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Characteristics associated with poor COVID-19 outcomes in people with psoriasis, psoriatic arthritis and axial spondyloarthritis: data from the COVID-19 PsoProtect and Global Rheumatology Alliance physician-reported registries

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ABSTRACT

Objectives To investigate factors associated with severe COVID-19 in people with psoriasis (PsO), psoriatic arthritis (PsA) and axial spondyloarthritis (axSpA).

Methods Demographic data, clinical characteristics and COVID-19 outcome severity of adults with PsO, PsA and axSpA were obtained from two international physician-reported registries. A three-point ordinal COVID-19 severity scale was defined: no hospitalisation, hospitalisation (and no death) and death. ORs were estimated using multivariable ordinal logistic regression.

Results Of 5045 cases, 18.3% had PsO, 45.5% PsA and 36.3% axSpA. Most (83.6%) were not hospitalised, 14.6% were hospitalised and 1.8% died. Older age was non-linearly associated with COVID-19 severity. Male sex (OR 1.54, 95% CI 1.30 to 1.83), cardiovascular, respiratory, renal, metabolic and cancer comorbidities (ORs 1.25–2.89), moderate/high disease activity and/or glucocorticoid use (ORs 1.39–2.23, vs remission/low disease activity and no glucocorticoids) were associated with increased odds of severe COVID-19. Later pandemic time periods (ORs 0.42–0.52, vs until 15 June 2020), PsO (OR 0.49, 95% CI 0.37 to 0.65, vs PsA) and baseline exposure to TNFi, IL17i and IL-23i/IL-12+23i (OR 0.57, 95% CI 0.44 to 0.73; OR 0.62, 95% CI 0.45 to 0.87; OR 0.67, 95% CI 0.45 to 0.98; respectively; vs no disease-modifying antirheumatic drug) were associated with reduced odds of severe COVID-19.

Conclusion Older age, male sex, comorbidity burden, higher disease activity and glucocorticoid intake were associated with more severe COVID-19. Later pandemic time periods, PsO and exposure to TNFi, IL17i and IL-23i/IL-12+23i were associated with less severe COVID-19. These findings will enable risk stratification and inform management decisions for patients with PsO, PsA and axSpA during COVID-19 waves or similar future respiratory pandemics.

INTRODUCTION

The COVID-19 pandemic has significantly impacted people with immune-mediated inflammatory diseases (IMIDs), particularly those taking immunomodulatory drugs such as biological or targeted synthetic disease-modifying antirheumatic drugs (b/tsDMARDs).[1–4] While risk factors for severe COVID-19 outcomes have been demonstrated in both registry-based and population-based studies, for people with IMIDs collectively and for specific diseases such as rheumatoid arthritis, relevant risk factor data are limited for axial spondyloarthritis (axSpA) and psoriatic disease (including psoriasis without arthritis (PsO) and psoriatic arthritis

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Factors associated with severe COVID-19 outcomes have been demonstrated in both registry-based and population-based studies for people with immune-mediated inflammatory diseases (IMIDs) collectively and for specific IMIDs.
⇒ However, relevant risk factor data are limited for axial spondyloarthritis (axSpA) and psoriatic disease (including psoriasis without arthritis (PsO) and psoriatic arthritis (PsA)), a group of conditions that shares pathophysiological mechanisms and approved treatments, particularly targeted therapies.

WHAT THIS STUDY ADDS

⇒ Older age, male sex, comorbidity burden, higher disease activity and glucocorticoid intake were associated with more severe COVID-19.
⇒ Later pandemic time periods, PsO and exposure to TNFi, IL17i and IL-23i/IL-12+23i were associated with less severe COVID-19.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings from this study will enable risk stratification for patients with PsO, PsA and axSpA.
⇒ These findings will inform the development of tailored management strategies and evidence-based recommendations for patients with PsO, PsA and axSpA.

(PsA)).[5–13] The association of specific classes of b/tsDMARDs commonly used in this population, including IL-17 inhibitors (IL17i) and IL-23 or IL-12/23 inhibitors (IL-23i/IL-12+23i), with COVID-19 outcomes has not been well studied. Improved understanding of the risks associated with exposure to these medications in this population will address knowledge gaps as we continue to navigate COVID-19 risks in the postvaccination era.

We used data from the COVID-19 Global Rheumatology Alliance (C19-GRA) and the Psoriasis Patient Registry for Outcomes, Therapy and Epidemiology of COVID-19 Infection (PsoProtect) physician-reported registries to evaluate the associations of baseline characteristics, including different classes of b/tsDMARDs, with COVID-19 severity in people with PsO, PsA and axSpA.

METHODS

Data source

The C19-GRA physician-reported observational registry launched on 24 March 2020. Patients are eligible for inclusion if they have both a pre-existing rheumatic disease and SARS-CoV-2 infection. PsoProtect is a physician-reported observational registry launched on 27 March 2020. Patients are eligible for inclusion if they have both pre-existing PsO and SARS-CoV-2 infection. For both registries, data are entered voluntarily into the data entry systems by rheumatologists/dermatologists or under the supervision of rheumatologists/dermatologists. In Argentina, Brazil, France, Germany, Italy, Portugal and Sweden, C19-GRA data are transferred from national registries; in all other countries, data are entered directly into the registries' data entry systems. Countries were categorised according to the six WHO regions (www.who.int); the 'Americas' was further divided into north and south. Further details of the registries have been described elsewhere.[13–18] We used data collected on or before 25 October 2021.

COVID-19 reporting and primary outcome of interest

Both confirmed and presumptive cases of COVID-19 were reported. For analysis, patients were subsequently categorised into (1) confirmed or high likelihood of COVID-19 (chest imaging (CT or chest X-ray) showing bilateral infiltrates and/or symptoms after close contact with a known laboratory-confirmed COVID-19 positive patient) or (2) presumptive cases based on symptoms alone.

The primary outcome of interest of this study was COVID-19 outcome, assessed by use of an ordinal COVID-19 severity scale with three mutually exclusive categories: (1) no hospitalisation and no death; (2) hospitalisation, but no death and (3) death. 'Baseline characteristics' refer to demographic or clinical characteristics at the time of COVID-19 symptom onset (or diagnosis if asymptomatic).

IMID treatment prior to COVID-19

Medications used to treat the IMID prior to COVID-19 diagnosis were categorised into groups. Immunomodulatory drugs (conventional synthetic (cs)/biological (b)/targeted synthetic (ts) DMARDs) were distinguished from the PsO-specific non-biological systemic agent acitretin as well as from non-steroidal anti-inflammatory drugs (NSAIDs) and glucocorticoids (GC). csDMARDs included antimalarials, cyclosporine, leflunomide, methotrexate and sulfasalazine. bDMARDs included TNFi (eg, adalimumab, certolizumab, etanercept, golimumab, infliximab and TNFi biosimilars), IL-17i (eg, brodalumab, ixekizumab and secukinumab), IL-12/23i (ustekinumab) and IL-23i (eg, guselkumab, risankizumab and tildrakizumab). tsDMARDs included apremilast and JAKi (eg, baricitinib, tofacitinib and upadacitinib). IL-23i and IL-12/23i were combined in the same group for data analysis (IL-23i/IL-12+23 i). Regarding NSAIDs, we asked physicians to report if at the time of COVID-19 symptom onset (or diagnosis if asymptomatic), the patient was taking NSAIDs, without specifying a minimal duration of a continuous treatment with NSAIDs. We chose no current DMARD use as the reference group after considering the groups' sample size and internal validity to be used as comparator for exposure to the various IMID treatments. For more details regarding the choice of DMARD reference category, refer to online supplemental methods.

Statistical analyses

Descriptive tables were produced for the whole cohort and by diagnostic group (PsO, PsA and axSpA, as defined by the reporting healthcare professional). All patients with confirmed or presumptive COVID-19 were included in the primary analysis.

Independent associations between demographic and disease features and the ordinal COVID-19 outcome were estimated by multivariable ordinal logistic regression using the proportional odds model and were reported as OR and 95% CIs. In ordinal regression analysis, the effect size of a categorical predictor gives the change in log odds of being at least one level higher on the ordinal COVID-19 severity scale compared with the reference category of the predictor variable, while for a continuous predictor, it gives the change in odds of being one level higher on the ordinal COVID-19 severity scale for a unit increase in the continuous predictor. More details about assumptions of the proportional odds model are provided in online supplemental methods.

Factors potentially associated with the COVID-19 outcome considered in the models were age, sex, smoking habits (ever, unknown/missing, never), pandemic calendar period (until 15 June 2020, 16 June 2020 to 31 December 2020, 1 January 2021 and later), key comorbidities (chronic obstructive pulmonary disease (COPD) or asthma, other chronic lung disease, chronic kidney disease (CKD), hypertension, other cardiovascular disease (CVD), obesity, diabetes, cancer), IMID diagnostic category, IMID disease activity as per physician's global assessment (remission/low vs moderate/high), DMARD treatment prior to COVID-19 diagnosis, GC use and NSAID use.

For patients classified as having more than one IMID or being treated with more than one of the medications of interest, we created a hierarchy based on clinical expertise to categorise patients. This way, non-overlapping (mutually exclusive) categories are obtained, allowing a clear reference group for interpretation of the regression models, and avoiding collinearities. Patients labelled as having both PsA and axSpA were counted as PsA patients. Patients receiving multiple csDMARDs were grouped according to the following hierarchy: cyclosporine>sulfasalazine>leflunomide>methotrexate>antimalarials, where 'A>B' means 'A has priority over B'. Patients receiving a b/tsDMARD and additionally a csDMARD were considered in the model solely in the b/tsDMARD group (ie, b/tsDMARD>csDMARD).

We tested four two-way additive interactions in the models: hypertension and CVD; obesity and diabetes; cancer and smoking habits; and disease activity and prednisolone-equivalent GC use. Online supplemental methods provide more details regarding statistical interactions.

To account for heterogeneity between participating countries regarding healthcare systems and infection dynamics, countries were considered as random effects in the regression analyses. To appropriately estimate the well-established non-linear effect of age on the outcome of SARS-CoV-2 infection, we included restricted cubic splines in the regression models. Four knots were chosen for most analyses, while three knots were chosen for the outcome mortality and the disease-specific analyses due to the limited effective sample size.[19]

Missing data were handled using multiple imputation; results of the logistic regression analyses for 10 imputed datasets were pooled by Rubin's rules. As disease activity was missing for all patients entered from France in the C19-GRA registry, country-level life expectancy was used in the imputation model to explain potential structural differences in disease activity between countries not accounted for in the patient-level data (data from 2018, source: http://hdr.undp.org/). For more details regarding excluded patients and handling of missing data, refer to online supplemental methods.

IMIDs differ regarding the DMARDs approved for their treatment. To explore the impact of this heterogeneity on the associations of interest, in addition to the primary analysis with all patients, diagnostic categories were defined, and stratified secondary analyses were undertaken separately for patients with PsO, PsA and axSpA.

The following sensitivity analyses were also performed to examine the robustness of our findings: (1) analysis limited to patients with confirmed or highly likely COVID-19; (2) analysis using the alternative binary outcome 'hospitalisation'; (3) analysis using the alternative binary outcome 'death'. In the model using death as dependent variable, comorbidities were analysed as an independent binary variable (3 or more comorbidities vs less than 3), to minimise the risk of overfitting. Data were considered statistically significant for p values<0.05. All analyses were conducted in SAS (V.9.4) and R (V.4.0.4).

RESULTS

Study sample and baseline characteristics

The study population included 5045 cases, of which 921 (18.3%) were patients with PsO, 2293 (45.5%) with PsA, and 1831 (36.3%) with axSpA. Overall, the mean age was 50 years (SD 13.5), just over half were male (51.7%) and most were from Europe (77.5%) (table 1). Cases were reported fairly equally across the three pandemic time periods. Most cases had disease (IMIDs) in remission or minimal/low disease activity (82.7%). About half had no key comorbidities reported (52.9%). Of those with comorbidities, the most reported were hypertension (26.5%) and obesity (21.1%). Any csDMARD use was reported in 30.3%, with methotrexate as the most common (23.4%). Only 5.6% reported using sulfasalazine. bDMARD use was reported in 65.7% (TNFi 45.6%, IL17i 12.1%, IL-23i/IL-12+23i 8.1%). Only 1.2% reported JAKi use. Baseline GC use was reported in only 7.3% (4.6%, 0–7.5 mg/day and 1.4%, >7.5 mg/day) and NSAID use in 24%.

When stratified by condition (table 1), the main notable differences were that individuals with PsA were older (mean 53.2 years vs 46.9 years in axSpA and 48.4 years in PsO), a higher proportion of those with PsA had hypertension (32.8% vs 21.2% in axSpA and 21.3% in PsO) and a higher proportion of those with PsO were obese (29.2% vs 23% in PsA and 14.5% in axSpA). csDMARDs were most used among individuals with PsA (46.6% vs 19.3% in axSpA and 11.6% in PsO) while bDMARDs were most used among individuals with axSpA (73.6% vs 58.5% in PsA and 68.1% in PsO). Baseline GC usage was low overall but differed notably between the groups, with almost none in PsO (0.7%) vs 10.7% in PsA and 6.3% in axSpA. There was no difference across disease groups with regard to disease activity.

When stratified by medication group (online supplemental table 1), patients not taking DMARDs were slightly younger (mean 49.9 years) than patients taking DMARDs (range from 50 to 56.2 years, depending on the DMARD group) except for IL-17i/IL-23i/IL12+23i (mean 49.9 years) and TNFi (mean 48.3 years). Moreover, patients not taking DMARDs were slightly less often in remission/low disease activity (71.%) than patients taking DMARDs (range from 80.5% to 86.1%, depending on the DMARD group) except for JAKi (65.3% in remission/low disease activity).

COVID-19 outcomes

Baseline characteristics of the study population stratified by COVID-19 outcome are shown in online supplemental table 2. Most patients (4220, 83.6%) were not hospitalised, 736 (14.6%) were hospitalised and 89 (1.8%) died. The frequency of hospitalisation (without death) and death were slightly higher in PsA (17.1% and 2.2%, respectively), compared with axSpA (12.5% and 1.4%, respectively) and PsO (12.5% and 1.3%, respectively) (table 1).

Associations of baseline characteristics with COVID-19 severity

The results of the primary multivariable ordinal logistic regression model are shown in table 2 and the relationship between age and probability of hospitalisation and death is shown in figure 1.

Age was associated with COVID-19 severity in a non-linear way (stronger association for older age groups). Hypertension without CVD (OR 1.25, 95% CI 1.01 to 1.55), CVD without hypertension (OR 1.87, 95% CI 1.21 to 2.90), COPD or asthma (OR 1.75, 95% CI 1.33 to 2.31), other lung disease (OR 2.54, 95% CI 1.64 to 3.93), CKD (OR 2.32, 95% CI 1.50 to 3.58),

Table 1 Baseline characteristics of the study population (total and stratified by immune-mediated inflammatory disease diagnosis)

Parameter	Psoriatic arthritis	Axial spondyloarthritis	Psoriasis (without arthritis)	Total
N	2293	1831	921	5045
General				
Age (years)	53.2 (12.8)	46.9 (13.4)	48.4 (13.6)	50 (13.5)
≤30 years	110 (4.8)	211 (11.5)	100 (10.9)	421 (8.3)
31–50 years	785 (34.2)	900 (49.2)	400 (43.4)	2085 (41.3)
51–65 years	1032 (45)	567 (31)	336 (36.5)	1935 (38.4)
66–75 years	280 (12.2)	109 (6)	59 (6.4)	448 (8.9)
>75 years	86 (3.8)	44 (2.4)	26 (2.8)	156 (3.1)
Male sex	1053 (45.9)	996 (54.4)	557 (60.5)	2606 (51.7)
Ever-smoker	566 (33.2) (N=1705) (Missing=588)	313 (23.9) (N=1311) (Missing=520)	334 (36.3) (N=921) (Missing=0)	1213 (30.8) (N=3937) (Missing=1108)
Regions				
African Region	5 (0.2)	5 (0.3)	4 (0.4)	14 (0.3)
Eastern Mediterranean Region	34 (1.5)	31 (1.7)	7 (0.8)	72 (1.4)
European Region	1707 (74.4)	1396 (76.2)	805 (87.4)	3908 (77.5)
North American Region	454 (19.8)	221 (12.1)	53 (5.8)	728 (14.4)
South American Region	62 (2.7)	159 (8.7)	46 (5)	267 (5.3)
South-East Asian Region	10 (0.4)	8 (0.4)	3 (0.3)	21 (0.4)
Western Pacific Region	21 (0.9)	11 (0.6)	3 (0.3)	35 (0.7)
Time period				
Until 15 June 2020	744 (32.4)	564 (30.8)	417 (45.3)	1725 (34.2)
From 16 June 2020 to 31 December 2020	1043 (45.5)	880 (48.1)	340 (36.9)	2263 (44.9)
1 January 2021 and later	506 (22.1)	387 (21.1)	164 (17.8)	1057 (21)
Ordinal outcome				
Not hospitalised, no death	1850 (80.7)	1576 (86.1)	794 (86.2)	4220 (83.6)
Hospitalised, no death	392 (17.1)	229 (12.5)	115 (12.5)	736 (14.6)
Death	51 (2.2)	26 (1.4)	12 (1.3)	89 (1.8)
Disease activity	(N=2014) (Missing=279)	(N=1288) (Missing=532)	(N=920) (Missing=1)	N=4233 (Missing=812)
Remission/low disease activity	1670 (82.9)	1090 (83.9)	740 (80.4)	3500 (82.7)
Moderate/high disease activity	344 (17.1)	209 (16.1)	180 (19.6)	733 (17.3)
Comorbidities	(N=2266) (Missing=27)	(N=1809) (Missing=22)	(N=921) (Missing=0)	N=4996 (Missing=49)
Hypertension	744 (32.8)	383 (21.2)	196 (21.3)	1323 (26.5)
Cardiovascular disease	179 (7.9)	88 (4.9)	71 (7.7)	338 (6.8)
COPD or asthma	185 (8.2)	114 (6.3)	62 (6.7)	361 (7.
Other chronic lung disease	47 (2.1)	30 (1.7)	22 (2.4)	99 (2)
Chronic kidney disease	60 (2.6)	24 (1.3)	17 (1.8)	101 (2)
Diabetes	316 (13.9)	126 (7)	120 (13)	562 (11.2)
Cancer	65 (2.9)	26 (1.4)	24 (2.6)	115 (2.3)
Obesity	522 (23)	262 (14.5)	269 (29.2)	1053 (21.1)
No of comorbidities	1 (1.2)	0.6 (1)	1 (1.2)	0.8 (1.1)
No comorbidity	1077 (47.5)	1124 (62.1)	442 (48)	2643 (52.9)
1 comorbidity	573 (25.3)	418 (23.1)	248 (26.9)	1239 (24.8)
2 comorbidities	350 (15.4)	181 (10)	127 (13.8)	658 (13.2)
≥3 comorbidities	266 (11.7)	86 (4.8)	104 (11.3)	456 (9.1)
DMARDs (monotherapy or combination therapy)				
csDMARDs	1068 (46.6)	353 (19.3)	107 (11.6)	1528 (30.3)
Antimalarials	30 (1.3)	7 (0.4)	0	37 (0.7)
Methotrexate	889 (38.8)	194 (10.6)	100 (10.9)	1183 (23.4)
Leflunomide	94 (4.1)	13 (0.7)	0	107 (2.1)
Sulfasalazine	119 (5.2)	164 (9)	0	283 (5.6)
Cyclosporine	11 (0.5)	0	8 (0.9)	19 (0.4)
bDMARDs	1341 (58.5)	1347 (73.6)	627 (68.1)	3315 (65.7)
TNF inhibitors	895 (39)	1176 (64.2)	227 (24.6)	2298 (45.6)

Continued

Table 1 Continued

Parameter	Psoriatic arthritis	Axial spondyloarthritis	Psoriasis (without arthritis)	Total
N	2293	1831	921	5045
IL-17 inhibitors	301 (13.1)	164 (9)	145 (15.7)	610 (12.1)
IL-23/IL-12+23 inhibitors	145 (6.3)	7 (0.4)	255 (27.7)	407 (8.1)
tsDMARDs	111 (4.8)	11 (0.6)	19 (2.1)	141 (2.8)
JAK inhibitors	51 (2.2)	11 (0.6)	0	62 (1.2)
Apremilast	60 (2.6)	0	19 (2.1)	79 (1.6)
No DMARD treatment	234 (10.2)	309 (16.9)	179 (19.4)	722 (14.3)
Other therapies				
Glucocorticoids (#)	241 (10.7) (N=2242) (Missing=51)	110 (6.3) (N=1760) (Missing=71)	6 (0.7) (N=921) (Missing=0)	357 (7.3) (N=4923) (Missing=122)
0 mg/day <glucocorticoids ≤7.5 mg/day	167 (7.5) (N=2215) (Missing=78)	54 (3.1) (N=1724) (Missing=107)	3 (0.3) (N=919) (Missing=2)	224 (4.6) (N=4858) (Missing=187)
Glucocorticoids >7.5 mg/day	46 (2.1) (N=2215) (Missing=78)	19 (1.1) (N=1724) (Missing=107)	1 (0.1) (N=919) (Missing=2)	66 (1.4) (N=4858) (Missing=187)
NSAIDs	512 (24.5) (N=2094) (Missing=199)	553 (35.5) (N=1559) (Missing=272)	32 (3.5) (N=921) (Missing=0)	1097 (24) (N=4574) (Missing=471)
Acitretin	3 (0.1)	0	26 (2.8)	29 (0.6)

Data are N (column %) for categorical variables or mean (SD) for continuous variables. Table includes patients diagnosed with psoriasis without arthritis, psoriatic arthritis or axial spondyloarthritis, with a non-missing ordinal outcome and non-missing values for age, sex, time period and DMARDs. Further, patients receiving multiple b/tsDMARDs or DMARDs not typical for the three diagnoses were excluded, as well as patients labelled as having additional inflammatory rheumatic diseases (529 patients excluded in total). Data refer to patients with non-missing values for the respective variable; total N for patients with non-missing values is given in parentheses for variables with missing values; the total number of missing values is also given in parenthesis, for the applicable variables. (#) Includes patients with a missing glucocorticoid dosage.
bDMARD, biological disease-modifying anti-rheumatic drugs; BMI, body mass index; COPD, chronic obstructive pulmonary disease; csDMARD, conventional synthetic DMARD; DMARD, disease-modifying antirheumatic drug; IL, interleukin; JAK, Janus kinase; N, number; NSAID, non-steroidal anti-inflammatory drugs; TNF, tumour necrosis factor; tsDMARD, targeted synthetic DMARD.

cancer in patients with missing data on smoking (OR 2.89, 95% CI 1.19 to 6.97), obesity without diabetes (OR 1.35, 95% CI 1.07 to 1.70), diabetes without obesity (OR 1.84, 95% CI 1.38 to 2.45), and coexistence of obesity and diabetes (OR 1.89, 95% CI 1.34 to 2.68) were associated with greater odds of worse COVID-19 severity compared with referents without each condition. Male sex was associated with 1.54 times greater odds of worse COVID-19 severity compared with female sex (95% CI 1.30 to 1.83). Moderate/high disease activity (with or without GC use) and remission/low disease activity (with GC use) were associated with higher odds of worse COVID-19 outcomes compared with being in remission/low disease activity without GC use (OR ranging from 1.39 to 2.23). Later pandemic time periods were associated with lower odds of worse COVID-19 severity compared with the baseline period of March 2020–15 June 2020 (OR 0.42, 95% CI 0.34 to 0.51 for 16 June 2020–31 December 2020; OR 0.52, 95% CI 0.41 to 0.67 for 1 January 2021 and later). Compared with PsA, PsO was associated with less COVID-19 severity (OR 0.49, 95% CI 0.37 to 0.65). For medication classes, none were associated with higher odds of COVID-19 severity. TNFi, IL17i and IL-23i/IL-12+23i all demonstrated reduced odds of severe COVID-19 outcomes (OR 0.57, 95% CI 0.44 to 0.73; OR 0.62, 95% CI 0.45 to 0.87; OR 0.67, 95% CI 0.45 to 0.98, respectively). Finally, NSAID use compared with no use of NSAIDs was associated with lower odds of severe COVID-19 outcomes (OR 0.77, 95% CI 0.60 to 0.98).

Stratified analyses

When stratified by condition, results were similar to the primary model (online supplemental table 3) and online supplemental figures 1-3) with the following notable exceptions: hypertension alone and CVD alone were only significantly associated with the COVID-19 severity outcome among those with axSpA (OR 1.49, 95% CI 1.01 to 2.19; and OR 2.77, 95% CI 1.25 to 6.13; respectively) whereas COPD and asthma were associated with the COVID-19 severity outcome only among those with PsA (OR 1.95, 95% CI 1.34 to 2.82). The association of IL-23i/IL-12+23i with less severe COVID-19 outcomes was only statistically significant among those with PsO (OR 0.43, 95% CI 0.23 to 0.82); however, IL-23i/IL-12+23i were not used among patients with axSpA (not efficacious/licensed for this indication) and numbers were lower for PsA.

Sensitivity analyses

The results of sensitivity analyses are shown in online supplemental tables 4-6 and online supplemental figures 4-6. When restricting the analysis to confirmed COVID-19 cases (n=4176), multivariable model results were consistent with the primary model. Results were also similar to the primary model for the binary outcome of hospitalisation.

For the binary outcome of death, male sex (OR 2.00, 95% CI 1.22 to 3.26), having three or more comorbidities (OR 3.34, 95% CI 1.98 to 5.63) and baseline GC use (OR 1.91, 95% CI 1.002 to 3.64) remained associated with the outcome of interest. In this model, TNFi and IL17i continued to demonstrate reduced odds of severe COVID-19 outcomes (OR 0.50, 95% CI 0.26 to 0.98 and OR 0.11, 95% CI 0.02 to 0.51; respectively). However, sulfasalazine use (OR 2.64, 95% CI 1.13 to 6.17) and JAKi use (OR 7.49, 95% CI 2.61 to 21.47) were associated with greater odds of severe COVID-19 outcomes in this model.

Table 2 Multivariable ordinal logistic regression analysis of factors associated with COVID-19 severity (primary model, all patients)

N total	5045			
N deaths/ hospitalisations without death/neither	89/736/4220			
	N deaths/hospitalisations without death/neither	OR	95% CI	
Male sex (vs female)	57/419/2130	**1.54**	**1.30**	**1.83**
Pandemic time period				
Until 15 June 2020	45/395/1285	1	(Reference)	
16 June 2020–31 December 2020	28/217/2018	**0.42**	**0.34**	**0.51**
1 January 2021 and later	16/124/917	**0.52**	**0.41**	**0.67**
Comorbidities				
Hypertension alone (vs no hypertension, no CVD)	28/242/847	**1.25**	**1.01**	**1.55**
CVD alone (vs no hypertension, no CVD)	7/38/76	**1.87**	**1.21**	**2.90**
CVD and hypertension (vs no hypertension, no CVD)	21/63/136	1.41	0.98	2.02
COPD or asthma	21/87/257	**1.75**	**1.33**	**2.31**
Other lung disease	11/34/55	**2.54**	**1.64**	**3.93**
Chronic kidney disease	14/42/46	**2.32**	**1.50**	**3.58**
Obesity alone (vs no obesity, no diabetes)	11/138/676	**1.35**	**1.07**	**1.70**
Diabetes mellitus alone (vs no obesity, no diabetes)	15/102/212	**1.84**	**1.38**	**2.45**
Obesity and diabetes mellitus (vs no obesity, no diabetes)	14/61/162	**1.89**	**1.34**	**2.68**
Cancer and known smoking habits (vs no cancer, never smoked)	4/29/57	1.13	0.68	1.88
Cancer and unknown smoking habits (vs no cancer, never smoked)	5/7/13	**2.89**	**1.19**	**6.97**
No cancer and ever smoked or unknown smoking habits (vs no cancer, never smoked)	38/281/1933	0.87	0.71	1.06
Rheumatic disease				
Psoriatic arthritis	51/392/1850	1	(Reference)	
Axial spondyloarthritis	26/229/1576	1.07	0.86	1.33
Psoriasis (without arthritis)	12/115/794	**0.49**	**0.37**	**0.65**
Medication				
No DMARD therapy	21/128/573	1	(Reference)	
Antimalarials	0/4/14	1.08	0.30	3.84
Methotrexate	13/133/449	1.03	0.76	1.40
Leflunomide	2/16/42	1.08	0.55	2.11
Sulfasalazine	12/32/136	1.41	0.91	2.17
Cyclosporine	0/1/18	0.31	0.04	2.47
TNF inhibitors	24/248/2026	**0.57**	**0.44**	**0.73**
IL-17 inhibitors	2/88/520	**0.62**	**0.45**	**0.87**
IL-23/IL-12+23 inhibitors	5/58/344	**0.67**	**0.45**	**0.98**
JAK inhibitors	7/10/45	1.58	0.83	3.01
Apremilast	3/18/58	1.04	0.57	1.91
Disease activity (DA) and glucocorticoids (GCs)				
Remission/low DA, no GCs	57/516/3358	1	(Reference)	
Remission/low DA, GCs	13/59/177	**1.97**	**1.39**	**2.79**
Moderate/high DA, no GCs	15/130/604	**1.39**	**1.09**	**1.76**
Moderate/high DA, GCs	5/32/82	**2.23**	**1.39**	**3.58**
NSAIDs	16/151/1072	**0.77**	**0.60**	**0.98**

Results for ordinal mixed effects logistic regression analysis in all patients (primary model). Shown are fixed effects, random effects for country are not shown. Missing values are imputed via multiple imputation, patient numbers may thus be rounded. The model was additionally adjusted for age employing four-knot restricted cubic splines. Significant associations highlighted in bold.
bDMARD, biological disease-modifying antirheumatic drug; BMI, body mass index; COPD, chronic obstructive pulmonary disease; csDMARD, conventional synthetic DMARD; CVD, cardiovascular disease; DMARD, disease-modifying antirheumatic drug; IL, interleukin; JAK, Janus kinase; N, number; NSAID, non-steroidal antiinflammatory drug; TNF, tumour necrosis factor; tsDMARD, targeted synthetic DMARD.

Discussion

In this registry-based study of individuals with PsO, PsA and axSpA with SARS-CoV-2 infection, we found that known risk factors for the general population (older age, the presence of comorbidities) and for IMIDs overall (higher disease activity, higher baseline GC usage) were associated with more severe COVID-19 outcomes. In addition, a diagnosis of COVID-19 in a later time period during the pandemic was associated with lower disease severity compared with early 2020. Consistent with previous studies, baseline TNFi use was associated with lower odds for severe COVID-19 outcomes; we also found that IL17i and IL-23i/IL-12+23i use had similar associations with lower odds for severe COVID-19 outcomes.

The findings of our study reiterate known risk factors in both the general population and among people with IMIDs: older age, male sex and presence of comorbidities, specifically cardiometabolic and pulmonary conditions, were associated with more severe COVID-19 outcomes.[5 6] Our findings that disease activity and GC usage at baseline have an additive interaction are consistent with prior findings in the C19-GRA registry.[20]

In this study, baseline use of TNFi was associated with lower odds of severe COVID-19 outcomes. This was previously shown in the C19-GRA registry,[7] in a combined rheumatic disease, inflammatory bowel disease (IBD) and PsO analysis,[8] and in a US-based administrative claims database study among individuals with RA.[21] Mechanistic plausibility for trialling TNFi therapies for COVID-19 treatment has been discussed in the literature.[22 23] These therapies neutralise TNF, a major cytokine

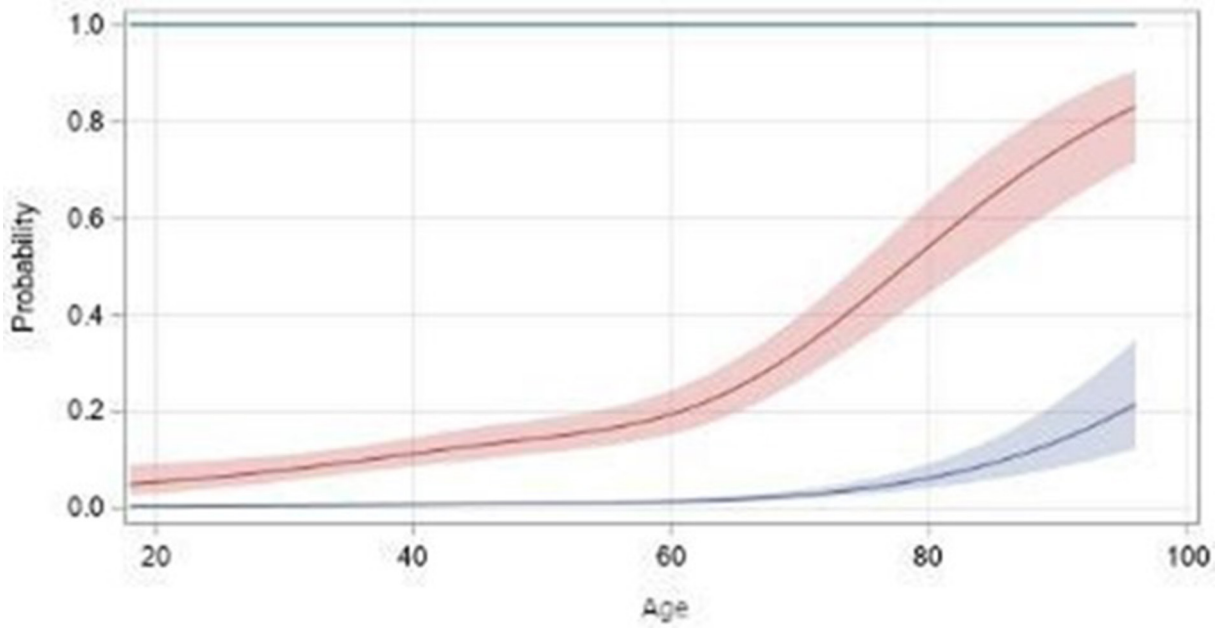

Figure 1 Relationship between age and probability of hospitalisation (red) and death (blue) estimated by four-knot restricted cubic splines, with 95% CIs (primary model, ordinal outcome, all patients).

in the excess inflammatory phase of COVID-19, and several trials are ongoing. A recent preprint announced results of a large randomised, placebo-controlled clinical trial led by the National Institutes of Health showing that treating adults hospitalised with COVID-19 with infliximab (a TNFi) did not significantly shorten time to recovery but did improve 14-day clinical status and substantially reduced 28-day mortality compared with standard of care[24]—the peer-reviewed publication is awaited.

We also demonstrated that using IL17i and IL-23i/IL-12+23i was also associated with lower odds of severe COVID-19 outcomes. Prior population-level data from Israel and the UK have shown that the use of IL-17i was not associated with worse COVID-19 outcomes.[25 26] At the same time, case reports and case series have also suggested that IL-17 and IL-23 inhibition may not have a negative effect on the course of COVID-19,[27–29] though further inference on whether exposure to these medications might be associated with better COVID-19 outcomes is limited. IL-17 may play a pathogenic role in acute respiratory distress syndrome and lung inflammation associated with severe COVID-19. Patients with COVID-19 who experience pulmonary complications have increased and activated Th17 cell populations, and lung damage and hyperinflammation are linked to these patients' increased Th17 cell responses.[30 31] The anti-IL-17 monoclonal antibody netakimab improved survival in a small clinical trial in patients with COVID-19; it decreased lung lesion volume and the need for oxygen support.[32] However, in another study, netakimab therapy improved some clinical parameters and decreased C reactive protein levels, but it had no effect on the need for mechanical ventilation or patient survival in COVID-19 patients.[33] Suppressing inflammation via a variety of mechanisms has been shown to improve COVID-19 outcomes in people with severe disease (ie, GC, IL-6i, JAKi, maybe TNFi). Whether IL-17 will also have a role remains to be determined and requires further study.[34 35] Importantly, in our study, we report associations and therefore we caution against interpreting our estimates causally, as the possibility of selection bias and unmeasured confounding cannot be excluded.

Apremilast was not associated with the severity of COVID-19 in patients with PsO/PsA. Although the number of patients taking apremilast was low, these data are important because they add to limited previous evidence of a favourable safety profile of apremilast on COVID-19 severity in patients with these conditions.[36–38]

The finding that baseline NSAID use was associated with less COVID-19 severity is interesting but should be interpreted with caution. NSAID use is particularly prone to reporting bias, and inconsistencies in reporting might have resulted from the fact that we did not specify a minimal duration of a continuous treatment with NSAID and did not use a standardised questionnaire to collect NSAID data (eg, type of NSAID, dose and duration of treatment). General population studies in the UK and Denmark have not found associations between NSAID use and COVID-19-related hospitalisation or death.[39–41] In our study, this association was seen particularly in individuals with axSpA and may be related to milder disease and/or well controlled of disease activity; confounding by indication cannot be excluded.

Finally, the results of one sensitivity analysis indicated that use of sulfasalazine and JAKi were associated with higher odds of death (binary outcome) due to COVID-19, though there were no associations with the ordinal COVID-19 severity outcome or with hospitalisation (binary outcome). In the C-19 GRA registry, we previously found an association of sulfasalazine use with worse COVID-19 outcome,[7] a finding which was also seen in initial analyses of the Surveillance Epidemiology of Coronavirus Under Research Exclusion (IBD) database[42] though later analyses were null.[43] While there are biologically plausible effects of sulfasalazine on SARS-CoV-2 viral entry,[44] our results may be due to residual confounding. The association of JAKi usage with COVID-19 outcomes is consistent with findings from some studies focused on people with RA.[9 45] However, results from this sensitivity analysis should be interpreted with caution as the proportion of patients on JAKi was low (and no patients with PsO were taking this medication) and the respective 95% CI was wide.

Our study has several strengths, including the international nature of the combined registries, the large sample size and the granularity of information regarding IMID medications and disease activity. Our study also has limitations. First, the C19-GRA and PsoProtect registries were dependent on voluntary provider entry of cases, and there may be bias towards cases with more severe COVID-19 and those on DMARD therapy, as mostly secondary care clinicians were submitting cases. As such, proportions of events in our study sample should not be interpreted as incidence rates. Second, while we tried to mitigate the impacts of selection bias and confounding by indication, it is possible that our results may still be biased. However, we performed a series of sensitivity analyses to confirm the robustness of our findings, including restricting to a sample of confirmed cases of COVID-19, and our results were consistent across these additional analyses. Third, although we were able to adjust for several potential confounders in our models, there may still be residual unmeasured confounding. We did not have data available on disease duration or prior medication use, apart from what was reported at the time of COVID-19 diagnosis. Finally, vaccination status was not available for the patients in this dataset; however, the model adjustment for pandemic calendar period used in this study may act as a surrogate for vaccination status.

In conclusion, more severe COVID-19 outcomes in PsO, PsA and axSpA are largely associated with age, comorbidities, active disease and GC use. None of the bDMARDs typically used in PsO, PsA and axSpA, including TNFi, IL-17i and IL-23i/IL-12+23i, were associated with severe COVID-19 outcomes, and no biologics-specific differences were found. Our findings will help clinicians, scientific societies and policy makers worldwide develop tailored management strategies for patients with PsO, PsA and axSpA during COVID-19 waves or similar future respiratory pandemics.

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Correction notice This article has been corrected since it published Online First. The first authorship statement has been added.

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Ethics approval Given that the registries collect deidentified data, the UK Health Research Authority, the University of California San Francisco Institutional Review Board and the Leeds Research Ethics Committee (UK) considered them exempt from patient consent. Local regulatory guidelines were followed by international sites.

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