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Implications of COVID-19 Vaccination on Hospital Encounters and Outcomes

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Adverse events, including cardiac involvement, after vaccination for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) have been reported. We sought to evaluate trends of hospital encounters for vaccine recipients before and after vaccination. We analyzed patients who received the coronavirus disease 2019 (COVID-19) vaccine in the MedStar Health system (11 hospitals in Washington, District of Columbia and Maryland) from December 2020 through August 2021. We then compared hospital encounters (emergency department visits) of patients 60 days before a vaccine dose and 30 days after a vaccine dose, along with encounters related to the SARS-CoV-2 infection itself. The cohort included 5,217 patients who were vaccinated against COVID-19. Our analysis revealed a total of 6,751 emergency department visits, and we divided this total into 3 cohorts: fully vaccinated (n = 1,779), in vaccination window (n = 1,420), and before vaccination (n = 3,552). We found no significant association between vaccination and rate of presentation for acute coronary syndrome, pericarditis, myocarditis, heart failure, conduction abnormality, or noncardiac conditions. Further, encounters for complications related to SARS-CoV-2 infection decreased significantly from those before vaccination (5.4%) to those in vaccination window (4.2%) to those who were fully vaccinated (1.6%). These findings were consistent when all vaccinated encounters were combined into 1 cohort (fully vaccinated + in vaccination window). In conclusion, our analysis suggests that there is no significant association of COVID-19 vaccination with the rate of hospital encounters for cardiac disease, including acute coronary syndrome, pericarditis, myocarditis, congestive heart failure, and conduction abnormality. Further, administration of the vaccine resulted in a significant decrease in hospital encounters for SARS-CoV-2 infections and associated complications. **© 2022 Published by Elsevier Inc. (Am J Cardiol 2022;170:105−111)**

The coronavirus disease 2019 (COVID-19) pandemic, caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has led to substantial global impact.[1] Regulations and measures taken to reduce viral transmission, along with improvements in treatment, have resulted in lower disease incidence and improved outcomes in infected patients.[2] The greatest advancement has been the creation, approval, and implementation of vaccinations against SARS-CoV-2.[3] With the deployment of mass vaccination to the general public, there have been reports of vaccine-related adverse events. For example, the United States Food and Drug Administration issued a temporary hold on the administration of the Ad26. COV2. S vaccine (Janssen/Johnson and Johnson) due to a feared complication of cerebral venous sinus thrombosis.[4] Further, rare cases of cardiac inflammation following SARS-CoV-2 vaccination, particularly in mRNA vaccines (Pfizer-BioNTech and Moderna), have been reported.[5−8] In the present study, we describe our large healthcare system's experience of patients receiving the COVID-19 vaccine and its relation with adverse events by comparing hospital encounters (emergency department visits) of patients before and after a vaccine dose.

Methods

We analyzed patients who received the COVID-19 vaccine in the MedStar Health system (11 hospitals in Washington, District of Columbia and Maryland) from December 10, 2020 through August 13, 2021. All patients age ≥18 years with documented COVID-19 vaccinations administered inside the system through the electronic medical record (EMR) system or state registries were included.

Next, these vaccinated patients were evaluated for emergency department encounters in the 60 days before and 30 days after vaccine administration. Vaccination status was based on the vaccine being administered at a MedStar facility or verbally reported by the patient. This time frame was selected by the investigators to capture the clinical course of patients before and after receiving the vaccines. Further, 30 days after initial vaccine administration included both the first and second dose, thus the category of

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Table 1
Baseline characteristics Patient demographics and vaccine type received

	Overall (N = 5,217)	Pfizer (N = 3,146)	Moderna (N = 1,682)	Johnson & Johnson (N = 389)	p-Value
Demographics					
Age ± SD (years)	58.23±17.84	57.75±17.89	59.90±17.75	55.31±17.19	<0.001
Male	36.2%	33.9%	36.9%	50.9%	<0.001
Ethnicity					
White	37.0%	34.1%	43.4%	33.2%	<0.001
Black	54.2%	56.1%	49.5%	59.5%	<0.001
Asian	1.9%	2.2%	1.7%	1.0%	0.201
Multi-ethnicity	0.5%	0.5%	0.4%	0.5%	0.941
Native American	0.1%	0.1%	0.2%	0.0%	0.680
Other	6.0%	6.8%	4.7%	5.5%	0.010

SD = standard deviation.

"in vaccination window." The final diagnosis and inclusion in our analysis as the primary end point was based on the hospital-stay International Classification of Diseases, Tenth Revision (ICD-10) codes from our EMR system. In our EMR system, this ICD-10 code is identified as "active encounter".

Baseline characteristics were collected for all patients. The rate of hospital encounter during the 60 days before vaccination was compared with the 30 days after vaccination. ICD-10 diagnosis rates were reported on a per hospital encounter basis rather than a per patient basis. Vaccination status at each visit was categorized as before vaccination, in vaccination window, or fully vaccinated. Before vaccination was defined as the encounter occurring before receiving any vaccine dose. In vaccination window was defined as the encounter having occurred after 1 dose but before the second dose of the Pfizer (New York, New York)-BioNTech or Moderna vaccine. Fully vaccinated was defined as the encounter having occurred after the single dose Ad26. COV2. S vaccine (Janssen/Johnson and Johnson) or both doses of the Pfizer-BioNTech or Moderna vaccine. These cohorts were compared individually, and then further analysis was performed with the in vaccination window and fully vaccinated cohorts being combined. This study was conducted in accordance with the Declaration of Helsinki and was approved by our institutional review board.

Descriptive statistics such as frequencies, means, and standard deviations were used to describe the study population. A *t* test or analysis of variance was used to compare mean values of normally distributed data. 2-tailed Fisher's exact test or chi-square test was used to compare categoric variables. Statistical significance was considered to be a p value <0.05. All analyses were done in SAS 9.4 (SAS Institute, Cary, North Carolina). One author (B.C.C.) has full access to all the data in the study and takes full responsibility for its integrity and the data analysis.

Results

The cohort included 5,217 patients who received the COVID-19 vaccine, with 3,146 receiving the Pfizer-BioNTech vaccine, 1,682 receiving the Moderna vaccine, and 389 receiving the Ad26. COV2. S vaccine (Janssen/Johnson and Johnson). Our analysis revealed a total of 6,751 emergency department visits, and we divided this total into 3 cohorts: fully vaccinated (26.35%), in vaccination window (21.03%), and before vaccination (52.61%). Baseline characteristics are displayed in Table 1. In this cohort of vaccinated patients, the mean age was 58.23 ± 17.84 years, and the majority were women. The majority received the Pfizer-BioNTech vaccine (60.3%), with the remaining patients receiving the Moderna vaccine (32.2%) or the Johnson and Johnson vaccine (7.5%).

Table 2 summarizes the hospital encounters during the 60 days before receiving the vaccine (before vaccination) compared with the 30 days after vaccination (fully vaccinated). In the 30 days after vaccination, there was a significantly increased rate of hospital encounters for cerebrovascular events. However, this increased rate of cerebrovascular event presentations was only seen in the subset of fully vaccinated patients; it was seen less in the in vaccination window group. In addition, this trend was not seen when the 2 vaccination

Table 2
Hospital encounters based on vaccination statusHospital encounters based on vaccination status using International Classification of Diseases, Tenth Revision codes

	Overall (N = 6,751)	Fully Vaccinated (N = 1,779)	In Vaccination Window (N = 1,420)	Before Vaccination (N = 3,552)	p-Value
Cardiovascular					
Coronary artery disease*	12.9%	14.1%	12.4%	12.6%	0.247
Congestive heart failure	12.2%	13.0%	10.8%	12.4%	0.170
Conduction abnormalities	12.7%	13.8%	12.9%	12.1%	0.201
Valvular heart disease	3.9%	4.6%	3.5%	3.80%	0.52
Pericarditis	0.52%	0.62%	0.42%	0.51%	0.738
Myocarditis	0.04%	0.11%	0.00%	0.03%	0.256

(*continued*)

Table 2 (*Continued*)

	Overall (N = 6,751)	Fully Vaccinated (N = 1,779)	In Vaccination Window (N = 1,420)	Before Vaccination (N = 3,552)	p-Value
Hypertension without complications	42.6%	44.5%	42.5%	41.8%	0.168
Hypertension with complications	12.9%	13.4%	11.8%	13.1%	0.320
Hypotension	3.5%	3.7%	3.6%	3.4%	0.854
Peripheral vascular disease	6.8%	7.3%	5.8%	7.0%	0.236
Hyperlipidemia	27.1%	29.5%	27.7%	25.7%	0.012
Neurologic					
Cerebrovascular event	3.5%	4.6%	2.7%	3.2%	0.011
Neurological disorder	13.3%	13.1%	11.8%	13.9%	0.121
Peripheral neuropathy	8.2%	8.4%	7.7%	8.4%	0.752
Pulmonary					
Pulmonary embolism	0.8%	0.7%	0.7%	0.8%	0.826
Chronic lung disease	21.7%	22.5%	21.2%	21.5%	0.620
Pulmonary hypertension	2.7%	2.9%	2.3%	2.8%	0.555
Respiratory infection	7.1%	5.6%	5.4%	8.5%	<0.001
Gastrointestinal					
Obesity	9.2%	8.3%	9.7%	9.4%	0.294
Metabolic disorder	4.8%	4.7%	4.7%	4.9%	0.943
Malnutrition	2.5%	2.6%	2.1%	2.6%	0.547
Upper GI disorders	10.8%	10.5%	10.7%	11.0%	0.839
Lower GI disorders	0.8%	1.0%	0.5%	0.9%	0.284
Liver/gallbladder disease	4.4%	4.1%	4.7%	4.4%	0.700
Pancreatic disease	1.6%	1.5%	1.7%	1.5%	0.916
GI bleed	2.1%	1.7%	1.9%	2.3%	0.383
Hematological					
Anemia	1.1%	1.0%	1.2%	1.0%	0.833
Coagulopathy	2.8%	3.0%	2.5%	2.8%	0.618
White blood cell disorder	5.8%	6.0%	4.9%	6.0%	0.317
Genitourinary					
Renal disease	19.1%	20.0%	17.7%	19.1%	0.267
Electrolyte abnormalities	17.2%	17.7%	15.8%	17.5%	0.319
Urinary disorders	5.7%	5.9%	5.0%	5.9%	0.409
Urologic disorders	4.1%	4.6%	3.5%	4.0%	0.290
Gynecological disorders	2.9%	2.9%	3.0%	2.8%	0.939
Pregnancy	0.8%	0.9%	1.1%	0.6%	0.236
Other					
Musculoskeletal disorders	32.5%	35.7%	31.1%	31.5%	0.004
Diabetes	24.9%	26.1%	22.9%	25.1%	0.101
Trauma	15.5%	14.7%	15.6%	15.9%	0.533
Substance abuse	12.0%	10.6%	10.4%	13.4%	0.001
Infection	11.0%	9.7%	10.8%	11.7%	0.082
Psychiatric disorders	10.0%	9.6%	8.5%	10.9%	0.028
Thyroid disease	8.4%	9.0%	8.5%	8.1%	0.496
Malignancy	6.6%	6.6%	7.5%	6.3%	0.257
Eyes, ears, nose and throat disorders	6.5%	7.1%	5.7%	6.5%	0.290
Toxins	5.4%	6.0%	7.2%	4.3%	<0.001
Skin disorders	4.5%	4.7%	4.6%	4.3%	0.715
Autoimmune disorders	1.3%	1.5%	1.3%	1.2%	0.622
Allergic reaction	1.4%	1.3%	2.7%	0.9%	<0.001

Boldface type denotes statistical significance. GI = gastrointestinal; SD = standard deviation.

* Includes acute coronary syndrome.

cohorts were combined. There was also a significantly increased rate of hospital encounters for "musculoskeletal disease" and "hyperlipidemia." These findings are difficult to draw conclusions from and may be due to chance.

As expected, the rates of encounters for "respiratory infection" were significantly decreased after full vaccination. More importantly, we found no significant association between vaccination and rate of presentations for coronary artery disease (including acute coronary syndrome), pericarditis, myocarditis, heart failure, or conduction abnormality. Further, there was no difference when it came to gastrointestinal disorders, hematologic disorders, genitourinary disorders, and multiple other diagnoses.

Table 3 summarizes hospital encounters specifically related to COVID-19 and the direct administration of the vaccines themselves. An ICD-10 diagnosis of "vaccine reaction" was reported in 2.4% of hospital encounters in the in vaccination window cohort and in 2.1% of encounters for the fully vaccinated cohort. Specifically, the rate of allergic reactions in fully vaccinated patients was 0.4%,

Table 3
Hospital encounters related to vaccine and COVID-19 based on vaccination status Hospital encounters based on vaccination status for vaccine administration and COVID-19-related events

	Overall (N = 6,751)	Fully Vaccinated (N = 1,779)	In Vaccination Window (N = 1,420)	Before Vaccination (N = 3,552)	p-Value
Vaccine reaction	1.1%	2.1%	2.4%	0.0%	**<0.001**
Allergic reaction	0.1%	0.4%	0.3%	0.0%	**<0.001**
Adverse reaction	0.1%	0.2%	0.3%	0.0%	**0.011**
COVID-19 complication	4.1%	1.6%	4.2%	5.4%	**<0.001**
SARS-CoV-2 infection	4.1%	1.6%	4.2%	5.4%	**<0.001**
Acute respiratory failure	0.3%	0.1%	0.2%	0.5%	**0.035**
History of COVID-19	2.2%	2.0%	2.1%	2.3%	0.818
COVID-19 exposure	24.2%	25.1%	23.5%	24.0%	0.540

Boldface type denotes statistical significance. COVID-19 = coronavirus disease 2019; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.

and an encounter for an adverse reaction to the vaccines was 0.2%. More importantly, encounters for complications related to SARS-CoV-2 infection decreased significantly from those before vaccination (5.4%) to those who were fully vaccinated (1.6%). Furthermore, presentations for acute respiratory failure due to COVID-19 decreased significantly from 0.5% in the before vaccination cohort to 0.1% in the fully vaccinated cohort.

Tables 4 and 5 summarize our secondary analysis in which we combined the fully vaccinated and in vaccination window cohorts and compared them with the visits before vaccination. In Table 4, the diagnoses were similar in the 2 cohorts. Further, the previous differences of cerebrovascular events and musculoskeletal disorders are no longer seen, whereas hyperlipidemia and respiratory infections continued to differ between the 2 cohorts. Table 5 summarizes hospital encounters specifically related to COVID-19 based on vaccination status overall. Once again, findings were similar in this analysis with the 3 cohorts in Table 3.

Discussion

The results of our primary analysis from our large cohort suggests that there is no significant association of COVID-19 vaccination with the rate of hospital encounters for

Table 4
Hospital encounters based on vaccination status overall Hospital encounters based on vaccination status using International Classification of Diseases, Tenth Revision codes

	Overall (N = 6,751)	Vaccinated (N = 3,199)	Before Vaccination (N = 3,552)	p-Value
Coronary artery disease*	12.9%	13.3%	12.6%	0.352
Congestive heart failure	12.2%	12.0%	12.4%	0.684
Conduction abnormalities	12.7%	13.4%	12.1%	0.108
Valvular heart disease	3.9%	3.8%	3.80%	0.668
Pericarditis	0.52%	0.53%	0.51%	0.888
Myocarditis	0.04%	0.06%	0.03%	0.504
Hypertension without complications	42.6%	43.6%	41.8%	0.124
Hypertension with complications	12.9%	12.7%	13.1%	0.577
Hypotension	3.5%	3.6%	3.4%	0.580
Peripheral vascular disease	6.8%	6.7%	7.0%	0.630
Hyperlipidemia	27.1%	28.7%	25.7%	**0.006**
Neurologic				
Cerebrovascular event	3.5%	3.8%	3.2%	0.250
Neurological disorder	13.3%	12.5%	13.9%	0.083
Peripheral neuropathy	8.2%	8.1%	8.4%	0.692
Pulmonary				
Pulmonary embolism	0.8%	0.7%	0.8%	0.542
Chronic lung disease	21.7%	21.9%	21.5%	0.667
Pulmonary hypertension	2.7%	2.7%	2.8%	0.743
Respiratory infection	7.1%	5.5%	8.5%	**<0.001**
Gastrointestinal				
Obesity	9.2%	8.9%	9.4%	0.507
Metabolic disorder	4.8%	4.7%	4.9%	0.732
Malnutrition	2.5%	2.4%	2.6%	0.580
Upper GI disorders	10.8%	10.6%	11.0%	0.584
Lower GI disorders	0.8%	0.8%	0.9%	0.496
Liver/gallbladder disease	4.4%	4.4%	4.4%	0.975

(*continued*)

Table 4 (*Continued*)

	Overall (N = 6,751)	Vaccinated (N = 3,199)	Before Vaccination (N = 3,552)	p-Value
Pancreatic disease	1.6%	1.6%	1.5%	0.880
GI bleed	2.1%	1.8%	2.3%	0.177
Hematological				
Anemia	1.1%	1.1%	1.0%	0.746
Coagulopathy	2.8%	2.8%	2.8%	0.879
White blood cell disorder	5.8%	5.5%	6.0%	0.443
Genitourinary				
Renal disease	19.1%	19.0%	19.1%	0.885
Electrolyte abnormalities	17.2%	16.8%	17.5%	0.490
Urinary disorders	5.7%	5.5%	5.9%	0.439
Urologic disorders	4.1%	4.1%	4.0%	0.789
Gynecological disorders	2.9%	3.0%	2.8%	0.758
Pregnancy	0.8%	1.0%	0.6%	0.104
Other				
Musculoskeletal disorders	32.5%	33.7%	31.5%	0.055
Diabetes	24.9%	24.7%	25.1%	0.732
Trauma	15.5%	15.9%	15.9%	0.360
Substance abuse	12.0%	10.5%	13.4%	**<0.001**
Infection	11.0%	10.2%	11.7%	0.045
Psychiatric disorders	10.0%	9.1%	10.9%	**0.014**
Thyroid disease	8.4%	8.8%	8.1%	0.279
Malignancy	6.6%	7.0%	6.3%	0.214
Eyes, ears, nose and throat disorders	6.5%	6.5%	6.5%	0.919
Toxins	5.4%	6.5%	4.3%	**<0.001**
Skin disorders	4.5%	4.7%	4.3%	0.416
Autoimmune disorders	1.3%	1.4%	1.2%	0.356
Allergic reaction	1.4%	1.9%	0.9%	**<0.001**

Boldface type denotes statistical significance. GI = gastrointestinal; SD = standard deviation.
* Includes acute coronary syndrome.

cardiac disease, including acute coronary syndrome, pericarditis, myocarditis, congestive heart failure, and conduction abnormality. Second, there was no difference when it came to gastrointestinal disorders, hematologic disorders, genitourinary disorders, and multiple other diagnoses. Finally, the administration of the vaccines resulted in a significant decrease in hospital encounters for respiratory infections, SARS-CoV-2 infections, and COVID-19-related complications.

To date, there have been several case reports and case series documenting myocarditis following vaccination with an mRNA COVID-19 vaccine.[5,7,8] In addition, a recent population-level investigation of the Pfizer-BioNTech vaccine found significantly increased risk of myocarditis after vaccination. However, the same study also noted that the risk of myocarditis and other serious adverse cardiovascular events from SARS-CoV-2 infection was significantly higher than from vaccination.[9] Our large-scale analysis of post-vaccination hospital presentations failed to show any significantly increased incidence of myocarditis. One possible explanation for this discrepancy is that our study examined a population receiving a mixture of the 3 vaccines available to the United States market. It is likely that these 3 vaccines have different risk profiles and are associated with different adverse events. In addition, a recent large-scale study demonstrates that the complication rates of the

Table 5
Hospital encounters related to vaccine and COVID-19 based on vaccination status overall Hospital encounters based on vaccination status for vaccine administration and COVID-19-related events

	Overall (N = 6,751)	Vaccinated (N = 3,199)	Before Vaccination (N = 3,552)	p-Value
Vaccine reaction	1.1%	2.1%	0.0%	**<0.001**
Allergic reaction	0.1%	0.2%	0.0%	**0.010**
Adverse reaction	0.1%	0.3%	0.0%	**0.003**
COVID-19 complication	4.1%	2.7%	5.4%	**<0.001**
SARS-CoV-2 infection	4.1%	2.7%	5.4%	**<0.001**
Acute respiratory failure	0.3%	0.1%	0.5%	**0.014**
History of COVID-19	2.3%	2.1%	2.3%	0.541
COVID-19 exposure	24.2%	24.4%	24.0%	0.747

Boldface type denotes statistical significance. COVID-19 = coronavirus Disease 2019; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.

vaccines are less than the complication rates of having the SARS-CoV-2 infection.[10] Our findings are promising and ensure the safety of the vaccines.

Second, there was no evidence of worsening thrombosis, pulmonary embolism, or other thrombotic events in the vaccinated arm compared with other groups. Early on, during the COVID-19 vaccine development, there were reports of thromboembolic events thought to be related to the vaccines.[11] However, this was not seen in our large cohort, and this initial possible relation is unlikely. Further, the Food and Drug Administration issued a temporary hold on the administration of the Ad26. COV2. S vaccine (Janssen/Johnson and Johnson) due to a feared complication of cerebral venous sinus thrombosis.[4] However, this specific diagnosis was not seen in our observation.

Lastly, our analysis further highlights the effectiveness of the COVID-19 vaccines overall.[12,13] In our large cohort, we demonstrate that the incidence of SARS-CoV-2 infections decreased dramatically in both the in vaccination window group and the fully vaccinated group. Also, the rate of serious infections highlighted by "acute respiratory failure" also decreased dramatically for those who received partial or full vaccination. Ongoing efforts to roll out the COVID-19 vaccines are imperative to help fight this deadly infection.

There are limitations to our study. First, the analysis is retrospective and relies on ICD-10 codes to identify the patient population. ICD-10 categories were determined by 3 authors, but variability may exist. Also, the analysis only accounts for hospital encounters (emergency department visits) and does not designate hospitalizations. Further, it misses cases/encounters in outside care settings as well as inaccurate EMR vaccination information. In addition, our findings do not prove causation; however, the short span between vaccinations and hospital encounter/diagnosis in the study hospitals lends support to a possible relation. Finally, our data captured patients in the mid-Atlantic region of the United States; our findings may not represent the broader United States outcome data.

In conclusion, our analysis suggests that there is no significant association of COVID-19 vaccination with the rate of hospital encounters for cardiac disease, including acute coronary syndrome, pericarditis, myocarditis, congestive heart failure, and conduction abnormality. Further, administration of the vaccines resulted in a significant decrease in hospital encounters for respiratory infections, SARS-CoV-2 infections, and COVID-19 complications.

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Disclosures

Toby Rogers reports being a proctor and consultant for Medtronic and Edwards Lifesciences; serving on the advisory board of Medtronic; and holding equity interest: Transmural Systems Inc., outside the scope of the submitted work.

Ron Waksman reports serving on the advisory boards of Abbott Vascular, Boston Scientific, Medtronic, Philips IGT, and Pi-Cardia Ltd.; being a consultant for Abbott Vascular, Biotronik, Boston Scientific, Cordis, Medtronic, Philips IGT, Pi-Cardia Ltd., Swiss Interventional Systems/SIS Medical AG, Transmural Systems Inc., and Venus MedTech; receiving grant support from AstraZeneca, Biotronik, Boston Scientific, Chiesi, Medtronic, and Philips IGT; serving on the speakers bureau of AstraZeneca; and being an investor in Med Alliance and Transmural Systems Inc. outside the scope of the submitted work.

All other authors have no conflicts of interest to declare.

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