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Original Research

# Predictors of Post-Acute Sequelae of COVID-19 Development and Rehabilitation: A Retrospective Study

Nermine Abdelwahab MD;[1*] Nicholas E Ingraham MD;[2*] Nguyen Nguyen;[3] Lianne Siegel PhD;[4] Greg Silverman;[5] Himanshu Shekhar Sahoo,[5,6] Serguei Pakhomov PhD;[7] Leslie R Morse DO;[3] Joanne Billings MD MPH;[2] Michael G. Usher MD PhD;[1] Tanya E. Melnik MD;[1] Christopher J. Tignanelli MD;[5,8] Farha Ikramuddin MD MHA[3]

*Authors contributed equally to this manuscript

Author Affiliations:

[1] Department of Medicine, University of Minnesota, Division of General Internal Medicine, Minneapolis, MN, USA

[2] Department of Medicine, University of Minnesota, Division of Pulmonary and Critical Care, Minneapolis, MN, USA

[3] Department of Rehabilitation Medicine, University of Minnesota, Division of PM&R, Minneapolis, MN

[4] Division of Biostatistics, School of Public Health, University of Minnesota, Minneapolis, MN, USA

[5] Department of Surgery, University of Minnesota Division of Acute Care Surgery, Minneapolis, MN

[6] Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, USA

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[7] Department of Pharmaceutical Care and Health Systems, University of Minnesota, Minneapolis, USA

[8] Institute for Health Informatics, University of Minnesota, Minneapolis, MN

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Correspondence:

Nermine Abdelwahab, MD

MMC 276

420 Delaware St SE

Minneapolis, MN 55455

Office: (612) 626-1968

Fax: (612) 626-0439

Email: abde0124@umn.edu



*Abstract*

Objective: Clinical and demographic factors associated with the development, severity, and rehabilitation utilization of patients with Post-Acute Sequelae of COVID-19 (PASC) are not well defined. We examined the frequency of PASC, and the factors associated with rehabilitation utilization in a large adult population with PASC.

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Design: Retrospective study

Setting: Hospital health system

Participants: All COVID-19 patients from March 10, 2020 to January 17, 2021

Intervention: Not applicable.

Main outcome measure: Descriptive analyses were conducted across the entire cohort along with an adult subgroup analysis. A logistic regression was performed to assess factors associated with PASC development and rehabilitation utilization.

Results: In an analysis of 19,792 patients, the frequency of PASC was 42.8% in the adult population. Patients with PASC compared to those without had a higher utilization of rehabilitation services (8.6% vs 3.8%, p<0.001). Risk factors for rehabilitation utilization in patients with PASC included younger age (OR 0.99, 95% CI 0.98-1.00; p=0.01). In addition to several comorbidities and demographics factors, risk factors for rehabilitation utilization solely in the inpatient population included male sex (OR 1.24, 95% CI 1.02-1.50; p=0.03) with patients on angiotensin-converting-enzyme inhibitors or angiotensin-receptor blockers three months prior to COVID-19 infections having a decreased risk of needing rehabilitation (OR 0.80, 95% CI 0.64-0.99; p=0.04).

Conclusion: Patients with PASC had higher rehabilitation utilization. We identified several clinical and demographic factors associated with the development of PASC and rehabilitation utilization.

Key words: COVID-19, long covid, PASC, Rehabilitation, Function

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*Introduction*

There is a growing concern that patients infected with SARS-CoV-2 experience persistent symptoms long after the initial symptomatic phase.(1,2) Currently, there is no established definition to describe patients with COVID-19 sequelae, however, a commonly proposed characterization describes illness greater than four weeks after acute infection as late sequalae or post-acute sequalae of SARS-CoV-2 (PASC). (3–5) The frequency and timeline of PASC is unclear and varies widely with estimations as high as 50%.(6,7) The presentation also varies with multiple different organ systems affected, and in certain cases, the symptoms are severe enough to cause new disability.(8–11) There is limited information on exacerbating and mitigating factors that would predispose patients to develop PASC.(6,7) For patients that develop PASC, there is limited information on rehabilitation utilization and efficacy, however, case series have suggested improvement in patient's symptoms with rehabilitation. (2,12)

Given such a high overall reported frequency of PASC, more information is needed to help triage and recruit at risk patients to rehabilitation programs, thus, we thought to examine patient factors that increase the likelihood of development of PASC. In addition, we examined rehabilitation utilization in patients with PASC and the factors associated with the need for rehabilitation services. By better understanding the resource utilization of patients, we can implement patient tailored rehabilitation plans to at risk populations. We hypothesized that patients with more severe disease and more comorbidities would require more rehabilitation services.

*Methods*

*Study Design and Participants*

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This study is a retrospective analysis of data from March 10, 2020, to January 17, 2021, of COVID-19 patients who had their test done at a specific health system. Inclusion criteria included all patients with polymerase chain reaction (PCR)-confirmed COVID-19 treated at a participating hospital. Exclusion criteria included patients that died during their initial acute COVID-19 infection (hospitalized and non-hospitalized patients) and those who opted out of research.

*Description of Database*

The study database was created from Epic electronic health records (EHRs) and included: patient demographics (age, gender, race/ethnicity), medications, past medical history, and health encounters from January 1, 2019, to March 17, 2021. Additionally, information regarding state death certificates was obtained from the state's Department of Health.(16) Patients without prior encounters within each hospital were included in the primary analysis as we did not want to exclude previously healthy patients that developed de novo COVID-19 and subsequent chronic disease.

*Data Definitions*

The primary outcome was the development of PASC, which was defined as any patient that had PASC symptoms 31 days or more after COVID-19 and did not have these symptoms at baseline (i.e., a patient with chronic obstructive lung disease (COPD) and a chronic cough that has a cough after COVID-19 would not be considered PASC). This was done to reduce possible confounding factors. Resource utilization related to PASC was categorized using variables (i.e., physical medicine and rehabilitation referrals, pulmonary and cardiac rehabilitation) shown in

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Supplementary Table 1: Variables labeled as new denote the patient was not receiving this therapy prior to the diagnosis of COVID-19. A hypothesis-generating analysis was conducted to evaluate the independent association of clinically important variables (exposures) and the need for rehabilitation services. A list of PASC, COVID-19 symptoms, and clinically important variables was catalogued by subject matter experts who lacked direct access to the PASC database but with expertise treating patients with PASC and chronic critical illness. (13,14) All COVID-19/PASC symptoms listed by the CDC as of April 7, 2021 were also included.(15) The overall list of PASC symptoms and clinically important variables hypothesized to be associated with PASC can be found in Supplementary Table 2.

*Statistical Analysis*

The university's Natural Language Processing and Information Extraction Laboratory used the list of PASC and COVID-19 symptoms that was developed for this study to extract symptoms from health encounter visits.(17) This process is referred to as the creation of a rule-based gazetteer and relied on linguistic rules constructed from the lexicon to match any mentions of the symptoms and their linguistic variants in notes. Each symptom mention was marked as positive or negative based on whether it occurred in a negated context (e.g., "denies cough" would be marked as a negative instance of the cough symptom). The overall performance of the gazetteer was validated against a reference standard set of manually annotated ED clinical notes and yielded a precision of 0.90, recall of 0.87, and f1-score of 0.88.(17–19)

Statistical analysis was conducted by an independent investigator not involved in variable selection. For descriptive purposes, data were expressed as median and IQR for continuous

variables with a skewed observed distribution and as percentages for categorical variables. Student's t-tests, Mann-Whitney U tests, and Pearson $\chi 2$ tests were used in the preliminary analyses as appropriate for the assumed variable distribution. Multivariable logistic regression was performed to evaluate the independent association of variables of interest on the need for rehabilitation services in patients with PASC. Subgroup analyses for rehabilitation utilization were conducted on adults that were hospitalized during their initial COVID-19 infection. An additional adjustment was performed on this population to account for confounding variables (i.e., demographics, comorbidities, medications, inpatient data) which can be also found in Supplementary Table 2.

All statistical analysis was performed using Stata-MP Version 16 (StataCorp, College Station, TX). Goodness of fit was assessed with Hosmer-Lemeshow tests, where a p-value < 0.1 was considered statistically significant. All other tests were two sided and significance was defined with an alpha of < 0.05.

*Results*

Outcomes:

*Overall Population*

19,792 patients were included in the analysis (Figure 1). In the adult population, the age range was 18 years to 90 years or older. The median age of patients who developed PASC was 51.4 years old (32.8-66.4) with 38% identifying as male. The characteristics of patients with PASC compared to those without are shown in Table 1. The frequency of PASC was 42.8% in the adult population. Table 1 shows the outpatient rehabilitation services that were analyzed which include physical therapy, occupational therapy and speech language pathology. Patients with PASC

compared to those without PASC had a higher frequency of rehabilitation services during COVID-19 (8.6% vs 3.8%, p<0.001), after COVID-19 (8.4% vs 3.0%, p<0.001) as well as outpatient physiatry referrals (3.1% vs 1.7%, p<0.001) (Table 1).

*Factors Associated with Development of PASC*

The factors associated with the development of PASC in all patients can be found in Table 2. Male sex was a protective factor against the development of PASC (OR 0.82, 95% CI 0.76-0.87; p<0.001). Compared to being white, being Asian (OR 1.26, 95% CI 1.09-1.45; p=0.002), being Black (OR 1.11, 95% CI 1.00-1.23; p<0.05), rural living (OR 1.15, 95% CI 1.07-1.23; p<0.001), being non-English speaking (OR 1.23, 95% CI 1.10-1.39; p<0.01), and pregnancy (OR 1.18, 95% CI 1.06-1.30; p<0.01) were all risk factors for development of PASC. Patients who required inpatient admission (OR 1.97, 95% CI 1.77-2.19; p<0.001) and those who required any rehabilitation program prior to COVID-19 illness were also at higher risk of developing PASC (OR 1.91, 95% CI 1.78-2.05; p<0.001). Several comorbidities and medications that patients were on 3 months prior were associated with an increased risk of PASC (Table 2).

*Factors associated with Rehabilitation Utilization in Patients with PASC*

Risk factors for need for rehabilitation in patients with PASC included younger age (OR 0.99, 95% CI 0.98-1.00; p=0.01, those who were pregnant (OR 3.30, 95% CI 1.92-5.66; p<0.001), as well as other comorbidities which can be found in Table 3. Risk factors for rehabilitation utilization solely in the inpatient populations were also explored and can be found in Supplementary Table 3. Male sex (OR 1.24, 95% CI 1.02-1.50; p=0.03), older age (OR 1.01, 95% CI 1.01-1.02; p<0.001), being Asian (OR 2.48, 95% CI 1.75-3.50; p<0.001), being Hispanic

(OR 2.34, 95% CI 1.55-3.54; p<0.001), and several comorbidities were associated with higher rehabilitation use in the inpatient population. Patients on angiotensin-converting-enzyme inhibitors (ACEI) or angiotensin-receptor-blockers (ARBs) three months prior to COVID-19 infections had a decreased risk of needing rehabilitation (OR 0.80, 95% CI 0.64-0.99; p=0.04) compared to non-users of ACE inhibitors or ARBs.

*Discussion*

The purpose of this study was to explore rehabilitation utilization for patients with PASC and identify mitigating and protective factors associated with the development of PASC. In our study, we identified three key findings. First, there were high rates of PASC in our patient population. Second, in patients with PASC, younger patients had higher rehabilitation utilization and several comorbidities were found to be risk factors for rehabilitation utilization, especially in cases of severe COVID-19. Third, patients on ACEI/ARB had decreased risk of requiring rehabilitation resource in the inpatient population.

The frequency of PASC in the adult population was 42.8%. Because of the lack of a standardized definition, the rates reported in other studies often ranges between the low teens to up to more than half of the population. PASC was present in both mild and severe disease, however, having severe disease, defined as requiring hospital admission, was a risk factor for development of PASC. Several comorbidities were found to be risk factors including patients with hypertension, chronic kidney disease, and asthma, which is similar to risk factors for acute COVID-19 illness.(20) There were several medications associated with an increased risk of PASC in the patients that were taking it prior to acute illness; this is likely due to the association of those

medications with comorbidities. In our study, non-English speaking populations and being Asian or Black were a risk factor for the development of PASC and being Asian or Hispanic was a risk factor for rehabilitation utilization within the inpatient population. Given this increased risk among non-English speakers and patients of color, information regarding PASC needs to be culturally and linguistically accessible as a possible tool to help mitigate this discrepancy.

Resource utilization was high in patients with PASC. Specifically, there was a higher number of therapy sessions and physical medicine and rehabilitation referrals . PASC patients underwent more therapy focused on activities of daily living, cognitive function, and neuromuscular education. Younger patients utilized rehabilitation services more overall (in combined severe and non-severe cases), but for patient's requiring inpatient admission, being older was a risk factor for needing rehabilitation services, and not surprisingly, those who required hospital admission made up the majority of patients needing rehabilitation. In the inpatient population, several demographic factors including male sex were risk factors for need for rehabilitation services. In addition, many comorbidities like hypertension, chronic obstructive lung disease, liver disease, and autoimmune disorders were also associated with increased rehabilitation utilization in the inpatient population. These data highlight not only the high rehabilitation utilization of patients with PASC but also speak to the effect PASC can have on society and the workforce. Additionally, this research can provide an introductory framework for hospital systems to implement rehabilitation programs targeting patients with multiple risk factors.

ACEIs/ARBs were associated with decreased risk of needing rehabilitation services in the inpatient population. This supports previous data suggesting possible protective benefits of

ACEIs/ARBs on mortality for COVID-19 patients.(21–23) Possible mechanisms for both medication categories include improved blood pressure control and potential downregulation of the Renin-angiotensin-aldosterone system (RAAS) with chronic use leading to decreased inflammation.(24–26) These data may suggest the benefit is more long-term and may reside across those with more severe disease.(27)

*Study Strengths and Limitations*

This study has many strengths. The large sample size, inclusion of both inpatient and outpatient participants, and extensive but relevant clinical variables allowed for a broader analysis of factors associated with PASC and rehabilitation. Additionally, our definition of PASC as new symptoms not present at baseline as well as the additional adjustments on the inpatient population reduced possible confounders. The study has several limitations. Our results do not suggest a casual inference and could be subject to residual confounding. Only patients diagnosed with COVID-19 at the healthcare system were included, and thus the population is not indicative of the whole healthcare system's patient population. There was a lack of a control non-COVID-19 cohort making us unable to compare the frequency and symptoms of PASC to a general post-viral illness syndrome. The information was also extracted from the electronic medical record from one hospital system, and taken from problem lists and notes, making data collection not standardized and possibly clinician dependent. Medications listed for patients don't ascertain actual medication use. Patients could have also received care at different healthcare systems and that information would not have been included. Additionally, there was no objective data collection analyzed (i.e., pulmonary function tests or computerized tomography (CT) imaging). Finally, the overall missingness of data was relatively low; only three variables had any

missingness > 0.2%: 17.8% of patients were missing body mass index, 4% were missing comorbidity data, and 6% of patients were missing race/ethnicity data. Given the low rate of missingness, multiple imputation was not done and a complete case analysis was conducted for multivariable analysis.(28)

*Conclusion*

Our study demonstrated a high frequency of PASC. Patients with PASC had a high amount of resource utilization and there were several demographic features and comorbidities that were associated with greater rehabilitation utilization. This study highlights the need for continued development of interdisciplinary teams and care facilities to address the needs of patients post-COVID-19 and provides a starting point for hospital systems to help triage at risk patients. Additional studies are needed that include a non-COVID-19 control group to accurately assess incidence, symptom presentations, and factors specific to PASC and patient's rehabilitation needs compared to general viral illnesses.

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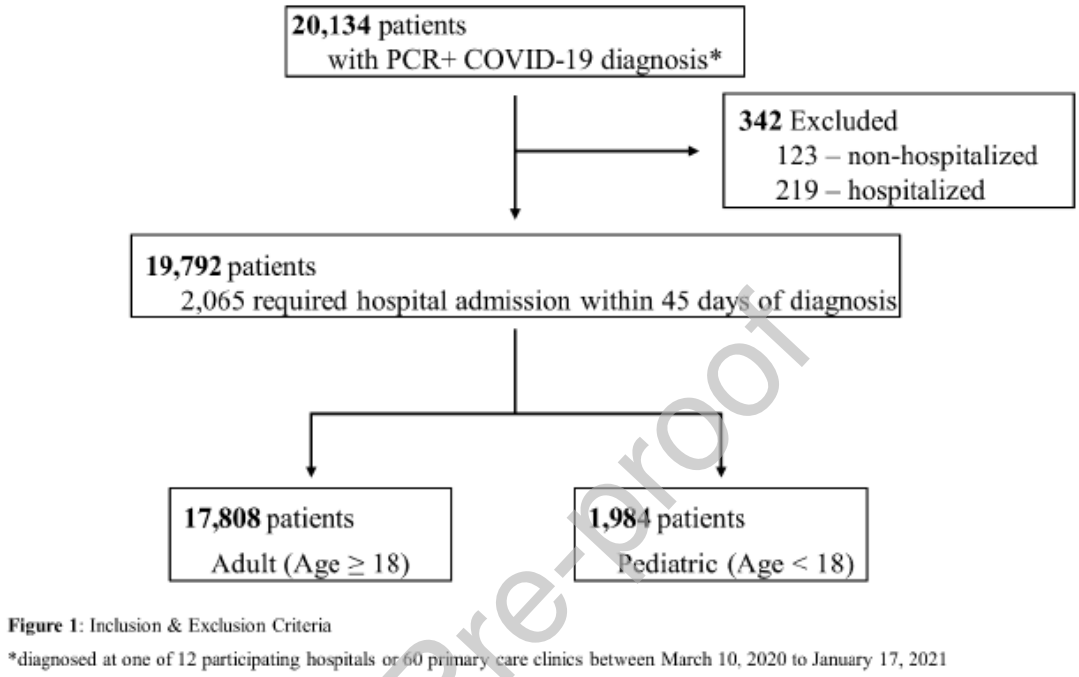


Figure 1: Study diagram of Patients Included in Final Analysis of COVID-19 Data Registry



**Table 1: Demographics and clinical characteristics of patients with PASC**

| | | No PASC (n=11,502) | Yes PASC (n=8290) | p-value |
|---|---|---|---|---|
| **Demographics** | | | | |
| Age | | 44.4 (27.9-59.9) | 51.4 (32.8-66.4) | <0.001 |
| Race | White | 8,052 (72.5%) | 5,746 (71.8%) | <0.001 |
| | Black | 1,401 (12.6%) | 1,040 (13.0%) | |
| | Asian | 600 (5.4%) | 579 (7.2%) | |
| | Hispanic | 463 (4.2%) | 332 (4.2%) | |
| | Declined | 472 (4.2%) | 218 (2.7%) | |

| | | | | |
|---|---|---|---|---|
| | Other | 123 (1.1%) | 83 (1.0%) | |
| Rural | | 7,475 (65.0%) | 5,768 (69.6%) | <0.001 |
| Male | | 4,924 (42.8%) | 3,149 (38.0%) | <0.001 |
| BMI | | 29.0 (8.4) | 29.9 (8.2) | <0.001 |
| Non-English Speaking | | 1,342 (11.7%) | 1,173 (14.1%) | <0.001 |
| **Comorbidities** | | | | |
| ELIX Comorbidity | | 1.0 (0.0-3.0) | 3.0 (1.0-6.0) | <0.001 |
| Pregnant | | 1,317 (11.5%) | 987 (11.9%) | 0.32 |
| Hypertension | | 4,187 (36.4%) | 4,240 (51.2%) | <0.001 |
| Type 1 Diabetes | | 356 (3.1%) | 527 (6.4%) | <0.001 |
| Type 2 Diabetes | | 1,624 (14.1%) | 1,899 (22.9%) | <0.001 |
| Coronary Artery Disease | | 930 (8.1%) | 1,265 (15.3%) | <0.001 |
| Heart failure with preserved ejection fraction | | 267 (2.3%) | 488 (5.9%) | <0.001 |
| Heart failure with reduced ejection fraction | | 288 (2.5%) | 416 (5.0%) | <0.001 |
| Transplant | | 139 (1.2%) | 143 (1.7%) | <0.01 |
| Liver Disease | | 805 (7.0%) | 933 (11.3%) | <0.001 |
| Autoimmune Disorder | | 600 (5.2%) | 782 (9.4%) | <0.001 |
| Chronic Obstructive Pulmonary Disease | | 518 (4.5%) | 809 (9.8%) | <0.001 |
| Interstitial Lung Disease | | 114 (1.0%) | 201 (2.4%) | <0.001 |
| Mild Asthma | | 896 (7.8%) | 877 (10.6%) | <0.001 |
| Mild Persistent Asthma | | 443 (3.9%) | 504 (6.1%) | <0.001 |
| Moderate Persistent Asthma | | 360 (3.1%) | 434 (5.2%) | <0.001 |
| Severe Asthma | | 53 (0.5%) | 62 (0.7%) | 0.01 |
| Sickle Cell | | 29 (0.3%) | 33 (0.4%) | 0.07 |
| Cancer | | 918 (8.0%) | 1,015 (12.3%) | <0.001 |
| **Medications (3 month Prior)** | | | | |
| Angiotensin- | | 1,720 | 1,888 | <0.001 |

| | | | | |
|---|---|---|---|---|
| converting-enzyme inhibitors/Angiotensin receptor blockers | | (15.0%) | (22.8%) | |
| Metformin | | 637 (9.7%) | 760 (11.9%) | <0.001 |
| Oral Steroids | | 640 (9.9%) | 861 (13.7%) | <0.001 |
| Cyclosporine /Tacrolimus | | 99 (1.6%) | 99 (1.6%) | 0.89 |
| Clopidogrel | | 120 (2.0%) | 171 (2.8%) | <0.01 |
| Inhaled Steroids | | 644 (10.5%) | 808 (13.4%) | <0.001 |
| Azithromycin | | 291 (4.9%) | 330 (5.6%) | 0.09 |
| Aspirin | | 1,583 (27.1%) | 1,814 (31.0%) | <0.001 |
| Tumor necrosis factor inhibitor | | 76 (0.7%) | 74 (0.9%) | 0.06 |
| Anticoagulation | | 483 (4.2%) | 658 (7.9%) | <0.001 |
| Beta 1Antagonist Beta 3Agonist | | 2 (0.0%) | 4 (0.1%) | 0.42 |
| Cardio selective Beta blocker | | 937 (17.3%) | 1,149 (21.0%) | <0.001 |
| Nonselective beta blocker | | 319 (6.3%) | 469 (9.0%) | <0.001 |
| Anti-Dementia | | 37 (0.5%) | 76 (1.1%) | <0.001 |
| Benzodiazepine | | 596 (5.2%) | 722 (6.3%) | 0.19 |
| Tricyclic antidepressants | | 170 (1.5%) | 246 (2.1%) | 0.03 |
| Serotonin Norepinephrine Reuptake Inhibitor | | 435 (3.8%) | 575 (5.0%) | 0.01 |
| Selective Serotonin Reuptake Inhibitor | | 1,235 (10.8%) | 1,365 (11.9%) | 0.51 |
| Antipsychotics | None | 10,907 (94.8%) | 7,486 (90.3%) | <0.001 |
| | Typical | 177 (1.5%) | 254 (3.1%) | |
| | Atypical | 378 (3.3%) | 469 (5.7%) | |
| | Both | 40 (0.3%) | 81 (1.0%) | |
| **Hospital Course or Complications** | | | | |
| Inpatient | | 746 (6.5%) | 1,382 (16.7%) | <0.001 |
| Intensive Care Unit | | 166 (1.4%) | 356 (4.3%) | <0.001 |
| Ventilation | | 50 (0.4%) | 113 (1.4%) | <0.001 |
| Remdesivir | | 338 (2.9%) | 653 (7.9%) | <0.001 |

| | | | | |
|---|---|---|---|---|
| Tocilizumab | | 21 (0.2%) | 32 (0.4%) | 0.01 |
| Received Steroids | | 138 (1.2%) | 213 (2.6%) | <0.001 |
| Bacteremia | | 45 (6.0%) | 73 (5.3%) | 0.48 |
| Acute Kidney Injury | | 84 (26.0%) | 162 (26.8%) | 0.80 |
| Venous Thromboembolism | | 79 (0.7%) | 150 (1.8%) | <0.001 |
| **Rehab** | | | | |
| Rehab during COVID | | 390 (3.8%) | 672 (8.6%) | <0.001 |
| Rehab after COVID | | 311 (3.0%) | 658 (8.4%) | <0.001 |
| Outpatient PMR | | 199 (1.7%) | 257 (3.1%) | <0.001 |
| Dysphagia | | 15 (0.1%) | 28 (0.3%) | <0.01 |
| Pulmonary Rehab | | 3 (0.0%) | 5 (0.1%) | 0.24 |
| Pulmonary Function Test | | 90 (0.8%) | 196 (2.4%) | <0.001 |
| Activities of Daily living therapy | | 22 (0.2%) | 67 (0.8%) | <0.001 |
| New Family Therapy | | 2 (0.0%) | 9 (0.1%) | 0.01 |
| New Cognitive function | | 3 (0.0%) | 10 (0.1%) | 0.01 |
| New neuromuscular education | | 134 (1.2%) | 210 (2.5%) | <0.001 |
| New therapy session | | 262 (2.3%) | 394 (4.8%) | <0.001 |
| New aphasia | | 11 (0.1%) | 24 (0.3%) | <0.01 |

Data are median (IQR) or n (%). Terms are according to the International Classification of Diseases.

**Table 2: Multivariate Logistic Regression of Independent Factors on the Development of PASC**

| | | **Odds Ratio** | **Confidence Interval** | **p-value** |
|---|---|---|---|---|
| **Demographics** | | | | |
| Male | | 0.82 | (0.76-0.87) | <0.001 |
| Age | | 1.00 | (1.00-1.00) | 0.60 |
| Race (compared to White) | Black | 1.11 | (1.00-1.23) | <0.05 |
| | Asian | 1.26 | (1.09-1.45) | 0.002 |
| | Hispanic | 1.09 | (0.93-1.29) | 0.29 |
| | Declined | 0.95 | (0.79-1.14) | 0.58 |
| | Other | 0.96 | (0.71-1.29) | 0.78 |

| | | | | |
|---|---|---|---|---|
| Rural | | 1.15 | (1.07-1.23) | <0.001 |
| Non-English Speaking | | 1.23 | (1.10-1.39) | <0.01 |
| **Comorbidities** | | | | |
| Pregnancy | | 1.18 | (1.06-1.30) | <0.01 |
| Body Mass Index | | 1.00 | (1.00-1.00) | 0.48 |
| Hypertension | | 1.15 | (1.06-1.26) | <0.01 |
| Asthma | | 1.14 | (1.04-1.24) | <0.01 |
| Chronic Obstructive Pulmonary Disease | | 1.13 | (0.99-1.30) | 0.07 |
| Interstitial Lung Disease | | 1.44 | (1.11-1.86) | <0.01 |
| Heart Failure | | 1.06 | (0.92-1.23) | 0.40 |
| Coronary Artery Disease | | 1.10 | (0.97-1.24) | 0.12 |
| Chronic Kidney Disease | | 1.33 | (1.18-1.50) | <0.001 |
| Type 1 Diabetes | | 0.84 | (0.69-1.03) | 0.10 |
| Type 2 Diabetes | | 1.09 | (0.98-1.21) | 0.13 |
| Cancer | | 0.97 | (0.87-1.08) | 0.57 |
| Liver Disease | | 1.07 | (0.96-1.20) | 0.22 |
| Sickle Cell | | 1.39 | (0.81-2.38) | 0.24 |
| Anxiety | | 1.24 | (1.09-1.41) | <0.01 |
| Depression | | 1.08 | (0.96-1.22) | 0.10 |
| Autoimmune | | 1.29 | (1.14-1.45) | <0.001 |
| Transplant | | 0.68 | (0.46-1.00) | <0.05 |
| **Medications (3 months prior)** | | | | |
| Aspirin | | 1.00 | (0.91-1.11) | 0.97 |
| Clopidogrel | | 1.03 | (0.78-1.35) | 0.85 |
| Anticoagulation | | 1.02 | (0.88-1.18) | 0.79 |
| Inhaled Steroids | | 1.12 | (0.99-1.27) | 0.09 |
| Oral Steroids | | 1.23 | (1.09-1.39) | <0.01 |
| Benzodiazepines | | 1.12 | (0.99-1.27) | 0.08 |
| Angiotensin-converting-enzyme inhibitors/Angiotensin receptor blockers | | 1.01 | (0.92-1.11) | 0.84 |
| Metformin | | 1.03 | (0.89-1.19) | 0.68 |
| Azithromycin | | 1.16 | (0.97-1.38) | 0.11 |
| Tumor necrosis factor inhibitor | | 1.02 | (0.72-1.46) | 0.91 |
| Cyclosporine /Tacrolimus | | 0.98 | (0.63-1.54) | 0.93 |

| | | | | |
|---|---|---|---|---|
| Testosterone | | 1.26 | (0.81-1.96) | 0.32 |
| Beta Blocker | | 1.14 | (1.02-1.26) | 0.02 |
| Antidementia | | | | |
| Selective Serotonin Reuptake Inhibitor | | 1.22 | (1.11-1.34) | <0.001 |
| Tricyclic antidepressants | | 1.36 | (1.10-1.69) | 0.01 |
| Serotonin Norepinephrine Reuptake Inhibitor | | 1.26 | (1.09-1.45) | <0.01 |
| Antipsychotics | Typical | 1.24 | (0.99-1.54) | 0.06 |
| | Atypical | 1.11 | (0.95-1.31) | 0.18 |
| | Both | 1.47 | (0.96-2.23) | 0.07 |
| **Other** | | | | |
| Inpatient | | 1.97 | (1.77-2.19) | <0.001 |
| Rehab before COVID | | 1.91 | (1.78-2.05) | <0.001 |

**Table 3: Multivariate Logistic Regression of Independent Factors on Rehabilitation Utilization in Patients with PASC**

| | | **Odds Ratio** | **Confidence Interval** | **p-value** |
|---|---|---|---|---|
| **Demographics** | | | | |
| Male | | 0.84 | (0.65-1.08) | 0.18 |
| Age | | 0.99 | (0.98-1.00) | 0.01 |
| Race | Black | 0.92 | (0.60-1.42) | 0.71 |
| | Asian | 1.03 | (0.63-1.68) | 0.91 |
| | Hispanic | 1.36 | (0.72-2.59) | 0.34 |
| | Declined | 2.22 | (0.77-6.38) | 0.14 |
| | Other | 1.00 | (0.34-2.95) | 1.00 |
| Rural | | 0.99 | (0.74-1.32) | 0.93 |
| Non-English Speaking | | 1.12 | (0.73-1.72) | 0.59 |
| **Comorbidities** | | | | |
| Pregnancy | | 3.30 | (1.92-5.66) | <0.001 |
| Body Mass Index | | 1.00 | (0.99-1.02) | 0.58 |
| Hypertension | | 1.20 | (0.84-1.72) | 0.31 |
| Asthma | | 1.37 | (1.00-1.85) | <0.05 |
| Chronic Obstructive | | 1.13 | (0.82-1.56) | 0.46 |

| | | | | |
|---|---|---|---|---|
| Pulmonary Disease | | | | |
| Interstitial Lung Disease | | 1.69 | (1.02-2.78) | 0.04 |
| Heart Failure | | 1.29 | (0.94-1.78) | 0.12 |
| Coronary Heart Disease | | 1.20 | (0.87-1.64) | 0.26 |
| Chronic Kidney Disease | | 1.09 | (0.79-1.49) | 0.61 |
| Type 1 Diabetes | | 1.42 | (0.84-2.39) | 0.19 |
| Type 2 Diabetes | | 0.76 | (0.55-1.04) | 0.09 |
| Cancer | | 0.85 | (0.62-1.15) | 0.29 |
| Liver Disease | | 1.17 | (0.85-1.59) | 0.34 |
| Sickle Cell | | 1.23 | (0.10-14.53) | 0.87 |
| Anxiety | | 1.17 | (0.73-1.89) | 0.51 |
| Depression | | 0.93 | (0.60-1.46) | 0.76 |
| Autoimmune | | 0.92 | (0.63-1.32) | 0.64 |
| Transplant | | 0.88 | (0.31-2.48) | 0.80 |
| **Medications (3 months prior)** | | | | |
| Aspirin | | 1.09 | (0.81-1.45) | 0.58 |
| Clopidogrel | | 0.76 | (0.40-1.44) | 0.40 |
| Anticoagulation | | 0.93 | (0.65-1.32) | 0.68 |
| Inhaled Steroids | | 0.73 | (0.50-1.06) | 0.10 |
| Oral Steroids | | 1.24 | (0.86-1.77) | 0.25 |
| Benzodiazepines | | 1.50 | (0.93-2.41) | 0.10 |
| Angiotensin-converting-enzyme inhibitors/Angiotensin receptor blockers | | 1.16 | (0.86-1.56) | 0.32 |
| Metformin | | 0.75 | (0.50-1.13) | 0.17 |
| Azithromycin | | 1.07 | (0.62-1.85) | 0.82 |
| Tumor necrosis factor inhibitor | | 2.98 | (0.49-18.10) | 0.24 |
| Cyclosporine /Tacrolimus | | 1.12 | (0.33-3.79) | 0.86 |
| Beta Blocker | | 1.36 | (1.00-1.85) | 0.05 |
| Selective Serotonin Reuptake Inhibitor | | 0.90 | (0.64-1.26) | 0.54 |
| Tricyclic antidepressants | | 2.01 | (0.99-4.09) | 0.05 |
| Serotonin Norepinephrine Reuptake Inhibitor | | 1.02 | (0.64-1.61) | 0.95 |
| Antipsychotics | Typical | 1.39 | (0.72-2.67) | 0.32 |

| | | | | |
|---|---|---|---|---|
| | Atypical | 0.90 | (0.55-1.45) | 0.65 |
| | Both | 0.56 | (0.21-1.50) | 0.25 |
| **Other** | | | | |
| Rehab before COVID | | 0.95 | (0.73-1.25) | 0.73 |

Supplementary Material

Supplemental Table 1: Variables and associated CPT codes used for Resource utilization in Patients with PASC

Supplemental Table 2: PASC Symptoms and Variables hypothesized to be associated with PASC development

Supplemental Table 3: Multivariate Logistic Regression of Independent Factors on Rehabilitation Services in the Inpatient Population with PASC