49	0.72	0.66–0.78	0.83	0.71–0.97	0.71	0.54–0.94	0.26	0.10–0.63
50–59	ref		ref		ref		ref	
60–69	1.19	1.11–1.27	0.84	0.72–0.99	1.32	1.09–1.59	0.79	0.43–1.44
70–79	1.07	1.00–1.14	0.58	0.41–0.81	1.54	1.28–1.86	1.37	0.63–2.95
≥80	0.96	0.87–1.05	0.60	0.32–1.14	1.54	1.24–1.92	0.75	0.21–2.61
Race/ethnicity								
White (vs. non-White)	1.07	0.90–1.28	1.02	0.70–1.47	0.86	0.55–1.35	2.18	0.40–11.95
Black (vs. non-Black)	1.53	1.27–1.84	1.10	0.75–1.61	1.11	0.71–1.76	2.82	0.52–15.36
Latinx (vs. non-Latinx)	1.35	1.22–1.48	1.03	0.83–1.29	1.26	0.99–1.60	0.69	0.21–2.30
Other	1.17	0.96–1.42	0.51	0.34–0.78	1.04	0.63–1.70	3.78	0.57–24.93
BMI category, kg/m^2								
<18.5	1.18	0.93–1.50	1.41	0.67–2.96	0.90	0.58–1.41	1.19	0.28–5.03
18.5–24.9	ref		ref		ref		ref	
25–29.9	1.01	0.93–1.09	1.74	1.35–2.23	1.02	0.87–1.20	0.78	0.35–1.72
30–34.9	1.45	1.33–1.58	2.66	2.04–3.46	1.26	1.04–1.52	1.13	0.54–2.35
35–39.9	2.13	1.95–2.33	4.30	3.26–5.67	1.53	1.17–1.99	1.53	0.70–3.37
≥40	3.95	3.60–4.34	7.87	6.08–10.19	2.43	1.85–3.18	2.26	0.98–5.20
Tobacco use								
Never	ref		ref		ref		ref	
Former	1.17	1.10–1.24	1.31	1.14–1.50	0.95	0.81–1.11	1.26	0.71–2.25
Current	1.54	1.45–1.63	1.41	1.24–1.61	1.09	0.93–1.27	0.95	0.54–1.65

Models additionally adjusted for geographic location by Veterans Integrated Service Networks location. Mean follow-up time was 193 days for individuals with a positive test for SARS-CoV-2 and 239 days for individuals without a positive test for SARS-CoV-2.

There are also some limitations. Findings may not be generalizable to populations that differ demographically from VHA patients, who are on average older with lower income and socioeconomic status (20) than the U.S. general population. Indicators of socioeconomic status are not available in VHA electronic health records; however, for individuals who are eligible, access to VHA care is provided without regard to income, which may attenuate associations of socioeconomic status with the likelihood of a positive test for SARS-CoV-2. Additionally, the proportion of women was low (14%); however, although women comprised only a small proportion of the sample, the number of female participants ($n = 376,274$) is adequate for robust statistical inference. In addition, because we included laboratory values and medication use as well as diagnostic codes, we were unable to distinguish subtypes of incident diabetes (type 1, type 2, or other). Further, although we conducted a subgroup analysis among the hospitalized to correct for diagnostic surveillance imbalance, there is still potential that surveillance bias may have occurred favoring detection of diabetes in the SARS-CoV-2–positive participants. We did not examine the role of prior glycemia below thresholds for diabetes diagnosis in the association of SARS-CoV-2 infection with incident diabetes, and we did not examine the role of systemic corticosteroid use in the pathogenesis of diabetes after SARS-CoV-2 infection or to what extent higher risk of diabetes was accounted for by this exposure. These are important areas deserving of future study. We did not ascertain admission diagnoses; however, cardiovascular disease is the leading cause of hospitalization in the VHA (21). Lastly, we did not identify SARS-CoV-2 infections that occurred outside VHA. This form of misclassification would tend to bias findings toward the null.

In conclusion, among veterans without prevalent diabetes, a COVID-19 diagnosis was associated with higher risk of incident diabetes even after increased surveillance related to hospitalization is accounted for. The magnitude of the association that we observed is greater than previous reports on this topic. Future research is needed to determine the clinical course of post–COVID-19 diabetes, assess pathophysiologic mechanisms, and optimize diabetes surveillance strategies among COVID-19 survivors.

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Author Contributions. P.L.W. conceived the project, designed the overall research plan, and wrote the first draft of the manuscript. E.L. analyzed data and reviewed and edited the manuscript. L.A.B. reviewed and edited the manuscript. L.T.-P. reviewed and edited the manuscript. A.K. contributed to the design and interpretation of the analyses and reviewed and edited the manuscript. A.C.P. contributed to the design and interpretation of the analyses and reviewed and edited the manuscript. S.E.K. contributed to interpretation of the analyses and reviewed and edited the manuscript. E.J.B. conceived the project, designed the overall research plan, and reviewed and edited the manuscript. P.L.W. and E.J.B. are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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