MAYO CLINIC

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INNOVATIONS, QUALITY & OUTCOMES

ORIGINAL ARTICLE

Assessing the Impact of Post-COVID Clinics on 6-Month Health Care Utilization for Patients With Long COVID: A Single-Center Experience

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Abstract

Objective: To assess the impact of post-COVID clinics by examining the association between their early usage and downstream health care utilization.

Patients and Methods: In a case-control study spanning data from March 11, 2020 to June 1, 2023, patients with Long COVID were identified from a major health system using diagnosis codes. The Fast, Large-Scale Almost Matching Exactly algorithm was used to match patients who presented early to post-COVID clinics with patients with Long COVID who did not attend such clinics. Matching was performed on demographic characteristics, acute COVID severity, comorbidities, diagnosis date, and vaccination, to reduce confounders for the comparison of the health care utilization and mortality between cohorts.

Results: When exactly matching on all 46 features, the algorithm yielded 2814 matched patients, of whom 692 (24.6%; 66.6% females; mean [SD] age, 48.8 [14.5] years) were seen in post-COVID clinics within the first 6 months and 2122 (75.4%; 64.1% females; mean [SD] age, 49.7 [15.2] years) who were not. The average treatment effect (95% CI) of early post-COVID clinic usage was −0.60 (−0.83 to −0.39) on inpatient visits, −0.19 (−0.26 to −0.11) on emergency department visits, 7.62 (6.96-8.56) on outpatient visits, −$3467 (−$6267 to −$754) on estimated costs, and −0.006 (−0.010 to −0.003) on mortality.

Conclusion: Early usage of post-COVID clinics by patients with Long COVID is associated with not only fewer downstream inpatient stays, emergency department visits, estimated costs, and reduced mortality within the first 6 months but also greater outpatient utilization. Results suggest early post-COVID clinic involvement shifts care to outpatient settings, potentially reducing costs and mortality.

CoronaVIrus Disease 2019 (COVID-19) has had enormous impacts on health care systems and will likely continue to for the foreseeable future.[1] Acute COVID-19 infection primarily affects not only the pulmonary system but also many other organs including the kidneys, liver, heart, nerves, stomach, and skin.[2] Certain COVID-19 patients experience longer-term clinical problems after their initial infection,[3] often termed postacute sequelae of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection or Long COVID.[4] Long COVID is defined by the World Health Organization as a condition that "occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually 3 months from the onset of COVID-19 with symptoms that last for at least 2 months and cannot be explained by an alternative diagnosis."[5]

Symptoms have been studied in international populations[6] and are highly varied, including but not limited to fatigue, dyspnea, cardiac abnormalities, cognitive difficulties, and musculoskeletal pains.[7] Symptoms can persist for very long, with studies finding that up to 91% of patients took more than 35 weeks

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to recover.[6] Although the estimated prevalence of Long COVID varies,[8-10] recent studies estimate that 6.9% of American adults have ever had Long COVID, whereas 3.4% were experiencing it concurrently.[11] Individuals diagnosed with Long COVID also have an increased risk of a wide variety of chronic and severe conditions.[12-15] For example, patients with Long COVID are over twice as likely to need care for cardiovascular diagnoses[16] and over 3 times as likely to have a pulmonary embolism, with effects on quality of life.[17] The exact causes of these symptoms are still an area of active research,[18] with both physiologic and psychosocial explanations being explored,[19,20] including persisting viral components,[21] immune dysregulation,[22-26] microbiome effects,[27,28] microvascular blood clotting,[29,30] and nervous system dysfunction.[31]

The widespread and complex nature of Long COVID contributes to large economic costs, with an estimated $2.6 trillion of global costs by the end of 2021.[32] Both acute COVID-19 and Long COVID will likely continue to be major health challenges, especially given high COVID-19 viral levels in wastewater continue to persist nationally,[33] indicating that COVID-19 is continuing to spread. Further exacerbating this issue is the low vaccination rates for COVID-19, with less than a quarter of US adults receiving updated vaccines, which may also contribute to continued spread of COVID-19.[34]

Several options have been proposed and developed as treatments for Long COVID. Several clinical trials are currently exploring the efficacy of drugs,[35] exercise programs, and dietary supplements for treating assorted Long COVID symptoms.[7] In the absence of definitive care models for this multiorgan condition, interdisciplinary specialty clinics have been established during the pandemic to address the complex care needs of patients with Long COVID.[36,37] Specifically, at Mayo Clinic Health System, informal interdisciplinary efforts for post-COVID treatment began in April 2020 and were formalized into a post-COVID clinic by June 2020.[36] Patients seen at these clinics may undergo assessments to detect COVID-associated conditions, physical/occupational therapy, and consultations with specialists familiar with Long COVID.[36] Given the overwhelming numbers of patients with Long COVID, many of these clinics faced high demand, evidenced by qualitative reports of months-long waitlists.[38-41] Although these clinics are seeing increased use,[42-44] empirical studies are still lacking regarding their effects on utilization. To address this gap, in this study, we assessed the impact of early post-COVID clinic usage by patients with Long COVID on downstream health care utilization of inpatient visits, emergency department (ED) visits, and outpatient visits.

PATIENTS AND METHODS

Data Source and Health Care Setting

Mayo Clinic Platform Discover is a software system that provides both computation and data access using SQL and Python scripts, which offers access to high-quality, comprehensive, longitudinal clinical data that few in the industry can provide. We analyzed deidentified electronic health record (EHR) data via Mayo Clinic Platform Discover. The data presented were extracted following a privacy-preserving protocol and deemed deidentified by an expert in accordance with Health Insurance Portability and Accountability Act Privacy Rule. Additional data, including raw EHR data, cannot be shared due to privacy limitations. For additional information about Mayo Clinic Platform Discover, contact the corresponding authors. As the data have been deidentified, this research does not constitute human patients research, and an institutional review board approval was not required. Data used included demographic characteristics, visits, procedures, laboratory reports, diagnoses, observations, and drug administration records for patients. These data were analyzed using Python, with packages including numpy,[45] pandas,[46] scikit-learn,[47] scipy,[48] and statsmodels.[49] This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.[50]

Patient Selection Criteria

The initial study population included adult patients with a diagnosis of Long COVID (Figure 1). Initial Long COVID diagnosis was determined by finding the earliest documentation of the International Classification

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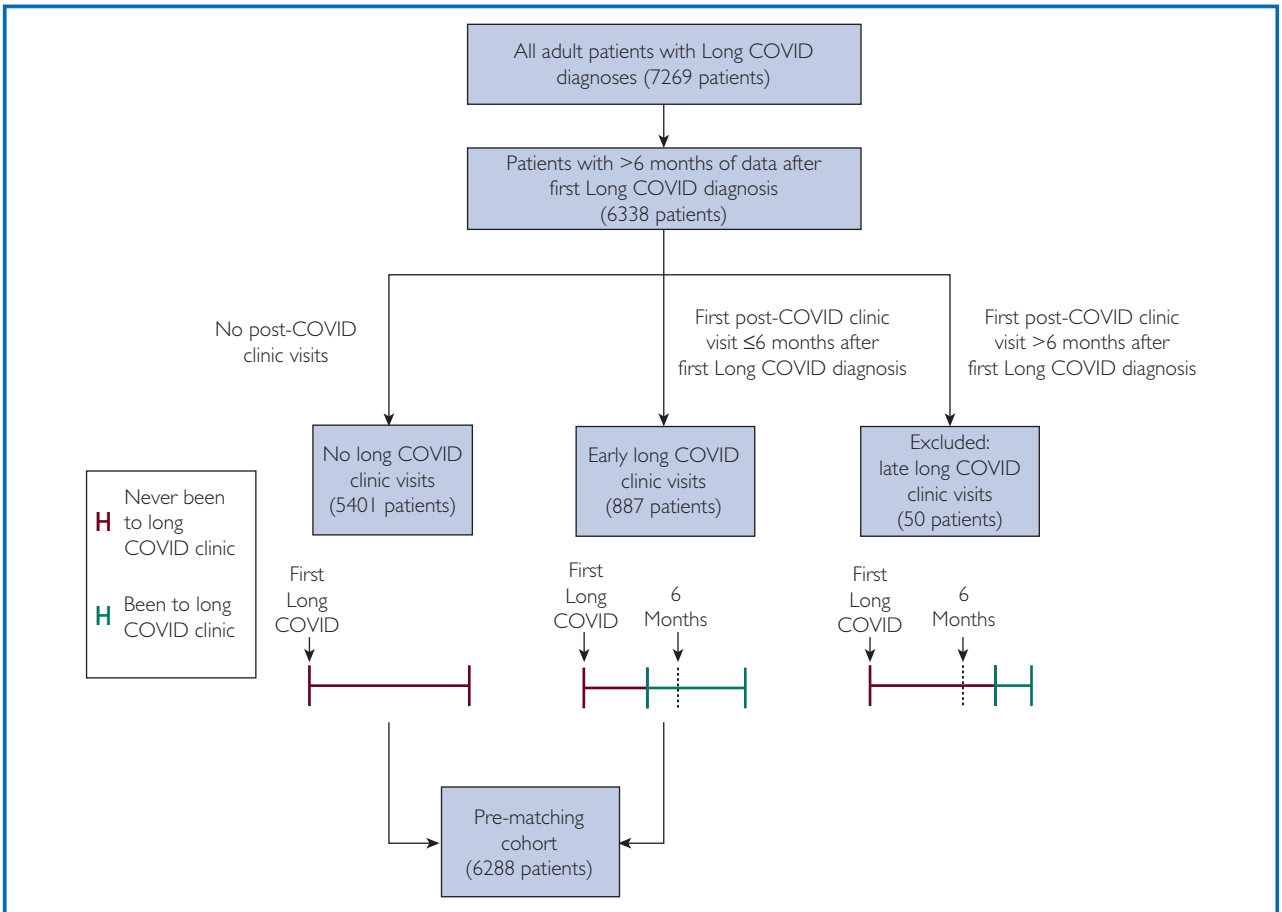

FIGURE 1. Patient selection process used in preparation for algorithmic matching. COVID, COronaVIrus Disease.

of Diseases (ICD)-10 codes for Long COVID, which include either U09.9 or B94.8 documented after June 1, 2020. Patients had to be at least 18 years old at the time of their Long COVID diagnosis. Patients were initially required to have at least 6 months of data coverage after their initial Long COVID ICD-10 documentation date to make the analysis of outcomes possible in the 6-month period after the patient's initial Long COVID documentation date. Patients whose first Long COVID diagnosis was on the same date or after their first post-COVID clinic date were retained because, for some patients, their first Long COVID diagnosis may have been at a post-COVID clinic visit. We excluded patients with Long COVID if they first went to a post-COVID clinic after 6 months of their initial Long COVID diagnosis date. We applied this exclusion criterion to focus our analysis on how post-COVID clinic visits taking place earlier in the care journeys of patients with Long COVID (and before having substantially used health care resources for Long COVID) could affect downstream health care utilization for patients with Long COVID. We define "early" post-COVID clinic use as having at least 1post-COVID clinic visit in the 6-month period after Long COVID ICD-10 diagnosis documentation (Figure 1). These post-COVID clinic visits were labeled as such in the EHR data in appointment descriptions, which were verified by staff at Mayo Clinic. Early post-COVID clinic usage was defined relative to the first Long COVID diagnosis since the onset time of Long COVID can vary widely, and often follows nonsevere acute COVID infections that would not result in health care utilization.[6,7]

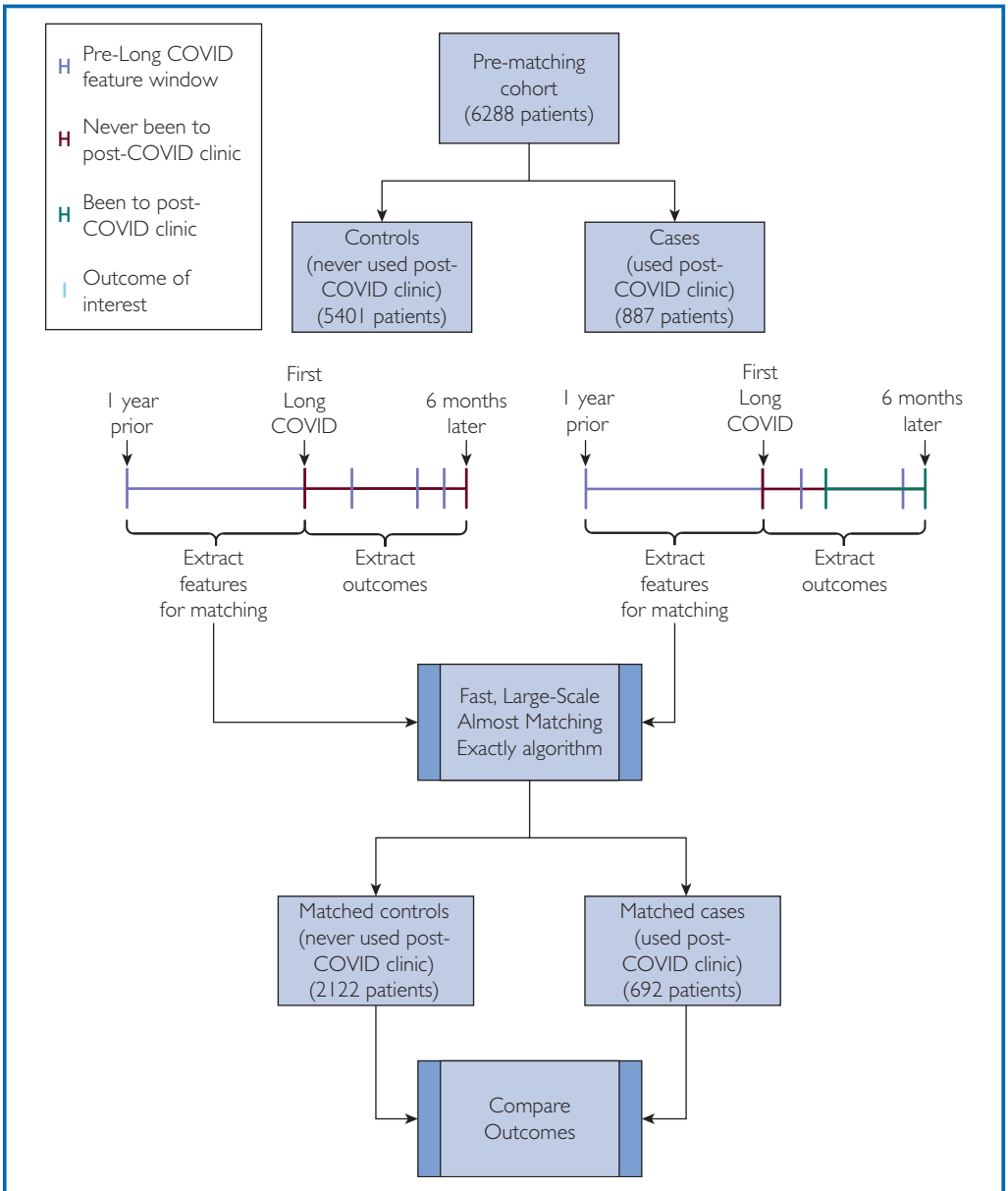

FIGURE 2. Matching and outcome comparison process, with sample sizes shown from the matching paradigm with exact matching on all features. COVID, COronaVIrus Disease.

Variables and Feature Development

All features, except for post-COVID clinic usage, were extracted from data up to 1 year before the initial Long COVID diagnosis date (Figure 2). Age was calculated at the date of Long COVID diagnosis and binned into categories of 18-24, 25-34, 35-49, 50-64, and 65 years and older. COVID-19 severity was defined as whether the patient had no encounter, or an outpatient, ED, or inpatient visit with a COVID-19 diagnosis code in the 365 days before the initial date of Long COVID. Race data were categorized into White, Black, Asian, Native American, unknown, and other categories. Finally, we included binary indicators of the 39 individual comorbidities contained in the Elixhauser Comorbidity Index using ICD-10 codes,[51] binary

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indicators of COVID vaccination, immune suppression, and calendar quarters elapsed since the start of the pandemic (March 11, 2020) at the time of initial Long COVID diagnosis (Supplemental Table 1, available online at http://www.mcpiqojournal.org). Post-COVID clinic usage was captured as a binary indicator of any post-COVID clinic visits in the 6 months following the date of initial Long COVID diagnosis. Features were compared between patients with and without post-COVID clinic visits using Mann-Whitney *U* tests for numerical features and χ^2 tests for categorical features.

Outcome Variables

To focus our analysis on the association of post-COVID clinic use on future health care utilization of patients with Long COVID, we examined an outcome window of 6 months after the first diagnosis of Long COVID. The number of inpatient visits, ED visits, outpatient visits, and mortality in this outcome window were counted for each patient, and each of the 3 outcomes were used as separate outcomes with their own matching analysis. Estimated costs were calculated by using mean costs from published literature for each outpatient ($478),[52] ED ($530),[53] and inpatient ($11,700)[54] visit and were also used as an outcome in the matching analysis. Outpatient visits were also categorized as related to post-COVID clinic care. These include appointments documented as being post-COVID clinic care or the result of referral from such post-COVID clinic appointments. Each patient analyzed (either a case or a control) had to have at least 6 months of data coverage after their initial Long COVID documentation date to make the analysis of outcomes possible (Figure 2). No outcome variables described in this study were used to match cases and controls but were analyzed for differences after matching.

Matching and Analysis Process

This analysis used the Fast Large-scale Almost Matching Exactly algorithm[55] that seeks to match patients on discrete features as closely as possible, using machine learning to decide which variables are least relevant and, based on user specifications, iteratively relaxes the least important features that must be matched. This methodology enables an estimation of average treatment effects between matched samples, adjusting for the features being matched on. In this study, patients with early post-COVID clinic usage (ie, cases) were matched with otherwise similar patients with Long COVID who never went to a post-COVID clinic (ie, controls). Matching was conducted for each outcome of interest separately at 3 different levels of exactness. The first approach (most stringent matching) was exact matching, where all matched samples must be exactly identical on all 46 features. The second approach (intermediate stringency) allowed for up to 10 features not to match exactly. The final level of exactness (least stringent approach) was whenever all early post-COVID clinic users could be matched. Bootstrapping with 1000 iterations was used to estimate 95% CI, where in each iteration a new data set of the same size (6288 samples in this study) was created by sampling from the original data with replacement, and then, the matching analysis was repeated. Previous simulation studies have found this bootstrapping approach in similar matching problems to be conservative.[56-58]

RESULTS

Patient Selection and Characteristics

We identified patients who satisfied all following criteria: (1) had 6 months of data coverage after initial Long COVID ICD-10 diagnosis, (2) had documentation of Long COVID ICD-10 code, and (3) either went to a post-COVID clinic within 6 months after initial Long COVID diagnosis (ie, cases) or never went to a post-COVID clinic (ie, controls). In total, 6288 patients satisfied all 3 criteria. Among those patients, 887 (14.1%) patients went to a post-COVID clinic within 6 months of their initial Long COVID diagnosis, whereas 5401 (85.9%) patients never visited a post-COVID clinic; 50 patients were excluded because their first post-COVID clinic visit was more than 6 months after their first Long COVID diagnosis.

A comparison of the features and outcomes of the 2 cohorts, those with early post-COVID clinic use and those with no post-COVID clinic usage, revealed distinct differences (Supplemental Table 2, available

online at http://www.mcpiqojournal.org). Statistically significant ($P<.05$) differences were observed in all outcomes and all features before matching, based on Mann-Whitney U tests for continuous variables and χ^2 testing for discrete variables. After exact matching, as expected, many features were less different between the 2 cohorts (Supplemental Table 3, available online at http://www.mcpiqojournal.org), with 27 of the 46 features no longer having statistically significant differences ($P<.05$). Owing to the matching process, matched samples had exactly the same features, but because multiple samples may be matched together, the feature distributions of all cases vs all controls were still different.

Post-COVID Clinic Usage Outcomes

Across all matching paradigms and for inpatient visits, ED visits, estimated costs, and mortality, the analyses estimated negative average treatment effects for post-COVID clinic usage. These results, along with corresponding sample sizes, means, and proportions with any of that outcome, can be found for the exactly matched analysis in the Table. Similar results were observed when using less exact matching (ie, intermediate stringency and least stringent approaches) and higher sample sizes (Supplemental Tables 4 and 5, available online at http://www.mcpiqojournal.org).

When matched exactly on all 46 features, patients with Long COVID who were seen at a post-COVID clinic within 6 months, compared with similar patients who were not seen at a post-COVID clinic, reported 7.62 (95% CI, 6.96-8.56) additional outpatient visits (of which an average of 3.889 were planned as part of the post-COVID clinic treatment program), but 0.19 (95% CI, 0.11-0.26) fewer ED visits and 0.60 (95% CI, 0.39-0.83) fewer inpatient visits (Table). Overall, the differences in health care utilization rates resulted in an estimated reduction of $3467 (95% CI, $755-$6267) in health care costs among patients who were seen at a post-COVID clinic within 6 months of being diagnosed with Long COVID compared with those among patients who were never seen at the post-COVID clinic after Long COVID diagnosis.

TABLE. Outcome Comparisons Between Early Users of Post-COVID Clinics and Nonusers of Post-COVID Clinics, Matched Exactly on All Features Studied, With 95% CIs Obtained Using 1000 Iterations of Bootstrapping

Outcome (6 mo)	Average treatment effect (95% CI)	Matched early clinic users (95% CI)	Matched nonclinic users (95% CI)	Mean outcome, early clinic users (95% CI)	Mean outcome, nonclinic users (95% CI)	Proportion with outcome, early clinic users (95% CI)	Proportion with outcome, nonclinic users (95% CI)
Outpatient visits	7.616 (6.958-8.558)	692 (629-725)	2122 (1939-2793)	13.809 (13.204-14.602)	6.365 (5.888-6.689)	0.970 (0.957-0.982)	0.781 (0.761-0.795)
Emergency visits	−0.186 (−0.264 to −0.111)	692 (629-725)	2122 (1939-2793)	0.129 (0.076-0.186)	0.322 (0.266-0.369)	0.040 (0.025-0.056)	0.105 (0.090-0.117)
Inpatient visits	−0.599 (−0.833 to −0.387)	692 (629-725)	2122 (1939-2793)	0.029 (0.003-0.067)	0.639 (0.428-0.862)	0.006 (0.001-0.012)	0.090 (0.076-0.101)
Estimated cost	−3467 (−6267 to −754)	692 (629-725)	2122 (1939-2793)	7007 (6511-7623)	10,695 (8122-13,324)	0.970 (0.957- 0.982)	0.800 (0.778-0.813)
Mortality	−0.006 (−0.010 to −0.003)	692 (629-725)	2122 (1939-2793)	0.001 (0.000-0.005)	0.007 (0.004-0.011)	0.001 (0.000- 0.005)	0.007 (0.004-0.011)

CI, Confidence Interval; COVID, COronaVirus Disease.

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Finally, mortality was lowered by 0.006 (95% CI, 0.003-0.010) among patients with Long COVID who received post-COVID clinic when compared with that in the control group (Table).

DISCUSSION

Main Findings

Overall, the findings support the hypothesis that early post-COVID clinic usage may reduce costly downstream health care utilization. Before matching, significant differences existed in all outcomes and features between the cases and controls, with early post-COVID clinic users having better outcomes, excluding outpatient visits. Even after using matching, and across all matching paradigms, notable associations were observed between early post-COVID clinic usage and significantly reduced inpatient stays, ED visits, estimated costs, and mortality. The association with outpatient visits was the opposite, which may be expected given the numerous multidisciplinary visits involved in the post-COVID clinic treatment program. A large portion of this difference can be directly attributed to post-COVID clinic care, with case samples averaging 3.889 post-COVID clinic-related outpatient visits in their outcome window before matching. Because these are planned follow-up outpatient visits rather than acute visits for new problems, they may be less costly.

Strengths

The major strength of this study is that sophisticated algorithmic matching was used to control for 46 confounding factors, including demographic characteristics, 39 comorbidities, vaccination, immune suppression, and timing in the pandemic. Although the effects of these factors were not completely accounted for in all analyses because not all features were exactly matched on in the less specific approaches, they are likely to be important predictors in health care utilization and so reducing their confounding impact is vital.

Comparison With Past Studies

Past studies have characterized the population of patients seen in post-COVID clinics, which varied significantly. Previous work on Mayo Clinic's post-COVID clinics unsurprisingly saw common trends with this study, such as more women than men being seen in post-COVID clinics, the average age being in the late 40s, and most patients not having been hospitalized for acute COVID-19.[36] Demographic characteristics and comorbidities of post-COVID clinic cohorts from other studies were quite variable.[42-44,59-62]

The existing literature on the utility of post-COVID clinics is still developing. Qualitative evidence from patients seems to indicate favorable opinions of post-COVID clinic treatments,[63] although such qualitative findings are highly subjective. Previous correlational evidence based on logistic regression models that controlled for less variables (age, sex, race, insurance, discharge location, and intensive care unit stays) came to similar conclusions as this study that usage of post-COVID clinics is associated with reduced health care utilization.[64]

Limitations

Despite the methodologic strengths, this study has some limitations that may affect the interpretation of the results. Data limitations included the following: (1) EHR data lack information on whether patients are using health care outside of this health system, and so, the requirement that patients have at least 6 months of data after their Long COVID diagnosis may have removed healthy patients or patients who received health care outside of Mayo Clinic Health System. (2) This is a single-center study, and as such, may not be fully representative of broader populations, such as with regards to the racial diversity of the US population mainly due to the geographical locations where data were collected. (3) Diagnosis codes for Long COVID were used as ground truth for determining which patients to include, but Long COVID is likely highly underdiagnosed and documentation of it may be flawed.[65-67] (4) Finally, our cost savings analysis used average national-level costs per encounter of each type from data published in 2018 through 2020[52-54] because cost information are lacking in EHR data. From 2018 to 2024, urban medical care in the United States has risen in price on average by 15%,[68] so these cost estimates are likely an underestimate and do not take

into account the specific types of care that may occur in each encounter.

Methodologic limitations included the following: (1) any confounding variables missed from the analysis will skew the results, although this study did attempt to use a wide variety of comorbidities and known risk factors for Long COVID. (2) Matching also introduces bias because only samples that are similar enough between the cases and controls will be retained in the analysis. In this study, it appears that results in the matched cohort are relatively less sick (eg, Supplemental Tables 2 vs 3), which may skew results, with actual effects likely being more pronounced on a sicker general population of patients with Long COVID. (3) Using matching to reduce the effect of confounding variables also obscures their effects on the outcomes being predicted. Estimating how important early post-COVID clinic usage is relative to other patient characteristics such as age or comorbidities was beyond the scope of this study.

Expansion Possibilities

Future studies may expand on these results in several ways. Other data sets could be used to study additional confounding variables not yet accounted for, such as more sophisticated social determinants of health. Individual-level feature analysis could help characterize the most important factors affecting health care utilization and potentially identify subgroups of patients that would benefit from specific post-COVID care pathways. With current limited post-COVID clinic capacity, effective risk stratification to enable identification of patients most likely to benefit from post-COVID clinics could contribute to improved outcomes.

CONCLUSION

This study provides evidence that early post-COVID clinic usage may reduce downstream ED and inpatient utilization in patients with Long COVID, potentially resulting in cost savings. Future studies could provide further evidence related to the costs and benefits of post-COVID clinics.

POTENTIAL COMPETING INTERESTS

Drs Afshar and Kharrazi, and Gong, Brown, and Alavi have financial interests in ArtiMed Inc., a company commercializing software solutions for specialized medical conditions including Long COVID. The other author reports no competing interests.

ETHICS STATEMENT

The data presented were extracted following a privacy-preserving protocol and deemed deidentified by an expert in accordance with the Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule. As the data have been deidentified, this research did not constitute human patients research, and an institutional review board approval was not required. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.

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Gong and Dr Afshar contributed equally to this work.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **COVID**, coronavirus disease; **COVID-19**, COronaVIrus Disease 2019; **ED**, emergency department; **EHR**, electronic health record; **ICD**, International Classification of Diseases; **SARS-CoV-2**, severe acute respiratory syndrome coronavirus 2

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