Received: 17 June 2022 | Accepted: 22 August 2022

DOI: 10.1002/jmv.28085

RESEARCH ARTICLE

JOURNAL OF MEDICAL VIROLOGY WILEY

Clinical characteristics and outcomes of patients with COVID-19 and psoriasis

Yu Meng[1,2] | Furong Zeng[1,2,3] | Huiyan Sun[1,2] | Yayun Li[1,2] | Xiang Chen[1,2] | Guangtong Deng[1,2]

[1]Department of Dermatology, Hunan Engineering Research Center of Skin Health and Disease, Hunan Key Laboratory of Skin Cancer and Psoriasis, Xiangya Hospital, Central South University, Changsha, Hunan, China

[2]National Clinical Research Center for Geriatric Disorders, Xiangya Hospital, Central South University, Changsha, Hunan, China

[3]Department of Oncology, Xiangya Hospital, Central South University, Changsha, Hunan, China

Correspondence

Guangtong Deng, Furong Zeng, Xiang Chen, Department of Dermatology, Xiangya Hospital, Central South University, 87# Xiangya Road, Changsha 410008, Hunan, China.

Email: dengguangtong@outlook.com; zengflorachn@hotmail.com and chenxiangck@126.com

Funding information

National Natural Science Foundation of China; Natural Science Foundation of Hunan Province

Abstract

To summarize the clinical characteristics and explore the role of treatment types in outcomes among psoriasis patients with coronavirus disease 2019 (COVID-19). The principal summary measures were pooled prevalence and risk ratio (RR) with 95% confidential interval (CI). R statistic software was used for all the analysis. A total of 19 studies including 4073 psoriasis patients with COVID-19 were eligible for the meta-analysis. The overall hospitalization rate is about 20.2% (95% CI: 12.7%–28.7%), and changed to be 18.0% (95% CI: 9.9%–27.6%) or 14.1% (95% CI: 5.9%–24.6%) after systemic or biologic treatment. Moreover, the overall fatality rate is 1.5% (95% CI: 0.4%–3.0%), and turned to be 0.7% (95% CI: 0%–2.0%) or 0.5% (95% CI: 0%–2.2%) after systemic or biologic therapy. Notably, a lower hospitalization RR was found in patients receiving biologic therapy than those receiving other treatments (RR = 0.62, 95% CI: 0.42–0.94). The results were consistent after sensitivity analysis and trim-and-fill analysis. Systemic, especially biologic therapy could lessen the clinical severity in psoriasis patients with COVID-19. Our finding will help to guide current recommendations and provide a reference for clinical decision-making.

KEYWORDS

clinical characteristics, COVID-19, outcomes, psoriasis, systemic or biologic therapy

1 | INTRODUCTION

Psoriasis is a chronic, immune-mediated inflammatory skin disease that affects over 125 million people in the world.[1] The coronavirus disease 2019 (COVID-19) pandemic raises concerns for psoriasis patients, especially those with moderate to severe psoriasis, because those patients usually had multi-comorbidities including hypertension, cardiovascular disease, diabetes and obesity, which is tightly associated with the clinical severity of COVID-19.[2,3] Increasing studies have tried to explore the clinical characteristics and outcomes among patients with COVID-19 and psoriasis.[4-20] However, small sample size and inconsistent results highlight the significance of a comprehensive analysis.

Systemic and biologic therapy represents an important breakthrough in the treatment of psoriasis patients,[21] while extensive debate has been proposed for the use of these treatments in patients with COVID-19 and psoriasis.[22–25] On one hand, the use of these treatments could control the psoriasis severity.[13,26] On the other hand, the achieved immunosuppression could increase the risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, interfere with antiviral immunity, and worsen clinical outcomes.[20,27,28] Several studies have concluded that psoriasis

Yu Meng and Furong Zeng have equal contribution.

patients had a similar or perhaps even lower incidence of COVID-19 after receiving systemic or biologic treatment.[24,29,30] However, how systemic and biologic therapy affected the outcomes of psoriasis patients with COVID-19 was still unknown.

Thus, we performed this meta-analysis to summarize the clinical characteristics and outcomes, and explored the role of treatment types in clinical outcomes among patients with COVID-19 and psoriasis. Our finding will help to guide current recommendations and provide a reference for clinical decision-making.

2 | METHODS

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines[31] and was registered on PROSPERO with the registration number CRD42022335563.

2.1 | Literature search

Databases including Pubmed, Embase and Cochrane Library were searched from inception to 25th March 2022 using the following terms: "Psoriasis" AND "COVID-19." There are no limitations on publication languages and study types. The detailed search strategies were available in Table S1.

2.2 | Inclusion and extraction criteria

Two of us (Y.M. and G.D.) independently screened all titles and abstracts after the initial deduplication. The inclusion criteria were as follows: (1) involving psoriasis patients with confirmed SARS-CoV-2 infection or COVID-19; (2) describing at least one of their characteristics and outcomes (hospitalization and mortality rates). Studies with less than 10 patients, conference papers or abstracts, preprint reports, article without full text, and studies with data inaccessible from the corresponding author were excluded. For studies with overlapping datasets, we selected those with the largest and most up-to-data studies. Discrepancies were solved by consensus.

2.3 | Data extraction and quality assessment

Two investigators (Y.M and F.Z.) independently extracted the following information, including first author, publication year, patient number, age, sex, geographic region of residence, comorbidity (hypertension, cardiovascular disease, and diabetes), common COVID-19 symptoms (fever, dyspnea, and cough), psoriasis phenotype, psoriasis treatment type, and clinical outcomes (rate of hospitalization and mortality). The quality of the included cohort studies was assessed by two researchers (G.D. and F.Z.) independently using the Newcastle-Ottawa Scale. The nine-stars scale is comprised of three broad characteristics: selection, comparison and exposure/outcome. A score of 7 or more was reflective of high quality, a score of 5 or 6 indicated moderate quality, and a score of 4 or less indicated low quality.

2.4 | Statistical analysis

Meta-analysis was performed using R statistic software (3.6.3). The principal summary measures were pooled prevalence and risk ratio (RR) with 95% confidential interval (CI). χ^2 test and I^2 statistic were performed to evaluate the statical heterogeneity of the results in the included studies. We considered heterogeneity to be significant when the p value by χ^2 test was <0.1 or the I^2 statistic was ≥50%.[32] Random-effects model was adopted if there was evidence of heterogeneity; otherwise, fixed-effects model was used.[33] The pooled prevalence was assessed using the Freeman-Tukey double arcsine method. DerSimonian and Laird method was used for the estimator of between-study variance. The funnel plots and Egger's test were used to assess for publication bias. If publication bias existed ($p < 0.1$), trim-and-fill analysis was performed to adjust publication bias and further evaluate the stability of the pooled results. A p value less than 0.05 was considered statistically significant.

3 | RESULTS

3.1 | Literature search and main characteristics of identified studies

The literature search identified 1743 records through database mining (Figure 1). After the removal of duplicate articles, 1326 records were screened. We further obtained 50 studies for eligibility. Of these, 31 were excluded for the following reasons: patients with suspected but not confirmed SARS-CoV-2 infection ($n = 10$), review ($n = 2$), and inaccessible outcomes ($n = 19$). Finally, a total of 19 studies were included in the meta-analysis.[4–20]

The main characteristics and clinical outcomes of the studies were shown in Table S2–6. In general, 4073 patients with COVID-19 and psoriasis were included, of which about 48.9% were men and 51.1% were women; most of the patients were over 45 years of age since the diagnosis of COVID-19 (Table S2). Fever and anomia were the most common presenting symptoms at time of hospital admission by using 5 studies where symptoms were recorded (Table S3). The most common comorbidities were hypertension and obesity (Table S4). Plaque psoriasis is the most common type in 6 reported studies (Table S5). The treatment types including systemic or biologic therapy were displayed in Table S6. All the studies reported at least 1 clinical outcomes (hospitalization and fatality rates) of patients with COVID-19 and psoriasis.

The quality of the cohort studies was assessed based on the NOS tool, which showed that 16 studies had high quality with score over

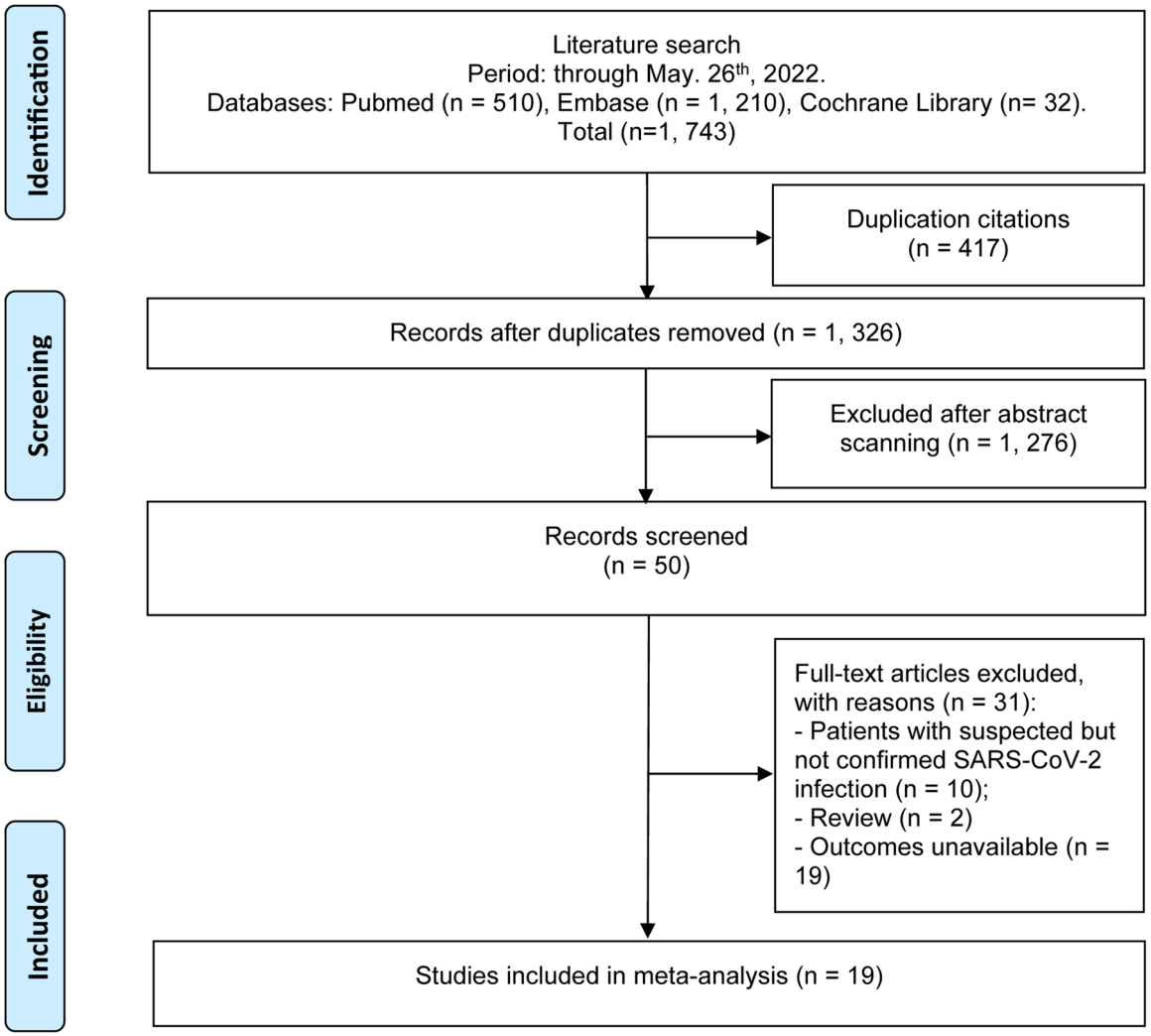

FIGURE 1 Flowcharts illustrating the article selection process

7, whereas one study were of moderate quality. The two case series studies were considered low quality (Table S7).

3.2 | Overall hospitalization and fatality rates

The meta-analysis of 16 studies with reported hospitalization rate as outcome indicated that the overall case hospitalization rate among patients with COVID-19 and psoriasis was 20.2% (95% CI: 12.7%–28.7%) (Figure 2A). The funnel plot and Egger's test ($p = 0.05$) suggested the existence of publication bias in these studies (Figure S1A). After 5 studies were filled, the funnel plot showed the relative symmetry (Figure S1B), and Egger's test showed no evidence of significant publication bias ($p = 0.74$). The overall hospitalization rate turned to be 10.9% (95% CI: 5.8%–18.1%). Besides, the sensitivity analysis performed by using the "leave-one-out" did not markedly change our results (Figure S1C). Neither of sensitivity analysis performed by excluding 2 case series studies demonstrated an obvious change in overall hospitalization rate in these patients with COVID-19 and psoriasis (23.6%, 95% CI: 15.2%–33.1%) (Figure S1D).

The meta-analysis of 15 studies with reported fatality rate as outcome indicated that the overall case fatality among patients with COVID-19 and psoriasis was 1.5% (95% CI: 0.4%–3.0%) (Figure 2B). The funnel plot and Egger's test ($p = 0.09$) suggested the evidence of publication bias in these studies (Figure S2A). After 3 studies were added, the funnel plot showed the relative symmetry (Figure S2B), and Egger's test showed no existence of significant publication bias ($p = 0.67$). The overall fatality rate turned as 0.7% (95% CI: 0%–2.0%). Moreover, the sensitivity analysis performed by using the "leave-one-out" did not markedly change our results except omitting Lima et al.'s study (Figure S2C). Neither of sensitivity analysis performed by excluding 2 case series studies demonstrated an obvious change in overall fatality rate in these patients with COVID-19 and psoriasis (1.8%, 95% CI: 0.6%–3.6%) (Figure S2D).

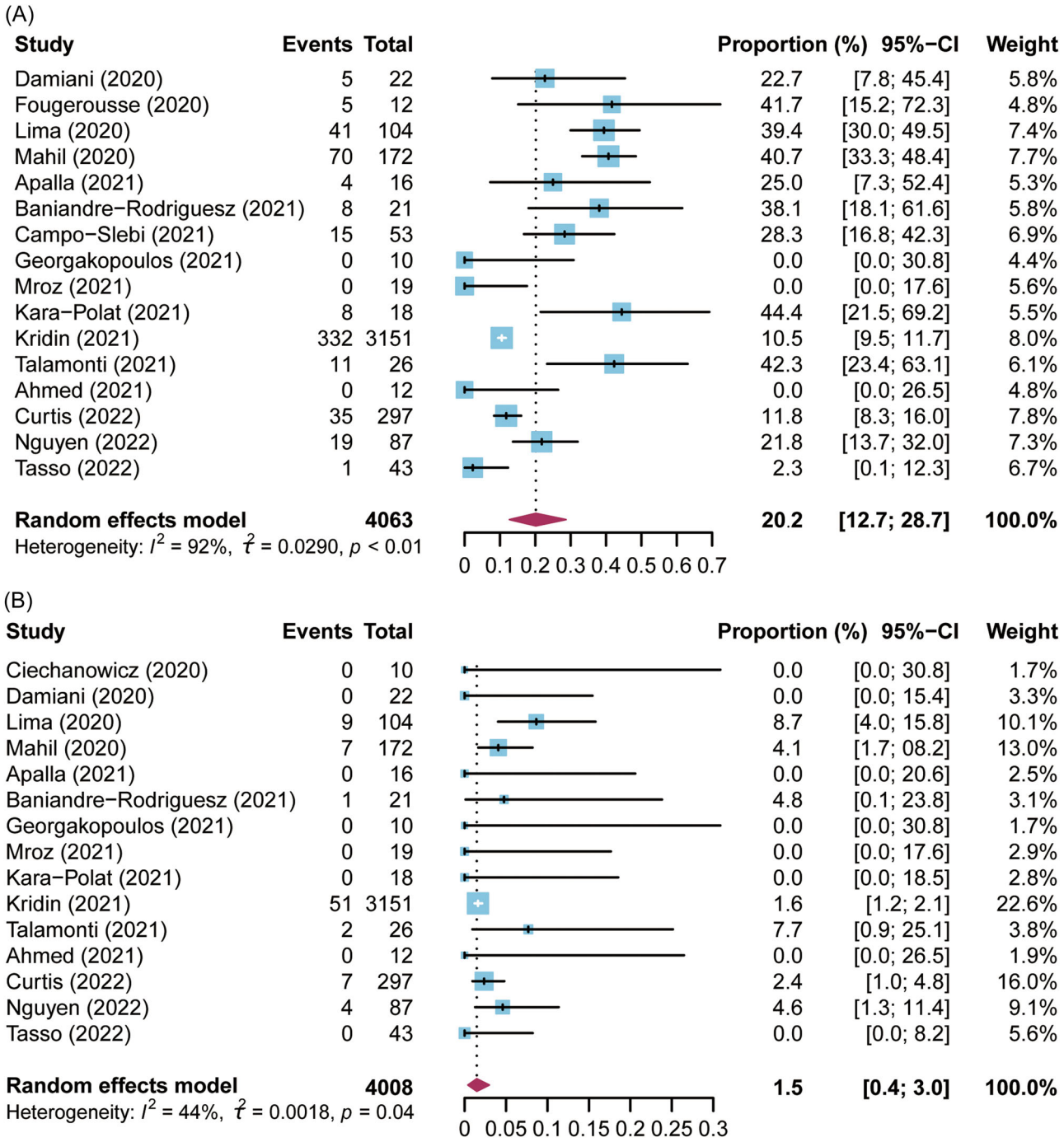

FIGURE 2 The pooled hospitalization rate (A) and fatality rate (B) among patients with COVID-19 and psoriasis. COVID-19, coronavirus disease 2019.

3.3 | Hospitalization and fatality rates after systemic therapy

The meta-analysis of 11 studies with reported hospitalization rate as outcome indicated that the overall case hospitalization rate among patients with COVID-19 and psoriasis after systemic therapy was 18.0% (95% CI: 9.9%–27.6%) (Figure 3A). The funnel plot and Egger's test (p = 0.32) did not detect the existence of publication bias (Figure S3A). The sensitivity analysis performed by using the "leave-one-out" did not significantly change our results (Figure S3B). Moreover, there is no statistical difference in the hospitalization rate between patients receiving systemic treatment or other treatments (RR = 0.89, 95% CI: 0.61–1.31) (Figure S3C).

The meta-analysis of 10 studies with reported fatality rate as outcome indicated that the overall case fatality rate among patients with COVID-19 and psoriasis after systemic therapy was 0.7% (95% CI: 0%–2.0%) (Figure 3B). No evidence of publication bias was observed after Egger's test (p = 0.57) and funnel plot (Figure S4A). The sensitivity

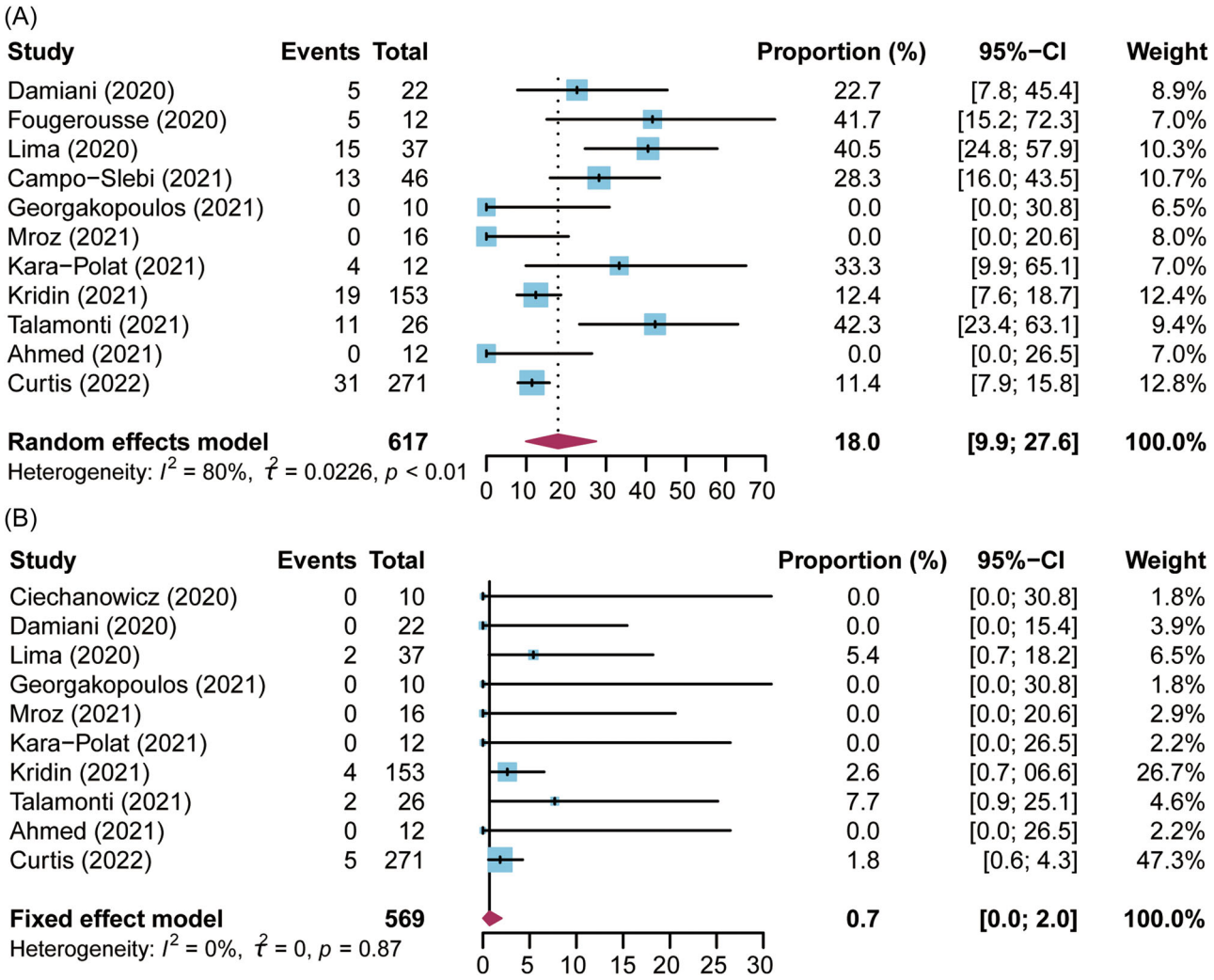

FIGURE 3 The pooled hospitalization rate (A) and fatality rate (B) among patients with COVID-19 and psoriasis after systemic therapy. COVID-19, coronavirus disease 2019.

analysis performed by using the "leave-one-out" did not significantly change our results (Figure S4B). No statistical difference was found in fatality rate between patients receiving systemic treatment or other treatments (RR = 0.40, 95% CI: 0.13–1.23) (Figure S3C).

3.4 | Hospitalization and fatality rates after biologic therapy

The meta-analysis of 10 studies with reported hospitalization rate as outcome indicated that the overall case hospitalization rate among patients with COVID-19 and psoriasis after biologic therapy was 14.1% (95% CI: 5.9%–24.6%) (Figure 4A). The funnel plot and Egger's test (p = 0.36) did not detect the existence of publication bias (Figure S5A). The sensitivity analysis performed by using the "leave-one-out" did not significantly change our results (Figure S5B). It is worth to note that patients with COVID-19 and psoriasis receiving biologic therapy had a lower hospitalization RR than those receiving other treatments (RR = 0.62, 95% CI: 0.42–0.94) (Figure S5C).

The meta-analysis of 9 studies with reported fatality rate as outcome indicated that the overall case fatality rate among patients with COVID-19 and psoriasis after systemic therapy was 0.5% (95% CI: 0%–2.2%) (Figure 4B). No evidence of publication bias was observed after Egger's test (p = 0.82) and funnel plot (Figure S6A). The sensitivity analysis performed by using the "leave-one-out" did not significantly change our results (Figure S6B). No statistical difference was found in fatality rate between patients receiving systemic treatment or other treatments (RR = 0.94, 95% CI: 0.29–3.05) (Figure S6C).

4 | DISCUSSION

Psoriasis is a chronic inflammatory disease associated with comorbidities known to increase the risk of severe COVID-19.[34] Therefore, concerns arise for the clinical characteristics and outcomes among patients with COVID-19 and psoriasis.

In the study, through combing data from 19 studies, we first summarized the clinical characteristics and illness outcomes in

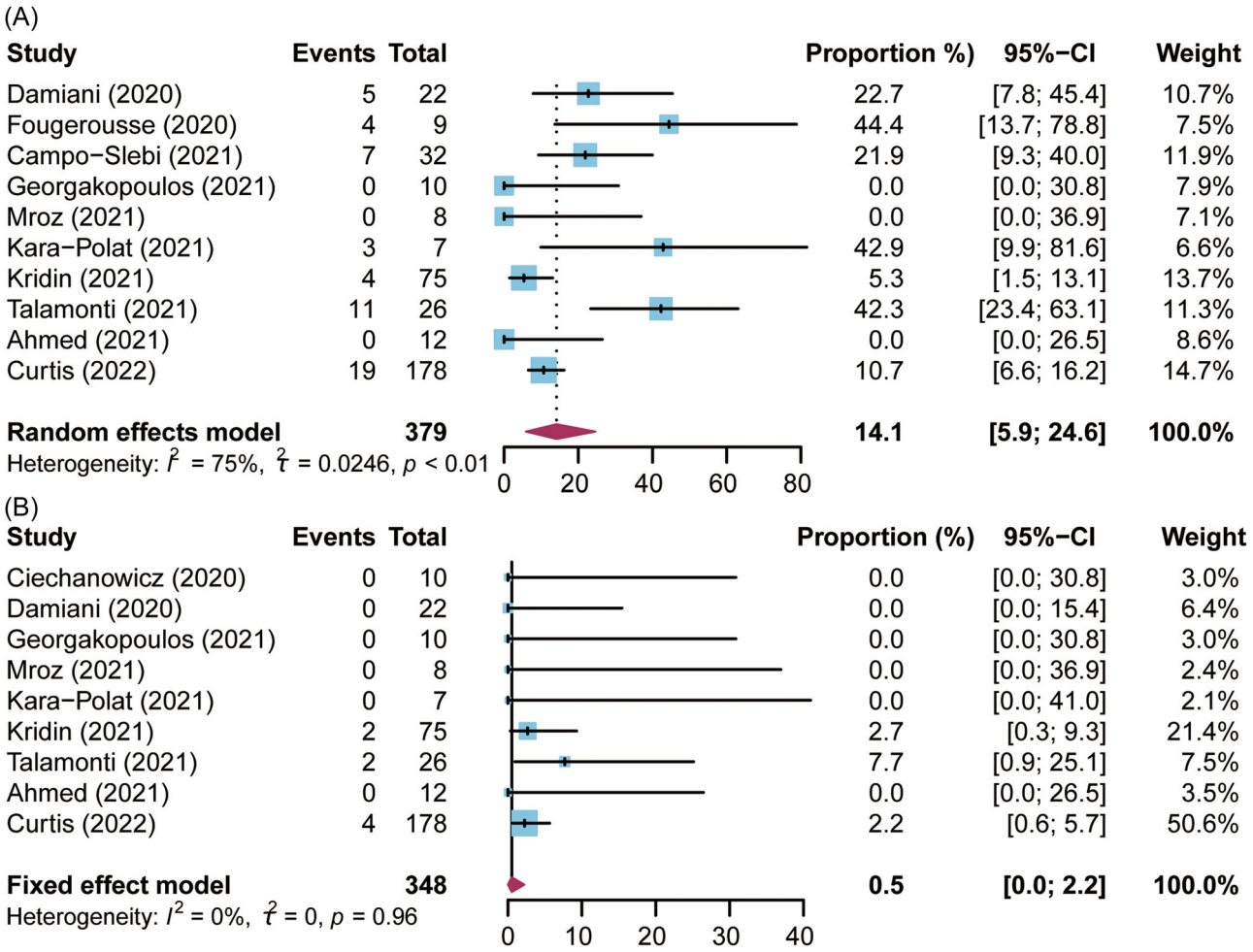

FIGURE 4 The pooled hospitalization rate (A) and fatality rate (B) among patients with COVID-19 and psoriasis after biologic therapy. COVID-19, coronavirus disease 2019.

patients with COVID-19 and psoriasis. Further, we found that the overall hospitalization rate is about 20.2%, and changed to be 18.0 or 14.1 after systemic or biologic treatment. In line with this finding, the overall fatality rate is 1.5%, and then turned to be 0.7 or 0.5 after systemic or biologic therapy. Notably, a lower hospitalization RR was found in patients receiving biologic therapy than those receiving other treatments. These results suggested that systemic, especially biologic therapy could lessen the clinical severity in patients with COVID-19 and psoriasis. Considering that hyperinflammation and cytokine storm play pivotal roles in driving the progression of COVID-19,[35–37] there is biologic plausibility for a protective effect of systemic or biologic treatments on the illness severity.

Whether to treat COVID-19 patients with biologics has been a big debate. Previous studies showed that the use of biologics including tumor necrosis factor (TNF) inhibitor and interleukin-17 inhibitors was related to an increased risk of serious infection.[38,39] However, several studies reported that TNF inhibitors could reduce the risk of COVID-19-associated hospitalization among patients with rheumatic disease and decrease the risk of hospitalization or fatality among IBD patients.[40,41] Moreover, discontinuation of systematic and biologic therapy could result in psoriasis relapse and therapy resistance.[42,43] It seems that our knowledge needs to progress in real time to meet the unprecedented challenges treating patients with COVID-19 and psoriasis. Here, we performed the first meta-analysis to date the risk of hospitalization and fatality in patients with COVID-19 and psoriasis after receiving systemic or biologic treatments. Our finding will help to guide current recommendations and provide a reference for clinical decision-making.

Admittedly, our study has several limitations. First, a number of demographic and clinical characteristics were lacking in included studies and could affect the prognosis evaluation. Second, notable heterogeneity or publication bias was seen in some comparisons, although sensitivity analysis, subgroup analysis and trim-and-fill analysis were used for meta-analysis. Third, comorbidities of psoriasis including hypertension, cardiovascular diseases and diabetes could impact our conclusions, and perspective clinical trials need to adjust for these confounders. Finally, it needs to be further clarified whether the conclusion is consistent among other countries, because the included studies were mainly from North America and Europe.

5 | CONCLUSION

In aggregate, our meta-analysis described the clinical characteristics and outcomes of patients with psoriasis and COVID-19. Besides, systemic therapy for psoriasis, especially biologics, might be associated with reduced risk of disease severity among these patients. Our study provides evidence that for psoriasis patients with COVID-19, systemic or biologic therapy should not be routinely withheld due to a fear of COVID-19 associated hospitalization and death.

AUTHOR CONTRIBUTIONS

Concept and design: Guangtong Deng, Xiang Chen, and Furong Zeng. *Acquisition and interpretation of data*: Yu Meng and Furong Zeng. *Drafting of the manuscript*: Furong Zeng and Yu Meng. *Critical revision of the manuscript*: Guangtong Deng, Xiang Chen, Huiyan Sun, and Yayun Li. *Final approval*: All authors.

ACKNOWLEDGMENTS

This research is supported by the National Natural Science Foundation of China (No. 82102803, 82103183), and Natural Science Foundation of Hunan province (No. 2021JJ40976, 2022JJ40767).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATE AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Guangtong Deng http://orcid.org/0000-0002-4424-9727

REFERENCES

1. Armstrong AW, Read C. Pathophysiology, clinical presentation, and treatment of psoriasis: a review. *JAMA*. 2020;323(19):1945-1960.
2. Deng G, Yin M, Chen X, Zeng F. Clinical determinants for fatality of 44,672 patients with COVID-19. *Crit Care*. 2020;24(1):179.
3. Longmore DK, Miller JE, Bekkering S, et al. Diabetes and overweight/obesity are independent, nonadditive risk factors for In-Hospital severity of COVID-19: an international, multicenter retrospective meta-analysis. *Diabetes Care*. 2021;44(6):1281-1290.
4. Damiani G, Pacifico A, Bragazzi NL, Malagoli P. Biologics increase the risk of SARS-CoV-2 infection and hospitalization, but not ICU admission and death: real-life data from a large cohort during red-zone declaration. *Dermatol Ther*. 2020;33(5):13475.
5. Talamonti M, Galluzzo M, Chiricozzi A, et al. Characteristic of chronic plaque psoriasis patients treated with biologics in Italy during the COVID-19 pandemic: risk analysis from the PSO-BIO-COVID observational study. *Expert Opin Biol Ther*. 2021;21(2):271-277.
6. Curtis JR, Zhou X, Rubin DT, et al. Characteristics, comorbidities, and outcomes of SARS-CoV-2 infection in patients with autoimmune conditions treated with systemic therapies: a population-based study. *J Rheumatol*. 2022;49(3):320-329.
7. Tasso M, Mostacciuolo E, Ugoccioni V, et al. COVID-19 clinical spectrum in psoriatic arthritis patients on biologics and tsDMARDs: results from a cohort at an Italian epicentre of the pandemic's third wave. *Clin Exp Rheumatol*. 2022;40(5):1061.
8. Campo-Slebi I, Meza-Corso MF, Cárdenas P, et al. COVID-19 in patients with psoriasis: a Latin American case series. *JAAD Int*. 2021;5:96-97.
9. Mahil SK, Dand N, Mason KJ, et al. Factors associated with adverse COVID-19 outcomes in patients with psoriasis-insights from a global registry-based study. *J Allergy Clin Immunol*. 2021;147(1):60-71.
10. Kara Polat A, Oguz Topal I, Karadag AS, et al. The impact of COVID-19 in patients with psoriasis: a multicenter study in Istanbul. *Dermatol Ther*. 2021;34(1):e14691.
11. Apalla Z, Fotiadou C, Emvalomati A, et al. The impact of COVID-19 pandemic on psoriasis patients in Northern Greece. *Dermatol Ther*. 2022;35(2):15244.
12. Baniandrés-Rodríguez O, Vilar-Alejo J, Rivera R, et al. Incidence of severe COVID-19 outcomes in psoriatic patients treated with systemic therapies during the pandemic: a biobadaderm cohort analysis. *J Am Acad Dermatol*. 2021;84(2):513-517.
13. Mroz M, Mućka S, Miodońska M, Ziolkowska D, Hadas E, Bożek A. Influence of SARS-CoV-2 virus infection on the course of psoriasis during treatment with biological drugs. *Medicina (Kaunas)*. 2021;57(9):881.
14. Ciechanowicz P, Dopytalska K, Mikucka-Wituszyńska A, et al. The prevalence of SARS-CoV-2 infection and the severity of the course of COVID-19 in patients with psoriasis treated with biologic therapy. *J Dermatolog Treat*. 2020;1-4.
15. Kridin K, Schonmann Y, Solomon A, et al. Risk of COVID-19 infection, hospitalization, and mortality in patients with psoriasis treated by interleukin-17 inhibitors. *Journal of Dermatological Treatment*. 2022;33(4):2014-2020.
16. Nguyen C, Shwe S, Yale K, et al. The role of gender, race, and ethnicity in psoriasis patients with COVID-19 infection: a cross-sectional study. *Int J Womens Dermatol*. 2022;8(1):e012.
17. Ahmed SMA, Volontè M, Isoletta E, et al. SARS-CoV-2 serology in patients on biological therapy or apremilast for psoriasis: a study of 93 patients in the Italian red zone. *J Eur Acad Dermatol Venereol*. 2022;36(2):e86-e88.
18. Lima XT, Cueva MA, Lopes EM, Alora MB. Severe COVID-19 outcomes in patients with psoriasis. *J Eur Acad Dermatol Venereol*. 2020;34(12):e776-e778.
19. Kridin K, Schonmann Y, Damiani G, et al. Tumor necrosis factor inhibitors are associated with a decreased risk of COVID-19-associated hospitalization in patients with psoriasis-A population-based cohort study. *Dermatol Ther*. 2021;34(4):e15003.
20. Kridin K, Schonmann Y, Tzur Bitan D, et al. Coronavirus disease 2019 (COVID-19)-associated hospitalization and mortality in patients with psoriasis: a population-based study. *Am J Clin Dermatol*. 2021;22(5):709-718.
21. Sbidian E, Chaimani A, Garcia-Doval I, et al. Systemic pharmacological treatments for chronic plaque psoriasis: a network meta-analysis. *The Cochrane Database of Systematic Reviews*. 2021;4(4):Cd011535.
22. Pahalyants V, Murphy WS, Klebanov N, et al. Immunosuppressive biologics did not increase the risk of COVID-19 or subsequent mortality: a retrospective matched cohort study from Massachusetts. *J Am Acad Dermatol*. 2022;86(1):252-255.
23. Piaserico S, Gisondi P, Cazzaniga S, Di Leo S, Naldi L. Assessing the risk and outcome of COVID-19 in patients with psoriasis or psoriatic arthritis on biologic treatment: a critical appraisal of the quality of the published evidence. *J Invest Dermatol*. 2022;142(2):355-363.
24. Lytvyn Y, Georgakopoulos JR, Mufti A, et al. Incidence and prognosis of COVID-19 in patients with psoriasis on apremilast: a multicentre retrospective cohort study. *J Eur Acad Dermatol Venereol*. 2022;36(2):e94-e95.

25. Zeng H, Wang S, Chen L, Shen Z. Biologics for psoriasis during the COVID-19 pandemic. *Front Med*. 2021;8:759568.
26. Wu JJ, Kavanaugh A, Lebwohl MG, Gniadecki R, Merola JF. Psoriasis and metabolic syndrome: implications for the management and treatment of psoriasis. *J Eur Acad Dermatol Venereol*. 2022;36(6):797-806.
27. Schoot TS, Kerckhoffs APM, Hilbrands LB, van Marum RJ. Immunosuppressive drugs and COVID-19: a review. *Front Pharmacol*. 2020;11:1333.
28. PriyankaChoudhary OP, Singh I. Protective immunity against COVID-19: unravelling the evidences for humoral vs. cellular components. *Travel Med Infect Dis*. 2021;39:101911.
29. Georgakopoulos JR, Mufti A, Vender R, Prajapati VH, Yeung J. Incidence and prognosis of COVID-19 in psoriasis patients on biologic therapy: a multicentre retrospective cohort study. *J Eur Acad Dermatol Venereol*. 2021;35(8):e485-e487.
30. Alamgir M, Jamgochian M, Cucalon J, Razi S, Farabi B, Rao B. Incidence of COVID-19 in a cohort of dermatology patients receiving immunomodulating biologic medications. *Int J Dermatol*. 2021;60(12):e500-e501.
31. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.
32. Lee A, Wong SY, Chai LYA, et al. Efficacy of covid-19 vaccines in immunocompromised patients: systematic review and meta-analysis. *BMJ (Clinical research ed)*. 2022;376:e068632.
33. Zeng F, Li L, Zeng J, et al. Can we predict the severity of coronavirus disease 2019 with a routine blood test? *Pol Arch Med Wewn*. 2020;130(5):400-406.
34. Lima XT, Cueva MA, Lopes EM, Alora MB. Severe COVID-19 outcomes in patients with psoriasis. *J Eur Acad Dermatol Venereol*. 2020;34(12):e776-e778.
35. Zeng F, Huang Y, Guo Y, et al. Association of inflammatory markers with the severity of COVID-19: A meta-analysis. *Int J Infect Dis*. 2020;96:467-474.
36. Jiang Y, Rubin L, Peng T, et al. Cytokine storm in COVID-19: from viral infection to immune responses, diagnosis and therapy. *Int J Biol Sci*. 2022;18(2):459-472.
37. Tan LY, Komarasamy TV, Rmt Balasubramaniam V. Hyperinflammatory immune response and COVID-19: a double edged sword. *Front Immunol*. 2021;12:742941.
38. Kalb RE, Fiorentino DF, Lebwohl MG, et al. Risk of serious infection with biologic and systemic treatment of psoriasis: results from the psoriasis longitudinal assessment and registry (PSOLAR). *JAMA Dermatology*. 2015;151(9):961-969.
39. Yiu ZZN, Ashcroft DM, Evans I, et al. Infliximab is associated with an increased risk of serious infection in patients with psoriasis in the U.K. and republic of Ireland: results from the British Association of Dermatologists Biologic Interventions Register (BADBIR). *Br J Dermatol*. 2019;180(2):329-337.
40. Brenner EJ, Ungaro RC, Gearry RB, et al. Corticosteroids, but not TNF antagonists, are associated with adverse COVID-19 outcomes in patients with inflammatory bowel diseases: results from an International Registry. *Gastroenterology*. 2020;159(2):481-491.
41. Gianfrancesco M, Hyrich KL, Al-Adely S, et al. Characteristics associated with hospitalisation for COVID-19 in people with rheumatic disease: data from the COVID-19 Global Rheumatology Alliance physician-reported registry. *Ann Rheum Dis*. 2020;79(7):859-866.
42. Nasiri S, Araghi F, Tabary M, Gheisari M, Mahboubi-Fooladi Z, Dadkhahfar S. A challenging case of psoriasis flare-up after COVID-19 infection. *J Dermatolog Treat*. 2020;31(5):448-449.
43. Masson Regnault M, Shourick J, Jendoubi F, Tauber M, Paul C. Time to relapse after discontinuing systemic treatment for psoriasis: a systematic review. *Am J Clin Dermatol*. 2022;23:433-447.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Meng Y, Zeng F, Sun H, Li Y, Chen X, Deng G. Clinical characteristics and outcomes of patients with COVID-19 and psoriasis. *J Med Virol*. 2022;1-8. doi:10.1002/jmv.28085