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MAJOR ARTICLE

Pneumocystis jirovecii Infections Among COVID-19 Patients: A Case Series and Literature Review

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Background. *Pneumocystis jirovecii* pneumonia (PCP) is a serious, emerging complication of coronavirus disease 2019 (COVID-19).

Methods. We performed a systematic review of published cases. We describe 6 new cases of PCP/COVID-19 coinfection. Among our cases (n = 6) and those in the literature (n = 69) with available data, the median age (interquartile range [IQR]) was 59 (44–77) years (n = 38), 72% (47/65) were male, and the mortality rate was 30.9% (21/68).

Results. Long-term corticosteroid use was noted in 45.1% (23/51), advanced HIV infection (defined as a CD4 count <200 cells/μL) in 17.6% (9/51), and antineoplastic chemotherapy in 13.7% (7/51), consistent with known PCP risk factors. Notably, 56.7% (38/47) had verifiable risk factors for PCP (high-dose corticosteroids, immunosuppressive therapy, and HIV infection) before COVID-19 infection. A median absolute lymphocyte count (IQR) of 0.61 (0.28–0.92) $\times 10^3$ cells/mm^3 (n = 23) and CD4 count (IQR) of 66 (33–291.5) cells/mm^3 (n = 20) were also discovered among the study population.

Conclusions. These findings suggest a need for greater attention to PCP risk factors among COVID-19 patients and consideration of PCP prophylaxis in these high-risk populations.

Keywords. COVID-19; PCP; coinfection; immunocompromised; invasive fungal infections; pneumocystis; *Pneumocystis jirovecii*.

Anecdotal reports of invasive fungal coinfections in patients with coronavirus disease 2019 (COVID-19) began emerging during the earliest days of the COVID-19 pandemic. Subsequently, numerous reports have emerged noting that those with severe COVID-19 have greater incidences of pulmonary aspergillosis [1] and mucormycosis [2] than those with mild COVID-19. Importantly, invasive fungal coinfections are associated with worse clinical outcomes, with mortality rates between 40% and 50% if appropriate antifungal treatment is delayed or absent [3]. There have also been case reports [4–24] of *Pneumocystis jirovecii* pneumonia (PCP) among patients with severe COVID-19 [25].

P. jirovecii is a ubiquitous environmental fungus found globally that can cause pneumonia following inhalation and colonization within the host's lungs. PCP is predominately seen in immunocompromised hosts and is typically characterized by progressive dyspnea, fever, ground glass opacities on radiographic imaging, and hypoxemia [26]. The similar clinical and radiographic appearances of PCP and COVID-19 have made discernment between the 2 infections challenging [27].

Despite its prominent correlation with advanced HIV infection, PCP also occurs in other immunocompromised populations, such as transplant recipients, patients with cancer receiving antineoplastic chemotherapy, and patients on long-term glucocorticoids [28]. Notably, non-HIV PCP populations may have a higher mortality rate (30.6%) [29] when compared with persons with HIV infection (9.7%–16.9%), which may be relevant to COVID-19 and PCP coinfection [30]. Herein we present 6 cases of PCP after or during COVID-19 infection and systematically review the current literature to better characterize potential risk factors and the clinical outcomes of PCP in the setting of COVID-19.

METHODS

Case Series

Following institutional review board approval, cases were retrospectively identified using International Classification of Diseases, 10th Revision, codes for PCP and COVID-19 between the dates of March 1, 2020, and June 1, 2022. De-identified data were collected and stored on REDCap (Vanderbilt University, Nashville, TN, USA). Persons 18 years of age and older with PCP concurrent with or within 1 year after COVID-19 infection were eligible. COVID-19 infection was defined as a positive polymerase chain reaction (PCR) or antigen test in the context of symptoms attributable to COVID-19. PCP was defined by Mycoses Study Group Education and Research Consortium criteria (Table 1).

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Table 1. *Pneumocystis jirovecii* Detection Criteria[a] [31]

Proven *P. jirovecii*	
Direct detection of the organism	• Detection of the organism microscopically in tissue, BAL fluid, expectorated sputum using conventional or immunofluorescence staining
Probable *P. jirovecii*[b]	
Host factors	• CD4 count <200 cells/mm^3 • Exposure to a medication with known anti-T-cell effects (antineoplastic, anti-inflammatory, or immunosuppressive) • ≥2 wk of prednisone equivalent dosing ≥0.3 mg/kg in the past 60 d • Solid organ transplant
Clinical features	• Radiographic features: particularly bilateral ground glass opacities, nodules, consolidations, cystic lesions, etc. • Respiratory symptoms accompany radiographic abnormalities: nodules, infiltrates, effusions, etc.
Mycologic evidence	• Detection of β–D-glucan ≥80 ng/L in >2 consecutive serum samples, provided exclusion of other etiologies • PCR detection of Pneumocystis jirovecii

Abbreviations: BAL, bronchoalveolar lavage; PCR, polymerase chain reaction.

[a]Table adapted from Donnelly et al. for the European Organization for Research and Treatment of Cancer and the Mycoses Study Group Education and Research Consortium.

[b]Must meet at least 1 criterion from each of the 3 categories.

Information collected for each patient included age at diagnosis, sex, hospital unit type, length of stay, risk factors for PCP and COVID-19, therapeutics used for PCP and COVID-19, mechanical ventilation requirement, lowest pulse oximetry measurement, renal replacement therapy requirement, days between COVID-19 and PCP diagnoses, mortality at hospital discharge, and laboratory testing including lowest PaO_2, lactate dehydrogenase (LDH), 1,3-β-D-glucan (BDG), CD4 and absolute lymphocyte counts at the time of PCP diagnosis, and diagnostic tests for PCP and COVID-19.

Literature Review

Systematic searches of Embase and Medline (January 2020–June 2022) were conducted to identify cases of PCP during or within 1 year of COVID-19. Duplicate results were removed, and the remaining papers were screened for inclusion criteria. Case reports, case series, case–control studies, and cohort studies with cases of PCP during or after COVID-19 were included. Reviews and opinion articles were excluded. Articles were only included if available in English or Spanish. Data collection was identical to our own reported cases as available.

Data from published reports and from the current report were combined as available for descriptive purposes.

RESULTS

Case Reports

Between March 1, 2020, and June 1, 2022, 6 patients were identified as having PCP among the 2324 patients hospitalized for COVID-19 pneumonia at our institution (incidence = 0.26% cases of PCP per COVID-19 hospitalization). Two of the cases are presented in narrative form below. All 6 cases are described below (Table 2).

Patient 1

An 84-year-old woman was hospitalized for COVID-19 pneumonia and pulmonary embolism and treated with remdesivir, dexamethasone, and apixaban. She was discharged after 15 days but readmitted a week later with worsening respiratory symptoms. Upon readmission, she was diagnosed with probable pulmonary histoplasmosis by detection of a positive urinary *Histoplasma* antigen and treated with itraconazole. BDG was also elevated at 191 pg/mL (reference range, <80 pg/mL).

Her hypoxemia increased, and she underwent bronchoalveolar lavage (BAL). PCR testing for *P. jirovecii* in BAL fluid was positive 39 days after her initial COVID-19 diagnosis, and she was started on trimethoprim-sulfamethoxazole (TMP-SMX). HIV testing was negative, but her CD4 count was 34 cells/mm^3. Therapy for PCP was changed to atovaquone due to thrombocytopenia. She improved and was discharged on itraconazole, atovaquone, and a prednisone taper. She was readmitted 81 days after her initial COVID-19 diagnosis with decompensated congestive heart failure, and voriconazole was substituted for itraconazole. She improved and was discharged home on day 101.

Patient 2

A 49-year-old woman with numerous comorbidities (Table 2) including a deceased donor kidney transplant a year before presentation (on prednisone, mycophenolate, and tacrolimus) was admitted for COVID-19. She was treated with remdesivir and dexamethasone, as well as 2 units of anti–severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) convalescent plasma. Tacrolimus and mycophenolate doses were reduced. She was discharged 6 days after admission to complete a course of dexamethasone for COVID-19, after which she would resume her prior prednisone.

The patient was readmitted to the intensive care unit (ICU) 11 days from initial presentation due to acute hypoxemic respiratory failure. Despite empiric antibiotic administration, her condition worsened, and she was intubated on day 15. On day 19 from the initial presentation, her BDG was elevated at 137 pg/mL and serum LDH was 627 unit/L (reference range, 91–180 unit/L). Computed tomography (CT) of the chest revealed pulmonary nodules and diffuse ground glass opacities. Given these findings, she was started on TMP-SMX for presumed PCP. Confirmation of PCP via BAL was unobtainable due to the patient's tenuous clinical status. Unfortunately, the patient's status continued to worsen, and she died 23 days after her initial presentation.

Systematic Review Results

A systematic review of the literature (Figure 1) was conducted, resulting in 29 articles (Table 3) describing 69 cases of PCP and

Table 2. Summary of Presented Cases at Time of PCP diagnosis

	Patients	1	2	3	4	5	6	Median [IQR] or No. (%)
Demographics	Age, y	84	49	58	61	69	66	63.5 [58–69]
…	Sex	Female	Female	Male	Female	Male	Male	3/6 (50) female
…	Mortality at hospital discharge[a]	Living	Deceased	Living	Living	Living	Living	1/6 (16.7) deceased
COVID-19	Risk factors at PCP diagnosis	HTN, CAD, asthma, IgM deficiency	DM2, HTN, CAD, obese, S/P SOT (tacrolimus, corticosteroids, mycophenolate)	MM II, S/P ASCT long-term corticosteroids	CKD, DLBL IV	Obese, methotrexate for RA	HTN	5/6 (83.3) had PCP risk factors before COVID-19
…	Treatment	Remdesivir, dexamethasone	Remdesivir, dexamethasone	Remdesivir, dexamethasone, bamlanivimab-etesevimab	Dexamethasone, baricitinib, casirivimab-imdevimab	Remdesivir, CP, dexamethasone	Remdesivir, dexamethasone	…
…	Prednisone-equivalent steroid administration,[b] mg	400	660 + 5 daily for SOT	240 + 130 weekly for MM/ASCT	1310	400	930	530 [400–930]
Pneumocystis	Status	Probable	Probable	Probable	Probable	Probable	Probable	6/6 (100)
…	Diagnosis method	BAL PCR, β −D-Glucan	β−D-Glucan, LDH, clinical picture	BAL PCR, β−D-Glucan	BAL PCR, β−D-Glucan	Sputum PCR, clinical picture	BAL PCR, β−D-Glucan	…
…	Risk factors at PCP diagnosis	Corticosteroids	Immune compromised, corticosteroids	Immune compromised, corticosteroids,	Immune compromised, corticosteroids	Immune compromised, corticosteroids	Corticosteroids	6/6 (100) corticosteroids
…	Treatment	TMP-SMX, then atovaquone	TMP-SMX	TMP-SMX, then atovaquone, prednisone	TMP-SMX, prednisone	TMP-SMX, then atovaquone	TMP-SMX, then atovaquone, prednisone	…
…	Time of PCP diagnosis, d from COVID-19 diagnosis	39	19	58	199	16	43	41 [19–58]
Laboratory findings	β−D-Glucan [<80], pg/mL	191	137	>500	>500	31	292	241.5 [137–>500]
…	LDH [91–180], units/L	303	536	204	320	398	428	359 [303–428]
…	ALC [1.0–4.8], K/mm^3	…	0.54	1.56	0.61	0.64	0.97	0.64 [0.58–1.27]
…	CD4 count [>200], cells/mm^3	34	…	243	382	56	…	200 [56–382]
…	Lowest PaO_2, mmHg	78	45	72	52	58	45	55 [45–72]
Imagining findings	CT chest	Bilateral infiltrates and diffuse ground glass opacities[c]	Bilateral nodules and diffuse ground glass opacities	Diffuse ground glass opacities with new, focal nodular opacities	Diffuse ground glass opacities	New peripheral infiltrates	Diffuse ground glass opacities and prominent mediastinal lymph nodes	…

Table 2. Continued

		Patients	1	2	3	4	5	6	Median [IQR] or No. (%)
Hospital stay	ICU stay		Yes	Yes	No	Yes	Yes	No	4/6 (66.7) ICU admission
…	ICU days	10		13	N/A	27	7	N/A	10 [4.5–20]
…	Mechanical ventilation	Yes		Yes	No	Yes	No	No	3/6 (50) MV

Roman numerals indicate stage of malignancy.

Abbreviations: ALC, absolute lymphocyte count; ASCT, autologous hematopoietic stem cell transplant; BAL, bronchoalveolar lavage; CAD, coronary artery disease; CKD, chronic kidney disease; CP, convalescent plasma; CT, computed tomography; DLBL, diffuse large B-cell lymphoma; DM2, type 2 diabetes mellitus; HM, hematogenic malignancy; HSCT, nonautologous hematopoietic stem cell transplant; HTN, hypertension; ICU, intensive care unit; IgM, immunoglobulin M; IQR, interquartile range; LDH, lactate dehydrogenase; MDS, myelodysplastic syndrome; MM, multiple myeloma; PaO_2, partial pressure of arterial oxygen; PCP, *Pneumocystis jirovecii* pneumonia; PCR, polymerase chain reaction; RA, rheumatoid arthritis; S/P, status post; SOT, solid organ transplant; TMP-SMX, trimethoprim-sulfamethoxazole.

[a]From hospitalization with PCP diagnosis.

[b]Prednisone-equivalent dosing from time of COVID-19 diagnosis until PCP diagnosis. Daily or weekly administration of steroids for existing conditions is in addition to administration during hospital admittance for at least 6 months before hospitalization.

[c]Imaging findings at time of diagnosis only available on PA and lateral chest x-ray, but improving and comparable findings were found on CT chest at 1-month follow up.

COVID-19 coinfections. Cohort studies from France [25, 33] and India [34] contained the largest collection of cases reported but had limited patient information. Alanio et al. reported 10 cases of PCP among 108 COVID-19 French ICU patients during a 1.5-month period (9.25%) [25]. Bretagne et al. reported PCP in 17 of 244 patients with fungal infections and COVID-19 during a 5-month period at 36 centers in France, but the number of total COVID-19 patients was not available, so an incidence of PCP/COVID-19 coinfection could not be calculated [33]. Smaller studies in India (n = 5 PCP infections), Jordan (n = 3 PCP infections), and France (n = 5 PCP infection), respectively, reported incidences of 2.6% (ICU patients only) [34], 9.7% (among hospitalized asthmatics with COVID-19) [4], and 7% (among patients receiving a BAL PCP within a month of COVID-19 diagnosis) [35].

Demographic, diagnostic, risk factor, and laboratory information is summarized in Table 4 for cases from our report and the literature review (n = 75). The median age (interquartile range [IQR]) was 59 (44–70) years (n = 38), and 72% were male (47/65) [4–12, 14–23, 35–38]. According to the previously described criteria by Donnelly et al., 8 cases were proven PCP and the remainder were probable [31]. Most patients had significant risk factors for PCP during their index COVID-19 illness, and 70% had risk factors for PCP before SARS-CoV-2 infection. Additionally, 82% (32/39) of patients received corticosteroids during their hospitalization for COVID-19. Mortality rates varied widely between studies, but overall, ~31% of patients died in the hospital, either during their index admission or during readmission for PCP. This mortality rate is consistent with previously reported mortality rates of PCP in patients without HIV (30.6%) [29].

DISCUSSION

The literature review identified demographic trends, with a median age of 59 years and a male predominance (72.3%). Patients in our case series were generally older (median age, 66 years), and the gender distribution was more equal, although we had only 6 cases. Variance between PCP prevalence among patient populations in our case series (0.26%) and the literature review (4.2%) [25, 34, 35] was impacted by 2 factors. First, our evaluation of patients at our institution was by no means exhaustive. Second, our prevalence was among all COVID-19 patients at our institution, and the literature review reflects a prevalence among COVID-19 patients admitted to the ICU [25, 34, 35].

While the causative relationship between moderate to severe COVID-19 and PCP still requires further investigation, the review revealed several potential risk factors. A previous review by Chong et al. identified 91.7% (11/12) of patients as having acquired immunodeficiencies through HIV infection, long-term glucocorticoid use, and other forms of immunosuppression [39]. Our larger review found that 56.7% (38/67, including

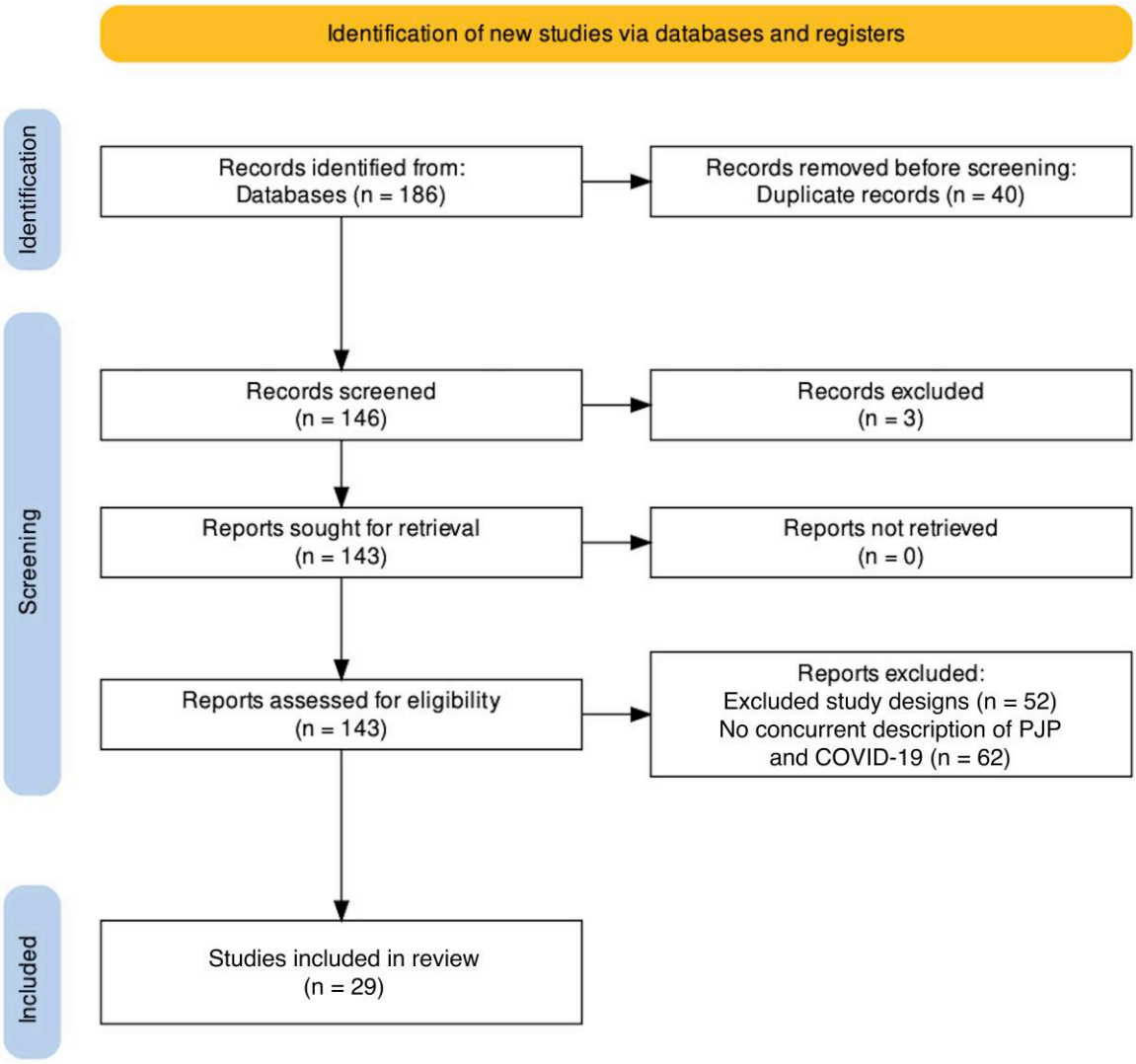

Figure 1. Study inclusion procedures. Excluded Medline articles: Out of 95 articles, 33 articles were excluded because they were review or opinion articles, 3 articles were not in English or Spanish, and 32 articles were excluded because there was no description of PCP/COVID-19 co- or postinfections. Excluded Embase articles: Out of 91 articles, 40 were excluded due to duplication with the Medline database, 19 were excluded because they were review or opinion articles, and 28 were excluded because they contained no description of PCP/COVID-19 co- or postinfections. Included studies: Cohort, cross-sectional, case series, and case report studies that described concurrent or post-COVID-19 infections with PCP were included in the original screening [32]. Abbreviations: COVID-19, coronavirus disease 2019; PCP, *Pneumocystis jirovecii* pneumonia.

5 of 6 new cases we reported) of patients had PCP risk factors (ie, lymphopenia, high-dose glucocorticoids, immunosuppression, and HIV) before COVID-19 diagnosis as defined by Donnelly et al. [31].

Long-term glucocorticoid use before and, notably, during COVID-19 infection may be one of the more significant contributing risk factors. Glucocorticoid administration was described in 45.1% (17/51) of patients before COVID-19 infection, but only 1 could be verified as receiving high-dose glucocorticoids, defined as >20 mg prednisone equivalent per day for >4 weeks, before COVID-19 infection [21]. Additionally, 82% (32/39) of PCP cases reported COVID-19 treatment regimens including dexamethasone, prednisone, or methylprednisolone. Only 3 cases could be verified as receiving high-dose glucocorticoid administration for treatment of COVID-19 [10, 36]. Steroid administration for COVID-19 was described for 13 patients, including our presented cohort, between their COVID-19 and PCP diagnoses. The median total prednisone equivalent dose (IQR) was 630 (400–946) mg before PCP diagnosis, illustrating a potentially significant risk factor for PCP [10, 19, 36]. Conversely, most cases did not specify steroid administration, and an additional 10 cases received glucocorticoids for a co-presentation of PCP and COVID-19. Similarly, the literature review demonstrated HIV infection as a risk factor in 17.6% (9/51, none of our 6 cases) of patients. Of the 9 cases identified with HIV, 8 were newly diagnosed HIV

Table 3. Literature Summary

Study Design	Studies	Cases	% of Total Cases
Case series	3	14	18.7
Case report	21	22	29.3
Prospective cohort study	4	35	46.7
Retrospective cohort study	1	4	5.3
Totals	29	75	100

infections at original presentation who were not on antiretroviral therapy (ART), and the 1 chronic case was receiving TMP-SMX PCP prophylaxis, suggesting a known CD4 count of <200 cells/mm^3.

Lymphopenia was also identified as a significant risk factor for those with PCP following COVID-19 infection. The median absolute lymphocyte count from the literature review including our cases (IQR) was 0.6 (0.26–0.86) ×10^3 cells/mm^3. However, we could only verify described lymphopenia at the time of COVID-19 diagnosis in 7 patients compared with the 25 cases identified with lymphopenia at the time of PCP diagnosis [5, 7, 8, 10, 11, 14, 16, 17, 21, 35, 36]. Our case series findings support lymphopenia as a possible risk factor for PCP in the setting of COVID-19 infection.

Of additional interest, BDG was only positive in 66.7% (26/39) of patients tested. In all cases where a BDG was collected, patients were verified to have PCP infection through clinical symptoms and a diagnostic PCP PCR testing. Discordance between BDG and PCP PCR is difficult to reconcile. It could indicate a false-negative BDG or a false-positive PCP PCR or represent PCP colonization rather than infection.

Lastly, outcomes were generally poor, with nearly 80% requiring ICU admission (46/58) and a >30% mortality rate (21/68). These outcomes are likely biased by both indication for testing (eg, testing for PCP is not done in those improving) and reporting (some reports only summarized ICU cases). A probable contributor to these poor outcomes, however, might be the lack of PCP prophylaxis administration in 3 patients with preexisting PCP risks before COVID-19 [14, 35].

Table 4. Summary of all Cases

	Characteristic	Patients With Available Data	Median [IQR]	(No.) %	Citations
Demographics	Age, y	n = 48	59 [44–70]	…	[5–12, 14, 16, 17, 19–23, 25, 34–37]
…	Sex: male	n = 65	…	(47/65) 72.3	[5–12, 14–23, 25, 33, 35–38]
COVID-19	Status: PCR-positive	n = 75	…	(74/75) 98.7	[4–12, 14-25, 33–38]
…	Treatment: corticosteroids	n = 39	…	(32/39) 82.1	[5, 7–12, 15–20, 23, 25, 36, 38]
Risk factors[a]	HIV	n = 51	…	(9/51) 17.6	[4–12, 14-25, 33–38]
…	Long-term corticosteroid use before COVID-19	n = 51	…	(23/51) 45.1	[4–12, 14–25, 33–38]
…	Prednisone-equivalent steroid administration,[b] mg	n = 13	630 [400–946]	…	[10, 19, 36]
…	Antineoplastic chemotherapy	n = 51	…	(7/51) 13.7	[4–12, 14–25, 33–38]
…	Transplant-related immunosuppression	n = 51	…	(3/51) 5.9	[4–12, 14–25, 33–38]
…	CKD, ESRD, or RRT	n = 51	…	(10/52) 19.2	[4–12, 14–25, 33–38]
…	Patients with verified PCP risk factors before COVID-19[c]	n = 67	…	(38/67) 56.7	[4–12, 14–23, 25, 33, 35–38]
Pneumocystis	Status: proven	n = 75	…	(8/75) 10.7	[4–12, 14–25, 33–38]
…	Status: probable	n = 75	…	(67/75) 89.3	[4–12, 14–25, 33–38]
…	PCP among severe COVID-19	n = 501	…	(12/279) 4.3	[25, 34, 35]
…	PCP among all COVID-19	n = 2324[d]	…	(6/2324) 0.26	…
…	Days from COVID-19 diagnosis	n = 29	25 [4.5–42.5]	…	[5–8, 10–12, 14–17, 19–22, 35, 36]
Labs	Elevated β–D-Glucan [<80], pg/mL	n = 39	…	(26/39) 66.7	[6, 8, 11, 14, 16, 18, 19, 25, 33, 35, 36]
…	LDH [91–180], unit/L	n = 31	508 [346–641]	…	[6–8, 10, 11, 16, 17, 19, 21, 25, 35, 36]
…	ALC [1.0–4.8], ×10^3 cells/mm^3	n = 23	0.60 [0.26–0.86]	…	[5, 7, 8, 10, 11, 14, 16, 17, 21, 35, 36]
…	CD4 count, cells/mm^3	n = 20	64 [33–267]	…	[6–11, 15–18, 22, 36]
…	Lowest PaO_2, mmHg	n = 16	64 [55–66.5]	…	[5–8, 19, 36]
Outcomes	ICU admission	n = 58	…	(46/58) 79.3	[4–6, 8–12, 15–17, 19, 23, 25, 33, 35–37]
…	ICU days admitted	n = 58	8.5 [3.5–16.0]	…	[4–6, 8–12, 15–17, 19, 23, 25, 33, 35–37]
…	Mechanical ventilation	n = 31	…	(19/30) 63.3	[4–6, 8–12, 15–17, 19, 23, 25, 35–37]
…	Mortality	n = 68	…	(21/68) 30.9	[4–12, 14–23, 25, 33, 35–38]

Abbreviations: ALC, absolute lymphocyte count; CKD, chronic kidney disease; COVID-19, coronavirus disease of 2019; ESRD, end-stage renal disease; ICU, intensive care unit; IQR, interquartile range; LDH, lactose dehydrogenase; PaO_2, partial pressure of arterial blood oxygen; PCP, *Pneumocystis jirovecii* pneumonia; PCR, polymerase chain reaction; RRT, renal replacement therapy.

[a]Risk factors were identified as those happening both during treatment for COVID-19 and before diagnosis.

[b]Prednisone equivalent determined using MedCalc(c).

[c]Risk factors for PCP before COVID-19 infection identified from described past medical histories and defined as immunosuppression from long-term corticosteroids, antineoplastic chemotherapy, untreated HIV, immunosuppressive therapies accompanying transplants, and other immunosuppressed states in accordance with Donnelly et al. [31].

[d]Based on the number of patients admitted to our institution between March 1, 2020, and June 1, 2022, for COVID-19.

Limitations

This study has several limitations. The most obvious is its small sample size and its retrospective design. Another limitation was lack of detail regarding immunomodulators used for the treatment of moderate to severe COVID-19. The literature we reviewed did not comment on the use of interleukin-6 or Janus kinase inhibitors. Additionally, the lack of a control population in our case series and literature review limits the strength of the association between identified patient risk factors and PCP in COVID-19 patients. However, this systematic review of 75 cases provides the most comprehensive look to date at PCP/COVID-19 coinfection.

CONCLUSIONS

This study adds to the growing body of evidence supporting an increased risk of invasive fungal infections in the context of COVID-19 and its treatment. This review highlights the importance of maintaining PCP as a diagnostic consideration in patients with severe COVID-19, especially when extended glucocorticoid courses are used to treat COVID-19 in the context of ongoing or worsening respiratory symptoms. While the exact mechanism that predisposes patients with severe COVID-19 to PCP infection is an area in need of further research, descriptive studies such as this one may raise awareness of this underreported phenomenon. We identified among the literature and our own cases a lack of PCP prophylaxis administration among patients meeting the high-risk categories described by the Mycoses Study Group Education and Research Consortium [31]. We recommend a low threshold for evaluation of PCP in the setting of COVID-19 patients with the following risk factors: high-dose corticosteroids within the past 60 days, advanced HIV infection, particularly those not on ART, immunosuppressive and antineoplastic treatment regimens, and lymphopenia [31]. With increased global collaboration, it is possible that greater insight might be gained into this deadly fungal coinfection and its prevention.

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Potential conflicts of interest. All authors: no reported conflicts.

Patient consent. The design of the work has been approved by local ethical committees; the study conforms to standards currently applied in the country of origin and includes the name of the authorizing body, which should be stated in the paper.

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