

Characteristics and outcomes of COVID-19 patients with and without asthma from the United States, South Korea, and Europe

Daniel R. Morales, Anna Ostropelets, Lana Lai, Anthony Sena, Scott Duvall, Marc Suchard, Katia Verhamme, Peter Rjinbeek, Joe Posada, Waheed Ahmed, Thamer Alshammary, Heba Alghoul, Osaid Alser, Carlos Areia, Clair Blacketer, Edward Burn, Paula Casajust, Seng Chan You, Dalia Dawoud, Asieh Golozar, Menchung Gong, Jitendra Jonnagaddala, Kristine Lynch, Michael Matheny, Evan Minty, Fredrik Nyberg, Albert Uribe, Martina Recalde, Christian Reich, Martijn Scheumie, Karishma Shah, Nigam Shah, Lisa Schilling, David Vizcaya, Lin Zhang, George Hripcsak, Patrick Ryan, Daniel Prieto-Alhambra, Talita Durate-Salles & Kristin Kostka

To cite this article: Daniel R. Morales, Anna Ostropelets, Lana Lai, Anthony Sena, Scott Duvall, Marc Suchard, Katia Verhamme, Peter Rjinbeek, Joe Posada, Waheed Ahmed, Thamer Alshammary, Heba Alghoul, Osaid Alser, Carlos Areia, Clair Blacketer, Edward Burn, Paula Casajust, Seng Chan You, Dalia Dawoud, Asieh Golozar, Menchung Gong, Jitendra Jonnagaddala, Kristine Lynch, Michael Matheny, Evan Minty, Fredrik Nyberg, Albert Uribe, Martina Recalde, Christian Reich, Martijn Scheumie, Karishma Shah, Nigam Shah, Lisa Schilling, David Vizcaya, Lin Zhang, George Hripcsak, Patrick Ryan, Daniel Prieto-Alhambra, Talita Durate-Salles & Kristin Kostka (2022): Characteristics and outcomes of COVID-19 patients with and without asthma from the United States, South Korea, and Europe, *Journal of Asthma*, DOI: [10.1080/02770903.2021.2025392](https://doi.org/10.1080/02770903.2021.2025392)

To link to this article: <https://doi.org/10.1080/02770903.2021.2025392>



© 2022 The Author(s). Published with license by Taylor & Francis Group, LLC.



View supplementary material [↗](#)



Published online: 11 Feb 2022.



Submit your article to this journal [↗](#)



Article views: 136



[View related articles](#) 



[View Crossmark data](#) 

Characteristics and outcomes of COVID-19 patients with and without asthma from the United States, South Korea, and Europe

Daniel R. Morales, PhD^{a,b} , Anna Ostropelets, MD^c, Lana Lai, PhD^d, Anthony Sena, BS^e, Scott Duvall, PhD^f, Marc Suchard, PhD^g, Katia Verhamme, PhD^h , Peter Rijnbeek, PhD^h, Joe Posada, PhDⁱ, Waheed Ahmed, MSc^j, Thamer Alshammary, PhD^k, Heba Alghoul, MD^l, Osaid Alser, MD^j, Carlos Areia, MSc^j, Clair Blacketer, MPH^h, Edward Burn, DPhil^j, Paula Casajust, MSc^m, Seng Chan You, PhDⁿ, Dalia Dawoud, PhDⁱ, Asieh Golozar, PhD^o, Menchung Gong, MD^p, Jitendra Jonnagaddala, PhD^q, Kristine Lynch, PhD^f, Michael Matheny, MD^f, Evan Minty, MD^r, Fredrik Nyberg, PhD^s, Albert Uribe, MD^j, Martina Recalde, MPH^t, Christian Reich, PhD^u, Martijn Scheumie, PhD^e, Karishma Shah, PhD^j, Nigam Shah, PhD^j, Lisa Schilling, MD^v, David Vizcaya, PhD^w, Lin Zhang, PhD^x, George Hripcsak, MD^c, Patrick Ryan, PhD^e, Daniel Prieto-Alhambra, PhD^j, Talita Durate-Salles, PhD^t and Kristin Kostka, MPH^u

^aDivision of Population Health and Genomics, University of Dundee, Dundee, United Kingdom of Great Britain and Northern Ireland;

^bDepartment of Public Health, University of Southern Denmark, Odense, Denmark; ^cDepartment of Biomedical Informatics, Columbia University, New York, NY, USA; ^dThe University of Manchester, University of Manchester, Manchester, United Kingdom of Great Britain and Northern Ireland; ^eJanssen Research and Development LLC, Raritan, NJ, USA; ^fUniversity of Utah Health, Epidemiology, Salt Lake City, UT, USA;

^gUCLA, Biomathematics, Los Angeles, CA, USA; ^hErasmus MC, Medical Informatics, Erasmus MC, Dr Molewaterplein, Rotterdam, CA, The Netherlands; ⁱStanford University, Medicine, Stanford, CA, USA; ^jDepartment of Orthopedics, University of Oxford, Oxford, United Kingdom of Great Britain and Northern Ireland; ^kKing Saud University, Medicine, Riyadh, Saudi Arabia; ^lIslamic University of Gaza, Medicine, Gaza, State of Palestine; ^mTrial Form Support, Real World Evidence, Barcelona, Spain; ⁿAjou University, Medicine, Suwon, The Republic of Korea; ^oJohns Hopkins University, Epidemiology, Baltimore, MD, USA; ^pDC Technologies, DC Technologies, China; ^qUNSW, Public Health, Sydney, Australia; ^rUniversity of Calgary, Public Health, Calgary, Alberta, Canada; ^sUniversity of Gothenburg, Public health, Goteborg, Sweden; ^tIDIA Jordi Gol, IDIAP, Barcelona, Spain; ^uIQVIA, Real World Solutions, Cambridge, MA, USA; ^vUniversity of Colorado, School of Medicine, Denver, CO, USA;

^wBayer Pharmaceuticals, Bayer, Spain; ^xChinese Academy of Medical Sciences and Peking Union Medical College, Public health, Beijing, China

ABSTRACT

Objective: Large international comparisons describing the clinical characteristics of patients with COVID-19 are limited. The aim of the study was to perform a large-scale descriptive characterization of COVID-19 patients with asthma.

Methods: We included nine databases contributing data from January to June 2020 from the US, South Korea (KR), Spain, UK and the Netherlands. We defined two cohorts of COVID-19 patients ('diagnosed' and 'hospitalized') based on COVID-19 disease codes. We followed patients from COVID-19 index date to 30 days or death. We performed descriptive analysis and reported the frequency of characteristics and outcomes in people with asthma defined by codes and prescriptions.

Results: The diagnosed and hospitalized cohorts contained 666,933 and 159,552 COVID-19 patients respectively. Exacerbation in people with asthma was recorded in 1.6–8.6% of patients at presentation. Asthma prevalence ranged from 6.2% (95% CI 5.7–6.8) to 18.5% (95% CI 18.2–18.8) in the diagnosed cohort and 5.2% (95% CI 4.0–6.8) to 20.5% (95% CI 18.6–22.6) in the hospitalized cohort. Asthma patients with COVID-19 had high prevalence of comorbidity including hypertension, heart disease, diabetes and obesity. Mortality ranged from 2.1% (95% CI 1.8–2.4) to 16.9% (95% CI 13.8–20.5) and similar or lower compared to COVID-19 patients without asthma. Acute respiratory distress syndrome occurred in 15–30% of hospitalized COVID-19 asthma patients.

Conclusion: The prevalence of asthma among COVID-19 patients varies internationally. Asthma patients with COVID-19 have high comorbidity. The prevalence of asthma exacerbation at presentation was low. Whilst mortality was similar among COVID-19 patients with and without asthma, this could be confounded by differences in clinical characteristics. Further research could help identify high-risk asthma patients.

KEY MESSAGES

- Asthma prevalence in COVID-19 patients varied internationally (5.2–20.5%).
- The prevalence of asthma exacerbation at presentation with COVID-19 in diagnosed and hospitalized patients was low.
- Comorbidities were common in COVID-19 patients with asthma.

ARTICLE HISTORY

Received 2 August 2021

Revised 17 December 2021

Accepted 30 December 2021

KEYWORDS

Asthma; COVID-19; comorbidity; epidemiology

CONTACT Daniel R. Morales  d.r.morales@dundee.ac.uk  Division of Population Health and Genomics University of Dundee Dundee United Kingdom of Great Britain and Northern Ireland.

 Supplemental data for this article can be accessed at [publisher's website](#).

© 2022 The Author(s). Published with license by Taylor & Francis Group, LLC.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Background

Coronavirus disease 2019 (COVID-19) causes severe lung injury and pneumonia as well as other complications including acute kidney injury, cardiovascular complications and death. In people with asthma, viral respiratory tract infections exacerbate the underlying disease and are associated with higher rates of morbidity and mortality (1–3). COVID-19 has been compared to seasonal influenza in terms of symptoms and complications, resulting in asthmatic individuals being classed as high risk. National policy measures consequently stipulated the need for asthmatic patients to shield or shelter during the COVID-19 pandemic (4).

Although COVID-19 causes greater morbidity and mortality than influenza among the general population, further information is required describing the characteristics of people with asthma and COVID-19 and their outcomes (5,6). It has been speculated that reduced susceptibility to COVID-19 may exist as a result of type 2 immunity linked to atopy and reduced expression of the angiotensin converting enzyme-2 receptor (ACE2) (7,8). In this regard, ACE2 is required by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) to enter human cells. Concerns have also been raised over the safety of inhaled corticosteroids (9).

Patients with severe COVID-19 have comorbidities including cardiovascular disease, diabetes and obesity (10,11). Some studies have found that asthma is a common comorbidity among severe and fatal COVID-19 cases (12,13). However, studies examining the association between asthma and risk of COVID-19 related death have been inconsistent (11,13–15). Existing studies are typically limited to smaller hospitalized COVID-19 populations, with uncertain generalizability across data sources and/or countries. Further detailed information on comorbidities, medication use and outcomes in people with asthma with milder and more severe COVID-19 would therefore be of value. The aim of this study was to describe the demographics, comorbidities, and outcomes of patients with COVID-19 and co-morbid asthma.

Methods

Study design

The Characterizing Health Associated Risks, and Your Baseline Disease In SARS-COV-2 (CHARYBDIS) study is a multinational cohort study using retrospective electronic health records and claims data on COVID-19 patients from the United States (US), Europe, and Asia. All data were standardized to the Observational

Medical Outcomes Partnership (OMOP) Common Data Model (CDM) (16,17). This allowed contributing centers to execute analytical code in a distributed/federated fashion without sharing patient-level data. The Charybdis protocol and source code can be found at (<https://github.com/ohdsi-studies/Covid19CharacterizationCharybdis>) (18).

Data sources

Of the sixteen available databases on 4th August 2020, nine were included that had a minimum pre-specified sample size of 140 COVID-19 patients with asthma. This was considered necessary to estimate the prevalence of a previous condition or 30-day risk of an outcome affecting 10% of the study population. **Supplementary Figure S1** presents the database selection process for this study. Data from the US included: the Columbia University Irving Medical Center data warehouse (CUIMC), Stanford Medicine Research Data Repository (STARR-OMOP) (19), Health Verity, IQVIA Open Claims, and the United States Department of Veterans Affairs (VA-OMOP). Data from South Korea included the Health Insurance Review and Assessment Service (HIRA) database. Data from Europe included the Spanish Information System for Research in Primary Care (SIDIAP) database (20); the Integrated Primary Care Information (IPCI) database from the Netherlands (21), and the UK Clinical Practice Research Datalink (CPRD) (22). Further information about databases considered for inclusion is contained in **Appendix 1**.

Study participants and follow-up

COVID-19 cohorts: Two non-mutually exclusive cohorts were defined. Patients “diagnosed” with COVID-19 were defined by patients having a clinical diagnosis and/or positive test for SARS-CoV-2 from outpatient and inpatient records. In the diagnosed cohort, index date was the earliest date of COVID-19 diagnosis or a first positive test. Patients “hospitalized” with COVID-19 were defined by a hospitalization episode with a clinical diagnosis or positive SARS-CoV-2 test within 21 days prior to admission and up to the end of hospitalization. This time window was chosen to include patients with a diagnosis prior to hospitalization and to allow for delays in recording of test results. In the hospitalized cohort, index date was the day of hospitalization. All patients were required to have at least a year of observation time prior to index date. Patients were followed from the index date to the earliest of death, end of the

study (30 days after index date) or end of data capture.

Asthma definition: Asthma was defined as either: a) an occurrence of an asthma diagnosis code along with prescription or administration of asthma medications using any time before the COVID-19 index date or b) by at least two prescriptions or administration of asthma medications at least six months apart within the year prior to index date in patients younger than 55 years old ([Appendix 3](#)). We excluded patients with a diagnosis of chronic obstructive pulmonary disease (COPD) or prescription of a long-acting muscarinic antagonist (LAMA) prior to the asthma definition. Patients with a COPD diagnosis occurring after asthma diagnosis were included to measure COPD comorbidity. Codes used to define these cohorts are described in [Appendix 2](#).

Baseline characteristics

Conditions and procedures were identified within day −365 to −1 prior to the index date using Systematized Nomenclature of Medicine (SNOMED CT) codes with all descendent codes included. We report pre-specified demographics and conditions related to asthma and COVID-19. Other conditions analyzed as part of the larger CHARYBDIS project are reported in the accompanying website (<https://data.ohdsi.org/Covid19CharacterizationCharybdis/>). Asthma exacerbation was defined by an asthma exacerbation code at index date.

The following medication use (recent use) was identified within day −30 to −1 prior to index date to characterize how patients were managed prior to the COVID-19 index date: systemic corticosteroids, inhaled corticosteroids (ICS), short-acting beta2-agonists (SABA), long-acting beta2-agonists (LABA), leukotriene receptor antagonists (LTRA), methylxanthines, decongestants and other nasal preparations for topical use (comprising preparations for local treatment in case of nasal congestion (e.g. sympathomimetics) or for prophylaxis and treatment of allergic rhinitis (e.g. corticosteroids, cromoglicate preparations)), antibiotics (beta-lactam penicillins, macrolides, fluoroquinolones), acetaminophen, NSAIDs and opioids. Medication use was calculated using drug eras that began on the start date of the first drug exposure medication record and ended on the observed end date of the last concatenated medication record. A grace period of 30 days between medication records allowed for sequential medication records to be considered as continuous drug exposure.

Outcomes

We report the following outcomes within 30 days after hospitalization: death, use of intensive services (identified by a recorded mechanical ventilation and/or a tracheostomy and/or extracorporeal membrane oxygenation procedure), acute respiratory distress syndrome (ARDS), acute renal failure syndrome (ARFS), cardiac arrhythmia, heart failure, myocardial infarction, sepsis, bleeding, venous thromboembolism (VTE), pulmonary embolism (PE) and stroke (ischaemic and haemorrhagic). Other conditions analyzed as part of the larger CHARYBDIS project are reported in the accompanying website.

Analysis

A common analytical code for Charybdis was developed for the Observational Health Data Science and Informatics (OHDSI) Methods library and was run locally in each database. Only aggregate results from each database were then shared for characteristics and cohort that it captured. We report the number and proportion by socio-demographics, comorbidities, and commonly used medications in each population with 95% confidence intervals (CI) calculated using the Wilson score method. Crude comparisons in the characteristics of study cohorts were undertaken by calculating standardized mean differences (SMD). SMD are a commonly used statistic to examine the distribution of covariate balance between groups and are not influenced by differences in sample size. A SMD threshold of 0.1 or greater indicates potential imbalance in the prevalence of a binary covariate between groups (23). In the main text we report the median prevalence and range across all databases per cohort, with detailed individual database results presented in the online supplementary. We used R version 3.6.0 for data visualization. All the data partners obtained Institutional Review Board (IRB) approval or equivalent governance approval to conduct this study.

Results

Prevalence of asthma and asthma exacerbation at presentation

The study included 666 933 patients diagnosed with COVID-19 and 159 552 patients hospitalized with COVID-19. The prevalence of asthma ranged from 6.2% (95% CI 5.7–6.8) to 18.5% (95% CI 18.2–18.8) among diagnosed COVID-19 patients and 5.2% (95% CI 4.0–6.8) to 20.5% (95% CI 18.6–22.6) among hospitalized

COVID-19 patients (Table 1). The prevalence of asthma exacerbation ranged from 1.6% (95% CI 1.2–2.1) to 5.3% (95% CI 4.2–6.6) among asthma patients diagnosed with COVID-19 and 0.8% (95% CI 0.5–1.4) to 8.6% (95% CI 6.1–12.0) among hospitalized COVID-19 patients with asthma (Supplementary Table S1).

Demographics

Children aged 0 to 14 years old accounted for less than 5% of COVID-19 patients with asthma. Asthma patients diagnosed and hospitalized with COVID-19 were more commonly female (range 60.8–69.2%, respectively), apart from VA-OMOP (Supplementary Tables S2 and S3) while those without asthma were more commonly male. Hospitalized asthma patients were typically older than those in the diagnosed asthma cohort (Supplementary Figure S2). Asthma patients with COVID-19 were more commonly under 60 years of age compared to patients without asthma although differences were modest (SMD all <0.1 for the diagnosed cohort) (Figures 1 and 2 and Supplementary Tables S4 and S5).

Prevalence of comorbidities

The prevalence of comorbidities is shown in Table 2 and Supplementary Table S4 and S5. The prevalence of comorbidity in asthma patients with COVID-19 was similar or greater than in patients without asthma (Figures 1 and 2, Supplementary Table S6 and S7). In the diagnosed cohort the largest differences were with obesity (median 48.1% vs 29.8% in those with and without asthma, respectively, median SMD [mSMD] 0.27), sleep apnea (median 9.9% vs 4.1%, mSMD 0.16), anxiety (median 15.1% vs 9.8%, mSMD 0.17), hypertension (median 46.9% vs 33.7%, mSMD 0.17) and heart disease (median 38.1% vs 25.0%, mSMD 0.11) that were greater in people with asthma. The prevalence of these comorbidities was greater in

asthma patients from the US than from Europe and South Korea (Supplementary Table S6).

Compared to patients in the diagnosed cohort, hospitalized asthma patients with COVID-19 had a greater prevalence of hypertension (median 46.9% vs 76%, mSMD 0.28), heart disease (median 38.1% vs 64.9%, mSMD 0.21), obesity (median 48.1% vs 55.9%, mSMD 0.14), T2DM (median 20.6% vs 49.7%, mSMD 0.25), chronic kidney disease (CKD) (median 16% vs 25.5%, mSMD 0.24) and comorbid COPD (median 5.9% vs 14%, mSMD 0.12) (Supplementary Figure S2, Supplementary Table S9).

Medication use

The median systemic corticosteroid use was 14.6% (range 6.1–17.5%) 30 days prior to COVID-19 diagnosis, and 17.9% (range 9.2–19.9%) 30 days prior to hospitalization (Table 3). The median ICS use was 41.4% (range 7.7–55.1%) in the diagnosed cohort and 21.6% (range 6.4–71.3%) in the hospitalized cohort. The prevalence of ICS and LABA use was greater in European asthma patients with COVID-19. For example, among asthma patients diagnosed with COVID-19, ICS use ranged from 7.7% (95% CI 6.8–8.6) in the US to 55.1% (95% CI 54.0–56.2) in Spain. The most commonly prescribed antibiotics 30 days before COVID-19 hospitalization were macrolides in the US and beta-lactam penicillins in South Korea and Europe (Supplementary Table S8). Acetaminophen and NSAIDs were also commonly prescribed to asthma patients, with use of both being more prevalent among hospitalized patients. Median acetaminophen prevalence 19.8% vs 31.3% and median NSAID prevalence 12.4% vs 26.8% in the diagnosed and hospitalized cohorts, respectively.

Mortality

The median 30-day mortality among asthma patients diagnosed with COVID-19 was 6.1% (range 2.1–9.6%)

Table 1. Prevalence of asthma among the COVID-19 patients in the diagnosed and hospitalized cohorts by country and database.

	US	US	US	US	US	KR	UK	NL	ES
Cohort	CUIMC	HealthVerity	IQVIA OpenClaims	STARR-OMOP	VA-OMOP	HIRA [#]	CPRD [†]	IPCI [†]	SIDIAP
Diagnosed COVID-19									
Asthma (n)	1338	3367	86328	501	2953	–	343	156	7536
Prevalence (%), 95% CI	15.7 (13.8–17.7)	8.7 (7.8–9.7)	18.5 (18.2–18.8)	15.1 (12.2–18.5)	12.0 (10.9–13.2)	–	14.7 (11.3–18.8)	11.7 (7.6–17.7)	6.2 (5.7–6.8)
Hospitalized COVID-19									
Asthma (n)	479	349	23211	119	607	1560	–	–	952
Prevalence (%), 95% CI	18.4 (15.2–22.1)	9.7 (7.0–13.3)	17.4 (16.9–17.9)	19.3 (13.2–27.3)	11.0 (8.8–13.7)	20.5 (18.6–22.6)	–	–	5.2 (4.0–6.8)

US = United States. KR = South Korea. ES = Spain. UK = United Kingdom. NL = The Netherlands. (n) = Number.

[†]Hospital data only.

[#]Primary care electronic health records only.

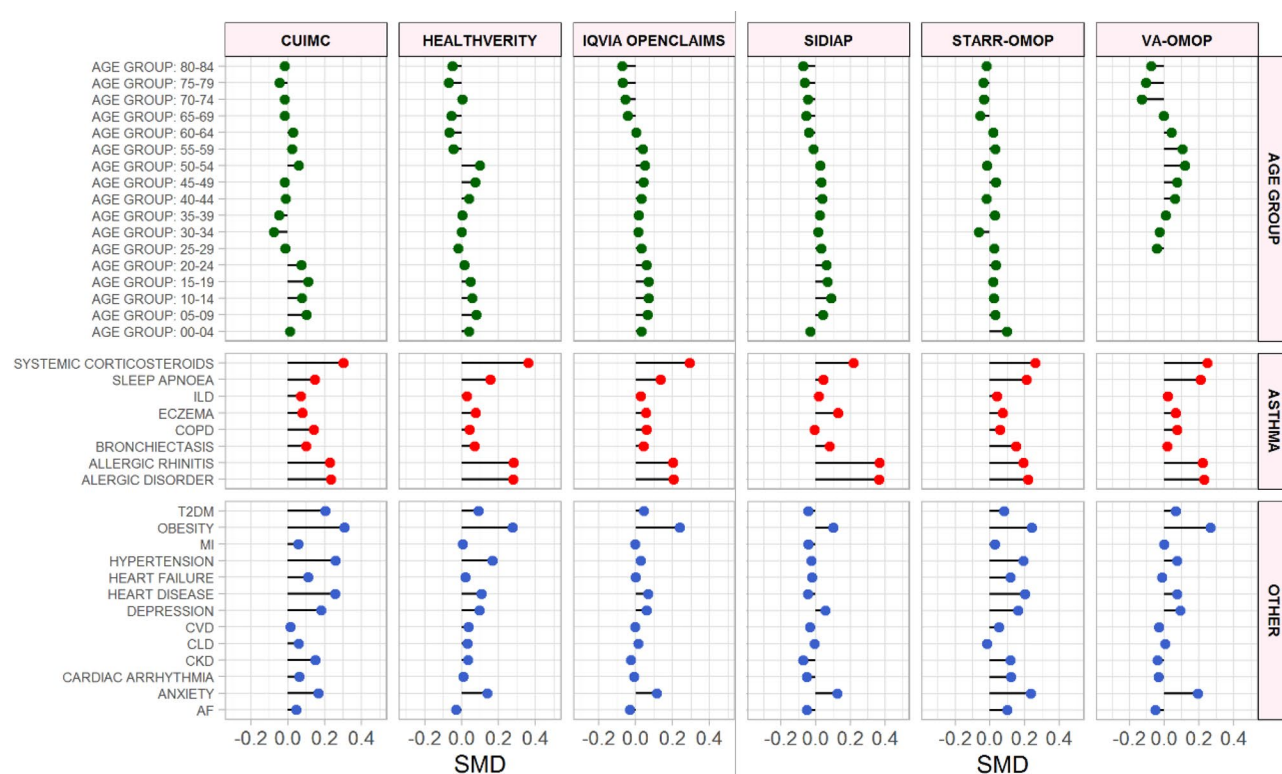


Figure 1. Standardized mean differences of characteristics between diagnosed COVID-19 patients with and without asthma. SMD < 0 = prevalence greater in COVID-19 patients without asthma. SMD > 0 = prevalence greater in COVID-19 patients with asthma. SMD greater or less than 0.1 suggests significant imbalance between groups. Only databases providing sufficient comparative information included. Asthma = Conditions related to asthma. SMD = Standardized mean difference. ILD = Interstitial lung disease. COPD = Chronic obstructive pulmonary disease. CVD = Cerebrovascular disease. CLD = Chronic liver disease. CKD = Chronic kidney disease. AF = Atrial fibrillation. T2DM = Type 2 diabetes mellitus. Asthma = Asthma related comorbidities. Other = Non-asthma related comorbidities. Top row = Name of the database.

and 6.3% (range 4.5–12.5%) in those without asthma (Table 4; Figure 3). In CUIMC (US) and IPCI (Netherlands) asthma patients diagnosed with COVID-19 had similar mortality to those without asthma (Supplementary Tables S10 and S11). However, mortality was lower in CPRD (UK) (7.3%, 95% CI 5.0–10.6 vs 12.5, 95% CI 11.1–14.0), SIDIAP (Spain) (2.1% [95% CI 1.8–2.4] vs 4.5% [95% CI 4.4–4.6]) and VA-OMOP (3.2% [95% CI 2.6–3.9] vs 5.2% [95% CI 4.9–5.5]). Among asthma patients hospitalized with COVID-19, mortality was lower compared to those without asthma in VA-OMOP (US) (12.9% [95% CI 10.5–15.8] vs 17.6% [95% CI 16.6–18.7]), SIDIAP (Spain) (7.7% [95% CI 6.2–9.6] vs 12.5% [95% CI 12.0–13.0]) and CUIMC (US) (16.9% [95% CI 13.8–20.5] vs 20.7% [95% CI 19.0–22.5]) but not in HIRA (South Korea) (3.7% [95% CI 2.9–4.8] vs 2.2% [95% CI 1.9–2.6]).

Other outcomes

The median prevalence of intensive services use in asthma patients hospitalized COVID-19 was similar

to those without asthma (10.1% (range 2.7–17.6) vs 9.8% (range 1.4–17.9) (Table 4). The most common outcomes among asthma patients hospitalized with COVID-19, were ARDS (median 26.1%, range 2.1–39.7), ARFS (median 16.0%, range 0.5–29.7), sepsis (median 17.2%, range <0.5–20.5) and cardiac arrhythmia (median 17.0%, range 3.5–29.7). The prevalence of heart failure, myocardial infarction, sepsis, bleeding, VTE, PE and stroke was similar in COVID-19 patients, regardless of their asthma status. However, outcomes occurred more often in the hospitalized patients (Table 4).

Discussion

In this international descriptive cohort study, the prevalence of asthma among patients diagnosed and hospitalized with COVID-19 patients was similar. Asthma prevalence was lowest in Spain and highest in US COVID-19 patients, which may be related to differences in shielding recommendations between countries during wave one of the pandemic. COVID-19 patients

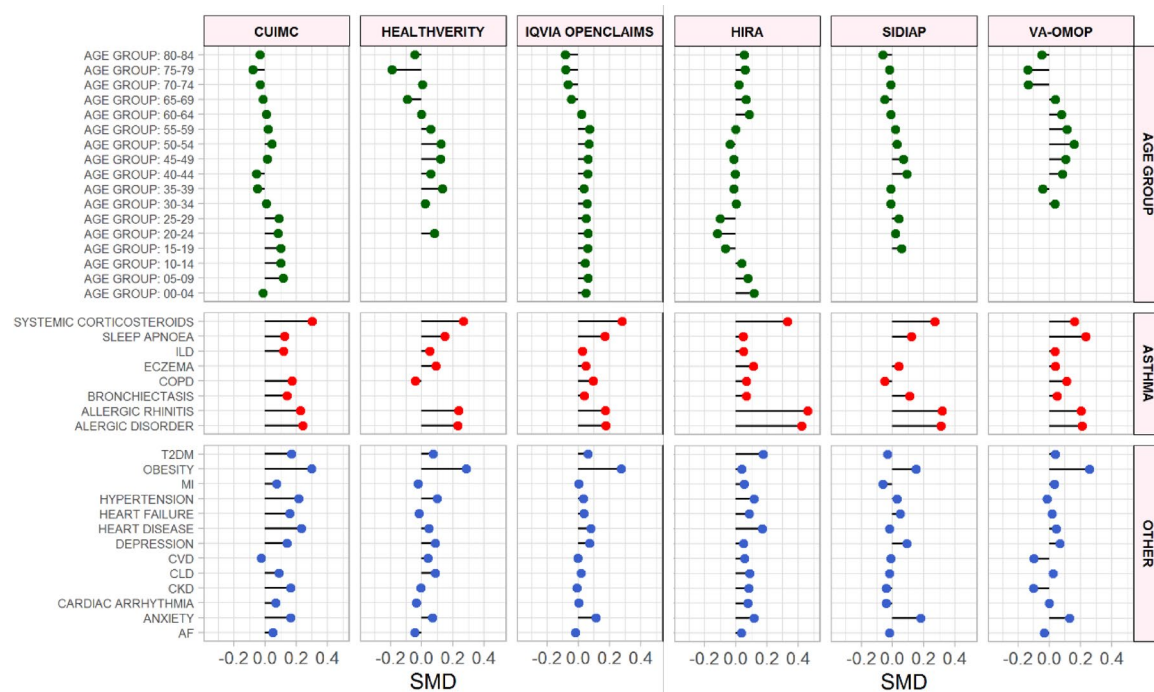


Figure 2. Standardized mean differences of characteristics between hospitalized COVID-19 patients with and without asthma. SMD < 0=prevalence greater in patients without asthma. SMD > 0=prevalence greater in patients with asthma. SMD greater or less than 0.1 suggests significant imbalance between groups. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD=Standardized mean difference. ILD=Interstitial lung disease. COPD=Chronic obstructive pulmonary disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. T2DM=Type 2 diabetes mellitus. Asthma=asthma related comorbidities. Other=Non-asthma related comorbidities. Top row=Name of the database.

Table 2. Comorbidities across databases in diagnosed and hospitalized COVID-19 patients with and without asthma.

Characteristic	Diagnosed asthma cohort			Hospitalized asthma cohort			Diagnosed non-asthma cohort			Hospitalized non-asthma cohort		
	Median (%)	Range (%)		Median (%)	Range (%)		Median (%)	Range (%)		Median (%)	Range (%)	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Respiratory/atopy related												
Allergic disorder	16	<1.5	35.7	20.4	9.2	86.3	4.2	0.6	14.1	9.9	1.6	61.1
Allergic rhinitis	12.4	<1.5	31.1	17.8	7.7	82.2	3.5	0.5	10.7	8.2	1.2	53.3
Bronchiectasis	0.9	0.5	3.8	1.2	<1.4	4.7	0.3	<0.3	0.9	0.7	0.4	1.9
COPD	5.9	2.3	17.6	14.0	2.8	30.3	4.7	2.1	13.7	13.6	1.4	23.4
Eczema	2.1	<1.5	9	3.3	<1	10.1	0.8	0.6	4.5	2.4	0.3	5.8
Exacerbation of asthma	8.5	1.7	14.0	13.2	1.3	23	–	–	–	–	–	–
Interstitial lung disease	1.3	0.0	1.5	2.9	0.5	3.8	0.5	0.0	1	1.6	0.1	3.0
Obesity	48.1	26.6	63	55.9	35.5	68.5	29.8	11.6	38.9	44.5	17.9	50.9
Sleep apnea	9.9	<1.5	35.5	13.5	0.8	39.4	4.9	<0.3	22.1	6.8	0.3	24.2
Urticaria	1.3	<1.5	5.3	4.4	0.9	18.5	0.5	0.3	3.2	0.5	<0.2	2.8
Cardiometabolic												
Atrial fibrillation	5.5	<1.5	8.6	10.4	1.3	14.5	4.3	2.1	9.2	11.2	0.8	16.1
Cardiac arrhythmia	9.0	1.7	14.2	18.7	4.4	24.2	8.7	2.5	14.4	18.5	2.4	24.2
Cerebrovascular disease	3.5	<1.5	4.5	4.9	2.3	7.6	3.1	1.4	4.6	7.1	2.5	8.3
Heart failure	7.8	<1.5	9.1	17.5	5.5	20.9	4.5	1.4	9.6	17	3	19.9
Myocardial infarction	2.3	0.0	3.7	5.4	1.2	8.9	2.4	0.6	3.7	5.3	0.7	7.6
Prevalent heart disease	38.1	12.4	53.7	64.9	19.9	72.8	25	14.6	48.4	48.8	11.2	69.8
Prevalent hypertension	46.9	16	70.4	76	29.6	85.7	33.7	17.2	65.5	62.1	22.4	86.4
Prevalent T2DM	20.6	6.5	41.3	49.7	16.1	58.2	17.7	8.1	36.8	37.8	17.9	55.4
Other												
Anxiety	15.1	5.8	44.1	17.2	11.7	38.7	9.8	2.9	30.8	13.6	5.3	30.1
Depression	13.5	4.4	33.1	20.1	5.0	32.1	10.9	4.3	23.2	11.8	4.4	26.1
Prevalent CKD	16	4.5	19.6	25.5	7.6	33	11.9	6.8	21.4	25.7	4.8	38.9
Chronic liver disease	1.3	0.0	4.5	4.6	1.5	8.7	1.1	0.0	4.3	2.3	1.9	7.8

Diagnosed cohort=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. Hospitalized cohort=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. Prevalent=Conditions defined using all person time otherwise within 365 days of index date. Depression=incident depression/major depressive disorder. CKD=Chronic kidney disease. T2DM=Type 2 diabetes mellitus. COPD=Chronic obstructive pulmonary disease.

Table 3. Treatments across databases in patients with asthma 30 days before COVID-19 diagnosis or hospitalization.

Characteristic	Diagnosed asthma cohort			Hospitalized asthma cohort		
	Median (%)	Range (%)		Median (%)	Range (%)	
		Lower	Upper		Lower	Upper
Asthma management						
Systemic corticosteroids	14.6	6.1	17.5	17.9	9.2	19.9
Inhaled corticosteroid	41.4	7.7	55.1	21.6	6.4	71.3
SABA	22.9	8.9	48.4	24.0	2.1	36.9
LABA	19.3	4.8	30.5	12.6	3.2	39.8
LTRA	6.8	3.2	9.4	8.8	3.4	10.5
Methylxanthines	0.1	0.0	1.7	0.2	0.0	2.5
Antibiotics						
Beta-lactam penicillins	4.6	1.2	16.3	6.5	<1.4	13.5
Fluoroquinolones	1.5	0.0	3.3	4.5	<1.4	6.9
Macrolides	6.1	<3.2	14.1	10.4	5.4	15.3
Covid-19 symptom management						
Acetaminophen	19.8	2.5	31.2	31.3	2.3	46.5
NSAIDs	12.4	3	44	26.8	5.2	49.9
Opioids	7.4	1.7	14.8	13.6	2.9	41.5
Other						
Nasal preparations	38.5	8.0	48.7	26.5	9.5	63.6

Diagnosed cohort=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. Hospitalized cohort=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. LTRA=Leukotriene receptor antagonist. Nasal preparations=decongestants and other nasal preparations for topical use (ATC R01A).

Table 4. Outcomes across databases in diagnosed and hospitalized COVID-19 patients with and without asthma.

Characteristic	Diagnosed asthma cohort			Hospitalized asthma cohort			Diagnosed non-asthma cohort			Hospitalized non-asthma cohort		
	Median (%)	Range (%)		Median (%)	Range (%)		Median (%)	Range (%)		Median (%)	Range (%)	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Death	6.1	2.1	9.6	12.9	3.7	16.9	6.3	4.5	12.5	17.6	2.2	20.7
Intensive services	2.9	0.7	3.7	10.1	2.7	17.6	2.9	0.5	4.0	9.8	1.4	17.9
ARDS	5.2	2.2	11.0	26.1	2.1	39.7	4.8	1.9	12.2	24.5	0.8	44.3
ARFS	2.3	<0.1	7.2	16.0	0.5	29.7	4.1	0.0	9.0	15.2	0.2	35.3
Cardiac arrhythmia	5.5	<1.5	10.0	17.0	3.5	29.7	6.4	1.0	10.3	16.1	1.8	31.9
Heart failure	2.0	0.0	3.9	7.2	3.4	19.8	1.4	0.0	4.0	5.8	2.3	20.4
Myocardial infarction	1.0	0.0	2.3	3.3	1.2	8.4	1.0	<0.3	2.9	3.6	1.9	11
Sepsis	2.1	0.0	6.8	17.2	<0.5	20.5	1.7	0.0	7.9	15.4	0.4	22.8
Bleeding	2.0	0.0	3.1	5.0	2.6	6.8	1.7	0.3	3.5	3.8	2.5	7.8
PE	0.3	0.0	4.1	1.9	<0.3	4.1	0.4	0.1	1.0	1.7	<0.1	3.5
Stroke	0.5	0.0	1.1	2.0	<0.5	2.7	0.1	0.0	0.7	2.2	0.2	3.2

Diagnosed cohort=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. Hospitalized cohort=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. ARDS=Acute respiratory distress syndrome. ARFS=Acute renal failure syndrome. Heart failure=during hospitalization.

with asthma were mainly adults, with hospitalized patients being expectedly older. Asthma exacerbation at presentation with COVID-19 diagnosis or hospitalization was relatively low among asthma patients and varied by type of data source and cohort, generally being lower among diagnosed patients and primary care databases. This may be associated with differences in the severity of symptoms at presentation, increased likelihood of detecting asymptomatic SARS-CoV-2 infection as a result of testing due to the nature of overlapping symptoms or differences in the coding of asthma exacerbations.

In contrast, the prevalence of comorbidity in COVID-19 patients with asthma was generally high, particularly for hypertension, heart disease, T2DM and obesity, and was modestly greater than in

COVID-19 patients without asthma. COVID-19 patients with asthma had a greater prevalence of allergic disorder and allergic rhinitis compared to those without asthma, but prevalence of these conditions was similar among hospitalized asthma patients with COVID-19 and those in the diagnosed cohort. Between one third to a half of asthma patients with COVID-19 had been prescribed systemic corticosteroids in the year prior to diagnosis. In both diagnosed and hospitalized asthma patients with COVID-19, use of nasal preparations, which included nasal corticosteroid and decongestants, was highly prevalent. Mortality in COVID-19 patients with asthma ranged from 2.1 to 16.9% depending upon the cohort and was similar or lower compared to those without asthma despite asthma patients appearing to have

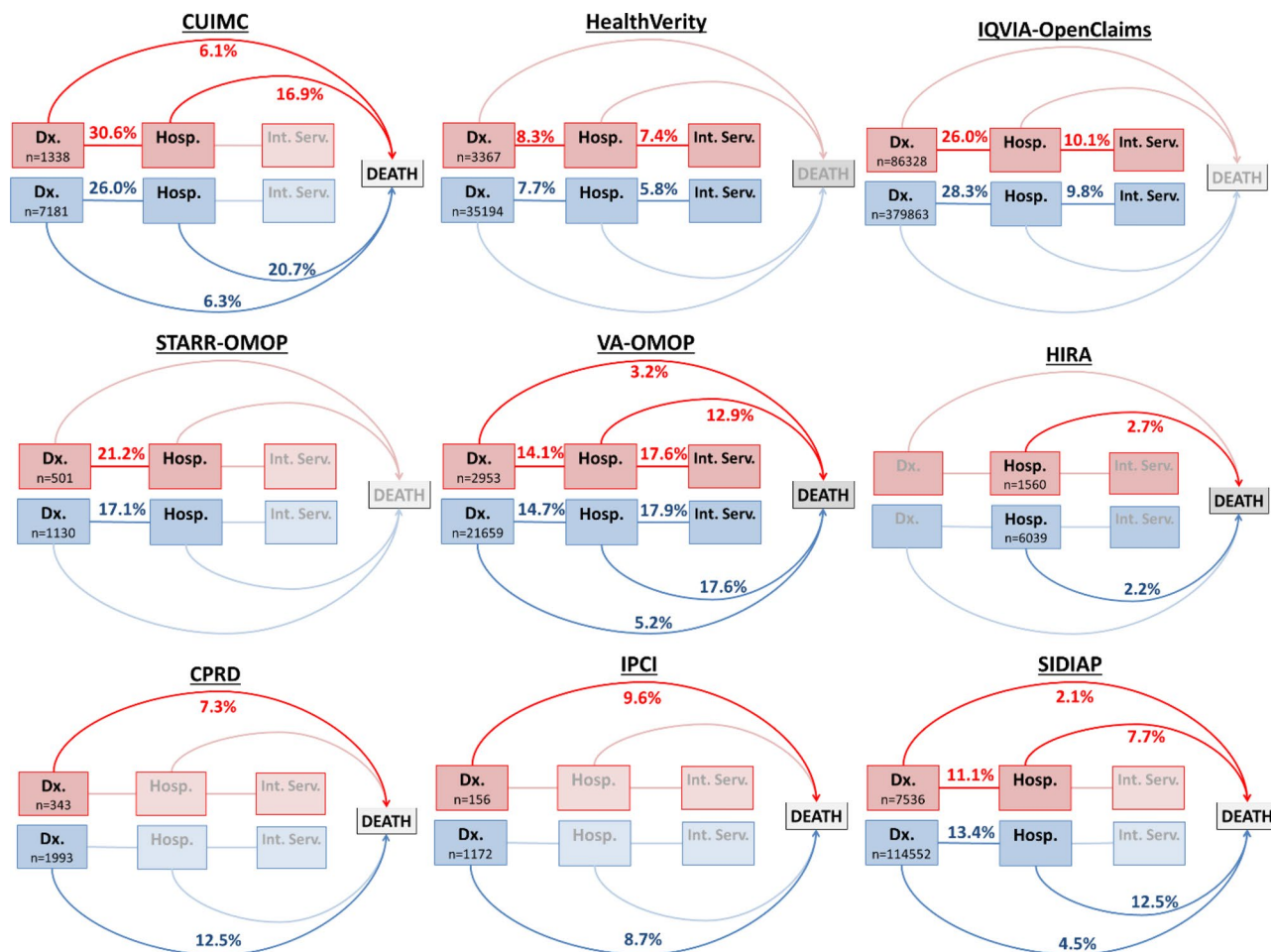


Figure 3. Hospitalization, intensive service use and death among COVID-19 patients with asthma (red) compared to those without asthma (blue) by database. Faded lines and boxes = No data available. Hospitalization = On or within 30 days of COVID-19 diagnosis. Dx = Diagnosis. Hosp = Hospitalization. Int. Serv = Intensive services. Top row = Name of the database.

moderately greater prevalence of comorbidity. These may be related to differences in age as asthma patients were more commonly under 60 years of age compared to patients without asthma. In this regard, comorbidity and age are risk factors for poor COVID-19 outcomes.

Early studies from China reported that <1% of COVID-19 patients had asthma but studies from the US have since reported a prevalence of between 7.4 and 17%, which are in line with our findings (24–28). This difference in prevalence could be due to China having a lower prevalence of asthma, were previous estimates from epidemiological studies have ranged from 12 to 58%, and/or lower testing and diagnosis of obstructive airways disease (28–30).

Hospitalized COVID-19 patients with asthma in our cohort consisted of very few children. This suggests that COVID-19 may have a milder course in children with asthma compared to adults with asthma, similar to that seen in children and adults without asthma elsewhere (31). There was some evidence of a higher proportion of children with asthma may have

been hospitalized with COVID-19 compared to children without asthma but differences were modest. A greater proportion of hospitalized asthma patients with COVID-19 were aged between 40 and 70 years old compared to COVID-19 patients without asthma. Whilst these differences could partly be related to difficulties in detecting older patients with asthma within routine health databases, this may also suggest that having asthma led to hospitalization with COVID-19 at a modestly younger age. This could be due to asthma patients having more severe COVID-19 illness or having a lower threshold for referral due to being considered high risk, particularly during wave one of the pandemic.

Comorbidity is common in patients with asthma with 62.6% of asthma patients reported to have ≥ 1 comorbidity compared to 46.2% in the general population (32–35). Comorbidities such as cardiovascular disease and diabetes may complicate asthma management, with men and obese patients being at greater risk of COVID-19 mortality (11,36). Recognized risk

factors such as obesity was highly prevalent in our population, although COVID-19 patients with asthma were more commonly female. There have been inconsistent reports as to whether COVID-19 patients with asthma are at higher risk of death (11,13–15). Among a large UK general population, patients with asthma had an 11–25% increased risk of COVID-19 death depending on whether patients had recently been prescribed oral corticosteroids (11). However, among 1,298 hospitalized patients in New York aged ≤ 65 years with severe COVID-19, a diagnosis of asthma was not associated with worse outcomes (13).

Respiratory viruses are a known trigger for asthma exacerbations; however, the risk of asthma exacerbations with COVID-19 is uncertain. We observed a low prevalence of asthma exacerbation at presentation with COVID-19, even if prior corticosteroid use is taken into account. Interestingly, among 768 hospitalized COVID-19 patients with asthma from France, none of them presented an asthma exacerbation (14). Also, in a case series involving 106 patients hospitalized with severe COVID-19, asthma appeared not to be a risk factor for severe SARS-CoV-2 pneumonia and did not induce severe asthma exacerbation (15). Furthermore, among 304 hospitalized COVID-19 patients in the Chinese Nanfang Hospital COVID-19 Research Database that contributed to Charybdis but was ineligible for our study, no patients had a reported history of asthma. This suggests that the mechanism of morbidity and mortality associated with COVID-19 may not be strongly related to worsening airway hyperresponsiveness.

It has been hypothesized that patients with type 2 immunity linked to atopy may have reduced susceptibility to COVID-19 as a result of reduced ACE2 expression (7,8). We observed only modest differences in the prevalence of allergic disorder and allergic rhinitis between hospitalized and diagnosed COVID-19 patients that could be explained by age, whilst the prevalence of eczema and urticaria within our cohorts was low limiting comparisons. The exception was among hospitalized COVID-19 patients in South Korea where the recorded prevalence of these conditions among COVID-19 patients was high. Whilst our data do not exclude the possibility of a protective mechanism associated with type 2 immunity, they do not provide strong evidence supporting this.

This study has several limitations. Firstly, the study utilizes routine electronic health data that is dependent upon the extent and quality of recording that could vary between the databases. Some COVID-19 symptoms may overlap with those of asthma and we cannot exclude the potential for detection bias. People with asthma may therefore have presented more frequently

with symptoms and be tested for SARS-CoV-2, which may influence the prevalence of asthma particularly when policy measures consider people with asthma as high risk. This may be one reason for the difference in prevalence between databases and countries where testing approaches differed, particularly during wave one. Differences may also be related to differences in shielding policies during wave one of the pandemic and/or recording within routine databases. Data were unavailable to characterize blood test results and some comorbidities were only identified in the year prior to diagnosis that may cause under-ascertainment in absolute prevalence. Furthermore, we were restricted to crude comparisons and further causal inference modeling studies would be required to adjust for important potential confounders such as age. Different data sources ranged from primary care health records to health insurance claims data that could result in heterogeneity. However, the vast majority of observations were informative and consistent across the databases. A major strength of this study is its size and international comparability, reporting standardized data comparisons on COVID-19 patients with asthma from the US, South Korea and several European countries.

The prevalence of asthma among patients with COVID-19 is variable, which may have related to differences in policy intervention at the beginning of the pandemic. People with asthma and comorbidity are similarly at high risk of COVID-19 hospitalization and should therefore be prioritized for policy interventions including vaccination programmes, particularly as asthma patients are at higher risk of developing comorbidities compared to the general population. Further research is required to identify higher risk asthma patients with COVID-19.

Ethical approval

All the data partners received Institutional Review Board (IRB) approval or exemption. STARR-OMOP had approval from IRB Panel #8 (RB-53248) registered to Leland Stanford Junior University under the Stanford Human Research Protection Program (HRPP). The use of VA data was reviewed by the Department of Veterans Affairs Central Institutional Review Board (IRB), was determined to meet the criteria for exemption under Exemption Category 4(3), and approved for Waiver of HIPAA Authorization. The research was approved by the Columbia University Institutional Review Board as an OHDSI network study. The use of SIDIAP was approved by the Clinical Research Ethics Committee of the IDIAPJGol (project code: 20/070-PCV). The use of CPRD was approved by the Independent Scientific

Advisory Committee (ISAC) (protocol number 20_059RA2). IQVIA OpenClaims is ADE-identified commercially available data product that could be purchased and licensed by any researcher. As these data are deemed commercial assets, there is no Institutional Review Board applicable to the usage and dissemination of these result sets or required registration of the protocol with additional ethics oversight. Compliance with Data Use Agreement terms, which stipulate how these data can be used and for what purpose, is sufficient for the licensing commercial entities. Further inquiry related to the governance oversight of these assets can be made to IQVIA (iqvia.com). At no point in the course of this study were the authors of this study exposed to identified patient-level data.

Competing interest statement

Transparency declaration

Lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing statement

Analyses were performed locally in compliance with all applicable data privacy laws. Although the underlying data is not readily available to be shared, authors contributing to this paper have direct access to the data sources used in this study. All results (e.g. aggregate statistics, not presented at a patient-level with redactions for minimum cell count) are available for public inquiry. These results are inclusive of site-identifiers by contributing data sources to enable interrogation of each contributing site. All analytic code and result sets are made available at: <https://github.com/ohdsi-studies/Covid19CharacterizationCharybdis>

Funding

This study was supported by Wellcome Trust (Grant 214588/Z/18/Z), Bill & Melinda Gates Foundation (Investment ID INV-016201 and INV-019257), Innovative Medicines Initiative 2 Joint Undertaking (No 806968).

ORCID

Daniel R. Morales  <http://orcid.org/0000-0002-0063-8069>
Katia Verhamme  <http://orcid.org/0000-0001-8162-4904>

References

1. Sears MR. Epidemiology of asthma exacerbations. *J Allergy Clin Immunol.* 2008;122(4):662–668. doi:10.1016/j.jaci.2008.08.003.
2. Wark PA, Tooze M, Powell H, Parsons K. Viral and bacterial infection in acute asthma and chronic obstructive pulmonary disease increases the risk of re-admission. *Respirology.* 2013;18(6):996–1002. doi:10.1111/resp.12099.
3. Ko FW-S, Chan PK-S, Chan RWY, Chan K-P, Ip A, Kwok A, Ngai JC-L, Ng S-S, On CT, Hui DS-C, et al. Molecular detection of respiratory pathogens and typing of human rhinovirus of adults hospitalized for exacerbation of asthma and chronic obstructive pulmonary disease. *Respir Res.* 2019;20(1):210. doi:10.1186/s12931-019-1181-0.
4. British Thoracic Society. BTS guidance for health care professionals in relation to shielding. 2020. <https://www.brit-thoracic.org.uk/about-us/covid-19-identifying-patients-for-shielding/> Accessed 22/09/20.
5. Trinh P, Jung TH, Keene D, Demmer RT, Perzanowski M, Lovasi G. Temporal and spatial associations between influenza and asthma hospitalisations in New York City from 2002 to 2012: a longitudinal ecological study. *BMJ Open.* 2018;8(9):e020362. doi:10.1136/bmjopen-2017-020362.
6. Puig-Barberà J, Natividad-Sancho A, Trushakova S, Sominina A, Pisareva M, Ciblak MA, Badur S, Yu H, Cowling BJ, El Guerche-Séblain C, Global Influenza Hospital Surveillance Study Group (GIHSN), et al. Epidemiology of hospital admissions with Influenza during the 2013/2014 Northern Hemisphere Influenza Season: results from the Global Influenza Hospital Surveillance Network. *PLoS One.* 2016;11(5):e0154970 doi:10.1371/journal.pone.0154970
7. Wang H, Song J, Yao Y, Deng Y-K, Wang Z-C, Liao B, Ma J, He C, Pan L, Liu Y, et al. Angiotensin-converting enzyme II expression and its implication in the association between COVID-19 and allergic rhinitis [published online ahead of print, 2020 Aug 27]. *Allergy.* 2021;76(3):906–910. doi:10.1111/all.14569.
8. Shi W, Gao Z, Ding Y, Zhu T, Zhang W, Xu Y. Clinical characteristics of COVID-19 patients combined with allergy. *Allergy.* 2020;75(9):2405–2408. doi:10.1111/all.14434
9. Halpin DMG, Singh D, Hadfield RM. Inhaled corticosteroids and COVID-19: a systematic review and clinical perspective. *Eur Respir J.* 2020;55(5):2001009 (Published 2020 May 7. doi:10.1183/13993003.01009-2020.
10. Burn E, You SC, Sena AG, Kostka K, Abedtash H, Abrahão MTF, Alberga A, Alghoul H, Alser O, Alshammari TM, et al. Deep phenotyping of 34,128 adult patients hospitalised with COVID-19 in an international network study. *Nat Commun.* 2020;11(1):5009. doi:10.1038/s41467-020-18849-z.
11. Williamson EJ, Walker AJ, Bhaskaran K, Bacon S, Bates C, Morton CE, Curtis HJ, Mehrkar A, Evans D, Inglesby P, et al. Factors associated with COVID-19-related death using OpenSAFELY. *Nature.* 2020;584(7821):430–436. doi:10.1038/s41586-020-2521-4

12. Chhibba KD, Patel GB, Vu THT, Chen MM, Guo A, Kudlaty E, Mai Q, Yeh C, Muhammad LN, Harris KE, et al. Prevalence and characterization of asthma in hospitalized and nonhospitalized patients with COVID-19. *J Allergy Clin Immunol.* 2020;146(2):307–314.e4. doi:10.1016/j.jaci.2020.06.010
13. Lovinsky-Desir S, Deshpande DR, De A, et al. Asthma among hospitalized patients with COVID-19 and related outcomes [published online ahead of print, 2020 Aug 6]. *J Allergy Clin Immunol.* 2020;S0091–6749(20):31100–31103. doi:10.1016/j.jaci.2020.07.026.
14. Beurnier A, Jutant E-M, Jevnikar M, Boucly A, Pichon J, Preda M, Frank M, Laurent J, Richard C, Monnet X, et al. Characteristics and outcomes of asthmatic patients with COVID-19 pneumonia who require hospitalisation [published online ahead of print, 2020 Jul 30]. *Eur Respir J.* 2020;56(5):2001875. doi:10.1183/13993003.01875-2020.
15. Grandbastien M, Piotin A, Godet J, Abessolo-Amougou I, Ederlé C, Enache I, Fraisse P, Tu Hoang TC, Kassegne L, Labani A, et al. SARS-CoV-2 pneumonia in hospitalized asthmatic patients did not induce severe exacerbation. *J Allergy Clin Immunol Pract.* 2020;8(8):2600–2607. doi:10.1016/j.jaip.2020.06.032.
16. Voss EA, Makadia R, Matcho A, Ma Q, Knoll C, Schuemie M, DeFalco FJ, Londhe A, Zhu V, Ryan PB, et al. Feasibility and utility of applications of the common data model to multiple, disparate observational health databases. *J Am Med Inform Assoc.* 2015;22(3):553–564. doi:10.1093/jamia/ocu023.
17. Hripcsak G, Duke JD, Shah NH, Reich CG, Huser V, Schuemie MJ, Suchard MA, Park RW, Wong IC, Rijnbeek PR, et al. Observational health data sciences and informatics (OHDSI): opportunities for observational researchers. *Stud Health Technol Inform.* 2015;216:574–578.
18. Sena A, Kostka K, Schuemie M, Posada JD. ohdsi-studies/Covid19CharacterizationCharybdis: Charybdis v1.1.1-Publication Package (Version v1.1.1). Zenodo. 2020. doi:10.5281/zenodo.4033034.
19. Datta S, Posada J, Olson G, et al. A new paradigm for accelerating clinical data science at Stanford Medicine. Published Online March 17. <http://arxiv.org/abs/2003.10534> (Accessed Aug 20, 2020).
20. Del Mar García-Gil M, Hermosilla E, Prieto-Alhambra D, et al. Construction and validation of a scoring system for the selection of high-quality data in a Spanish population primary care database (SIDAP). *Inform Prim Care.* 2012;19:135–145.
21. Engelkes M, de Ridder MA, Svensson E, Berencsi K, Prieto-Alhambra D, Lapi F, Giaquinto C, Picelli G, Boudiaf N, Albers FC, et al. Multinational cohort study of mortality in patients with asthma and severe asthma. *Respir Med.* 2020;Apr–May165:105919. doi:10.1016/j.rmed.2020.105919.
22. Herrett E, Gallagher AM, Bhaskaran K, Forbes H, Mathur R, van Staa T, Smeeth L. Data resource profile: clinical practice research datalink (CPRD). *Int J Epidemiol.* 2015;44(3):827–836. doi:10.1093/ije/dyv098.
23. Austin PC. Using the standardized difference to compare the prevalence of a binary variable between two groups in observational research. *Commun Stat Simul Comput.* 2009;38(6):1228–1234. doi:10.1080/03610910902859574.
24. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, Qiu Y, Wang J, Liu Y, Wei Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet.* 2020;395(10223):507–513. doi:10.1016/S0140-6736(20)30211-7.
25. Li X, Xu S, Yu M, Wang K, Tao Y, Zhou Y, et al. Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan. *J Allergy Clin Immunol.* 2020;146(1):110–118. doi:10.1016/j.jaci.2020.04.006.
26. Bhatraju PK, Ghassemieh BJ, Nichols M, Kim R, Jerome KR, Nalla AK, Greninger AL, Pipavath S, Wurfel MM, Evans L, et al. Covid-19 in critically ill patients in the Seattle region – case series. *N Engl J Med.* 2020;382(21):2012–2022. doi:10.1056/NEJMoa2004500.
27. Garg S. Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019—COVID-NET, 14 states, March 1–30, 2020. *MMWR Morb Mortal Wkly Rep.* 2020;69.
28. Myers LC, Parodi SM, Escobar GJ, Liu VX. Characteristics of hospitalized adults with COVID-19 in an integrated health care system in California. *JAMA.* 2020;323(21):2195–2198. doi:10.1001/jama.2020.7202.
29. Brusselle GG, Ko FW. Prevalence and burden of asthma in China: time to act. *Lancet.* 2019;394(10196):364–366. doi:10.1016/S0140-6736(19)31349-2.
30. The Global Asthma Report. 2018. <http://www.globalasthma-report.org/burden/burden.php>. Accessed 30/09/2020.
31. Centres for Disease Control and Prevention (CDC). COVID-19 hospitalization and death by age. <https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-age.html>. Accessed 16 Sep 2020.
32. Weatherburn CJ, Guthrie B, Mercer SW, Morales DR. Comorbidities in adults with asthma: population-based cross-sectional analysis of 1.4 million adults in Scotland. *Clin Exp Allergy.* 2017;Oct47(10):1246–1252. doi:10.1111/cea.12971.
33. Morales DR, Lipworth BJ, Donnan PT, Jackson C, Guthrie B. Respiratory effect of beta-blockers in people with asthma and cardiovascular disease: population-based nested case control study. *BMC Med.* 2017;Jan 15(1):18. doi:10.1186/s12916-017-0781-0.
34. Morales DR, Dreischulte T, Lipworth BJ, Donnan PT, Jackson C, Guthrie B. Respiratory effect of beta-blocker eye drops in asthma: population-based study and meta-analysis of clinical trials. *Br J Clin Pharmacol.* 2016;Sep82(3):814–822. doi:10.1111/bcp.13006.
35. Morales DR, Lipworth BJ, Guthrie B, Jackson C, Donnan PT, Santiago VH. Safety risks for patients with aspirin-exacerbated respiratory disease after acute exposure to selective nonsteroidal anti-inflammatory drugs and COX-2 inhibitors: meta-analysis of controlled clinical trials. *J Allergy Clin Immunol.* 2014;Jul134(1):40–45. doi:10.1016/j.jaci.2013.10.057.
36. Recalde M, Roel E, Pistillo A, et al. Characteristics and outcomes of 627 044 COVID-19 patients with and without obesity in the United States, Spain, and the United Kingdom. *Int J Obes.* 2021;45(11):2347–2357. doi:10.1101/2020.09.02.2018517.

Characteristics and outcomes of COVID-19 patients with and without asthma from the United States, South Korea, and Europe

SUPPLEMENTARY TABLES

Supplementary table S1. Prevalence of asthma exacerbation at presentation among patients diagnosed and hospitalized with COVID-19.

Cohort	US CUIMC	US HealthVerity	US IQVIA OpenClaims	US STARR-OMOP	US VA-OMOP	KR HIRA	UK CPRD	ES SIDIAP
Diagnosed COVID-19 (%) (95%CI)	5.3 (4.2-6.6)	2.7 (2.2-3.3)	3.9 (3.8-4.0)	5.2 (3.6-7.5)	1.6 (1.2-2.1)	-	1.7 (0.8-3.7)	1.6 (1.3-1.9)
Hospitalized COVID-19 (%) (95%CI)	4.6 (3.1-6.9)	8.6 (6.1-12.0)	6.1 (5.8-6.4)	-	3.3 (2.1-5.0)	0.8 (0.5-1.4)	-	2.1 (1.4-3.2)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. Grey=US databases. Red=South Korean database. Orange=European databases. Grey=US databases. Red=South Korean database. Orange=European databases. 95%CI = 95% Confidence Interval. IPCI data excluded as not recorded.

Supplementary table S2. Age and gender distribution of asthma patients diagnosed and hospitalized with COVID-19.

Characteristic	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC		HealthVerity		IQVIA OpenClaims		VA-OMOP		STARR-OMOP	HIRA	CPRD	IPCI	SIDIAP	
	N=1338	N=479	N=3367	N=349	N=86328	N=23211	N=2953	N=607	N=501	N=1560	N=343	N=156	N=7536	N=952
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
age group: 00-04	1.3%	1.5%	0.4%	0.0%	1.1%	1.1%	0.0%	0.0%	2.2%	1.9%	0.8%	0.0%	0.0%	0.0%
age group: 05-09	1.8%	2.3%	1.1%	<1.4%	1.5%	1.0%	0.0%	0.0%	1.0%	1.3%	1.7%	0.0%	0.0%	0.0%
age group: 10-14	1.3%	2.1%	1.1%	0.0%	1.6%	0.6%	0.0%	0.0%	1.0%	1.6%	2.4%	0.0%	<1.5%	<0.5%
age group: 15-19	2.2%	2.5%	1.8%	0.0%	2.4%	1.0%	0.0%	0.0%	2.6%	2.2%	2.5%	<1.2%	0.0%	0.80%
age group: 20-24	2.8%	2.7%	4.0%	1.7%	4.3%	1.8%	<0.2%	0.0%	4.2%	8.7%	5.3%	<1.2%	<1.5%	0.80%
age group: 25-29	5.1%	4.2%	5.0%	<1.4%	5.2%	2.4%	1.5%	<0.8%	5.0%	8.3%	6.5%	1.4%	3.8%	1.80%
age group: 30-34	6.3%	3.3%	6.7%	2.0%	5.8%	3.2%	4.5%	1.6%	4.0%	5.1%	6.8%	1.4%	6.7%	1.80%
age group: 35-39	7.0%	2.5%	7.4%	4.9%	6.3%	3.6%	6.4%	1.2%	7.6%	4.9%	9.4%	2.2%	4.7%	2.50%
age group: 40-44	7.3%	2.1%	9.1%	4.6%	7.2%	4.8%	7.5%	3.8%	6.0%	5.3%	12.4%	6.2%	5.8%	7.90%
age group: 45-49	6.7%	4.6%	11.6%	8.3%	8.4%	6.4%	8.3%	5.3%	7.8%	7.4%	11.9%	8.2%	7.9%	8.70%
age group: 50-54	10.3%	7.1%	15.1%	10.9%	10.1%	8.9%	13.1%	10.2%	8.6%	9.0%	10.5%	8.2%	12.5%	9.00%
age group: 55-59	9.6%	8.4%	10.1%	12.9%	11.0%	11.9%	14.1%	11.2%	12.2%	9.6%	8.1%	8.7%	10.5%	10.30%
age group: 60-64	10.1%	9.4%	8.6%	11.7%	9.7%	12.3%	14.1%	15.5%	11.0%	11.5%	5.6%	8.7%	10.8%	9.10%
age group: 65-69	7.4%	11.1%	6.3%	10.0%	6.9%	9.9%	10.5%	15.3%	8.0%	7.1%	2.9%	4.8%	6.4%	7.20%
age group: 70-74	6.5%	9.6%	6.0%	14.9%	5.6%	9.2%	9.9%	15.0%	8.2%	4.6%	2.9%	12.0%	5.2%	9.80%
age group: 75-79	4.3%	7.5%	2.4%	4.3%	4.2%	7.5%	4.8%	7.6%	5.6%	5.1%	2.5%	12.0%	6.4%	10.20%
age group: 80-84	4.3%	8.1%	2.2%	8.6%	3.4%	6.0%	2.1%	4.9%	3.2%	3.3%	2.2%	10.6%	7.6%	7.40%
age group: 85-89	2.8%	5.8%	0.0%	0.0%	5.3%	8.3%	1.9%	4.6%	1.8%	2.2%	3.0%	6.2%	6.7%	7.70%
age group: 90-94	2.2%	4.4%	1.2%	3.4%	0.0%	0.0%	0.8%	2.3%	<1.0%	1.0%	1.8%	6.2%	2.0%	4.00%
age group: 95-99	0.4%	<1.0%	0.0%	0.0%	0.0%	0.0%	0.4%	<0.8%	0.0%	<0.3%	0.6%	1.2%	<1.5%	0.80%
gender = female	68.0%	62.4%	66.1%	63.9%	64.2%	60.8%	22.7%	11.9%	65.3%	64.9%	66.1%	69.2%	60.3%	64.20%
gender = male	32.0%	37.6%	33.9%	36.1%	35.8%	39.2%	77.3%	88.1%	34.7%	35.1%	33.9%	30.8%	39.7%	35.80%

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. VA-OMOP population predominantly male.

Supplementary table S3. Age and gender distribution of patients without asthma diagnosed and hospitalized with COVID-19.

Characteristic	US CUIMC		US HealthVerity		US IQVIA OpenClaims		US VA-OMOP		US STARR-OMOP	KR HIRA	UK CPRD	NL IPCI	ES SIDIAP	
	(n = 7,181)	(n = 2,121)	(n = 35,194)	(n = 3,264)	(n = 379,863)	(n = 109,880)	(n = 21,659)	(n = 4,903)	(n = 2,827)	(n = 6,039)	(n = 1,993)	(n = 1,172)	(n = 114,522)	(n = 17,245)
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
age group: 00-04	1.1%	1.7%	0.1%	<0.2%	0.7%	0.5%	0.0%	0.0%	0.6%	0.2%	0.4%	<0.4%	1.2%	0.1%
age group: 05-09	0.3%	0.4%	0.2%	0.0%	0.6%	0.3%	0.0%	0.0%	0.6%	0.3%	0.5%	<0.4%	1.0%	0.0%
age group: 10-14	0.3%	0.5%	0.4%	0.0%	0.6%	0.2%	0.4%	0.0%	0.7%	1.0%	<0.3%	0.5%	0.8%	0.1%
age group: 15-19	0.4%	0.7%	1.0%	<0.2%	1.1%	0.3%	2.3%	0.0%	2.2%	3.8%	0.5%	0.8%	1.2%	0.2%
age group: 20-24	1.3%	1.1%	3.6%	0.5%	2.8%	0.8%	5.3%	0.1%	3.3%	13.9%	1.4%	3.3%	3.5%	0.6%
age group: 25-29	5.5%	2.0%	5.6%	0.9%	4.3%	1.4%	6.1%	0.4%	4.2%	12.5%	2.4%	4.4%	5.4%	1.1%
age group: 30-34	9.1%	3.1%	6.7%	1.6%	5.4%	1.9%	5.3%	1.0%	6.0%	5.0%	3.4%	4.7%	6.3%	1.9%
age group: 35-39	8.8%	3.7%	7.3%	1.6%	5.8%	2.7%	5.6%	1.9%	6.6%	5.3%	4.7%	4.9%	8.4%	2.8%
age group: 40-44	7.7%	3.3%	7.6%	3.0%	6.1%	3.1%	7.9%	1.8%	6.7%	5.4%	5.3%	7.2%	10.6%	4.8%
age group: 45-49	7.3%	4.2%	8.5%	4.2%	6.9%	4.4%	9.3%	2.4%	6.5%	7.9%	6.7%	10.2%	10.5%	6.0%
age group: 50-54	7.9%	5.6%	10.5%	6.0%	8.1%	6.3%	12.1%	4.4%	9.2%	10.5%	8.6%	9.4%	9.4%	7.8%
age group: 55-59	8.6%	7.6%	12.1%	10.3%	9.3%	8.8%	10.6%	6.6%	10.8%	9.6%	9.9%	10.2%	8.6%	9.4%
age group: 60-64	8.9%	9.1%	11.4%	11.8%	9.6%	11.3%	16.0%	11.7%	10.2%	7.9%	8.0%	9.5%	6.9%	9.5%
age group: 65-69	8.0%	11.6%	8.4%	14.2%	8.5%	11.8%	8.4%	13.3%	10.3%	4.9%	5.2%	6.4%	4.3%	9.0%
age group: 70-74	7.1%	10.9%	5.9%	14.6%	7.6%	12.0%	3.9%	22.3%	9.6%	4.0%	7.4%	5.7%	4.1%	10.4%
age group: 75-79	5.7%	10.7%	4.2%	11.5%	6.5%	10.7%	3.6%	13.5%	6.9%	3.4%	7.9%	7.6%	4.1%	11.2%
age group: 80-84	4.8%	9.4%	3.4%	10.4%	5.6%	9.1%	2.2%	6.5%	3.7%	2.1%	9.5%	5.2%	4.0%	9.8%
age group: 85-89	3.6%	7.2%	0.0%	9.3%	10.5%	14.3%	0.9%	6.8%	1.8%	1.7%	8.2%	6.1%	4.8%	9.1%
age group: 90-94	2.5%	5.3%	3.0%	0.0%	0.0%	0.0%	0.1%	4.8%	<0.4%	0.6%	6.9%	2.6%	3.5%	4.7%
age group: 95-99	0.7%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	0.1%	2.7%	0.7%	1.3%	1.3%
gender = female	43.6%	44.6%	45.3%	47.2%	47.4%	45.1%	15.4%	4.8%	50.7%	57.7%	43.8%	59.5%	57.3%	44.1%
gender = male	56.4%	55.3%	54.7%	52.8%	52.6%	54.9%	84.6%	95.2%	49.3%	42.3%	56.2%	40.5%	42.7%	55.9%

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. VA-OMOP population predominantly male.

Supplementary table S4. Comorbidities in COVID-19 patients with asthma in the diagnosed and hospitalized cohorts.

Characteristic (% 95%CI)	US CUIMC (% 95%CI)		US HealthVerity (% 95%CI)		US IQVIA OpenClaims (% 95%CI)		US VA-OMOP (% 95%CI)		US STARR- OMOP (% 95%CI)	KR HIRA (% 95%CI)	UK CPRD (% 95%CI)	NL IPCI (% 95%CI)	ES SIDIAP (% 95%CI)	
	N=1338	N=479	N=3367	N=349	N=86328	N=23211	N=2953	N=607	N=501	N=1560	N=343	N=156	N=7536	N=952
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
<i>Asthma/atopy related</i>														
Allergic disorder	10.2 (8.7-11.9)	9.2 (6.9-12.1)	15.8 (14.6-17.1)	13.2 (10-17.2)	14.1 (13.9-14.3)	11.3 (10.9-11.7)	22.8 (21.3-24.3)	20.4 (17.4-23.8)	12 (9.4-15.1)	86.3 (84.5-87.9)	<1.5	16 (11.1-22.6)	35.7 (34.6-36.8)	32.5 (29.6-35.5)
Allergic rhinitis	9.0 (7.6-10.7)	7.7 (5.6-10.4)	14.6 (13.4-15.8)	12 (9-15.8)	12.4 (12.2-12.6)	9.7 (9.3-10.1)	20.4 (19-21.9)	17.8 (15-21)	10.4 (8-13.4)	82.2 (80.2-84)	<1.5	8.3 (4.9-13.7)	31.1 (30.1-32.2)	27.7 (25-30.6)
Bronchiectasis	2.0 (1.4-2.9)	3.3 (2.0-5.3)	0.9 (0.6-1.3)	<1.4	0.7 (0.6-0.8)	1.2 (1.1-1.3)	0.5 (0.3-0.8)	1.2 (0.6-2.4)	3.8 (2.4-5.9)	1.2 (0.8-1.9)	<1.5	<3.2	2.3 (2-2.7)	4.7 (3.5-6.2)
COPD	6.7 (5.5-8.2)	11.5 (8.9-14.7)	5.9 (5.2-6.7)	14.0 (10.8-18)	9.9 (9.7-10.1)	18.6 (18.1-19.1)	17.6 (16.3-19)	30.3 (26.8-34.1)	4.2 (2.8-6.3)	2.8 (2.1-3.7)	2.3 (1.2-4.5)	4.5 (2.2-9)	3.4 (3-3.8)	6.6 (5.2-8.4)
Eczema	2.0 (1.4-2.9)	<1	2.1 (1.7-2.6)	2.3 (1.2-4.5)	2.1 (2-2.2)	1.8 (1.6-2)	3.8 (3.2-4.6)	3.3 (2.1-5)	2 (1.1-3.6)	10.1 (8.7-11.7)	<1.5	3.2 (1.4-7.3)	9 (8.4-9.7)	4.8 (3.6-6.3)
Exacerbation of asthma	8.5 (7.1-10.1)	9.2 (6.9-12.1)	14.0 (12.9-15.2)	17.8 (14.1-22.2)	10.6 (10.4-10.8)	13.2 (12.8-13.6)	6.5 (5.7-7.4)	7.7 (5.8-10.1)	12.4 (9.8-15.6)	1.3 (0.8-2)	4.7 (2.9-7.5)	0.0	1.7 (1.4-2)	23 (20.4-25.8)
Interstitial lung disease	1.5 (1.0-2.3)	3.8 (2.4-5.9)	0.7 (0.5-1)	2.9 (1.6-5.2)	1.3 (1.2-1.4)	3.7 (3.5-4)	1.3 (1-1.8)	2.3 (1.4-3.8)	1.4 (0.7-2.9)	0.5 (0.3-1)	0.0	0.0	0.2 (0.1-0.3)	<0.5
Obesity	56.1 (53.4-58.7)	63.3 (58.9-67.5)	26.6 (25.1-28.1)	35.5 (30.7-40.7)	46 (45.7-46.3)	53.4 (52.8-54)	63 (61.2-64.7)	68.5 (64.7-72.1)	48.1 (43.8-52.5)	N/A	58.6 (53.3-63.7)	30.1 (23.5-37.7)	36.1 (35-37.2)	55.9 (52.7-59)
Sleep apnoea	7.4 (6.1-8.9)	7.3 (5.3-10.0)	10.8 (9.8-11.9)	13.5 (10.3-17.5)	9.9 (9.7-10.1)	14.2 (13.8-14.7)	35.5 (33.8-37.2)	39.4 (35.6-43.3)	20.4 (17.1-24.1)	0.8 (0.5-1.4)	<1.5	<3.2	3.7 (3.3-4.2)	9.6 (7.9-11.6)
Urticaria	1.3 (0.8-2.1)	<1	1.3 (1-1.7)	<1.4	1.2 (1.1-1.3)	0.9 (0.8-1)	1 (0.7-1.4)	1.2 (0.6-2.4)	2 (1.1-3.6)	18.5 (16.7-20.5)	<1.5	<3.2	5.3 (4.8-5.8)	4.4 (3.3-5.9)
<i>Cardiometabolic</i>														
Atrial fibrillation	5.5 (4.4-6.9)	9 (6.8-11.9)	3.2 (2.7-3.8)	11.7 (8.7-15.5)	5.5 (5.3-5.7)	10.4 (10-10.8)	7.3 (6.4-8.3)	14.5 (11.9-17.5)	8.6 (6.4-11.4)	1.3 (0.8-2)	<1.5	3.2 (1.4-7.3)	2.9 (2.5-3.3)	8.0 (6.4-9.9)
Cardiac arrhythmia	9.0 (7.6-10.7)	14.2 (11.4-17.6)	6.4 (5.6-7.3)	17.2 (13.6-21.5)	10.3 (10.1-10.5)	18.7 (10-10.8)	12.9 (11.7-14.2)	24.2 (21-27.8)	14.2 (11.4-17.5)	4.4 (3.5-5.5)	1.7 (0.8-3.7)	4.5 (2.2-9)	7.6 (7-8.2)	16.1 (13.9-18.6)
Cerebrovascular disease	3.5 (2.6-4.6)	4.2 (2.7-6.4)	3.4 (2.8-4.1)	8.6 (6.1-12)	4.5 (4.4-4.6)	7.6 (7.3-7.9)	3.8 (3.2-4.6)	4.9 (3.4-6.9)	3.8 (2.4-5.9)	4.4 (3.5-5.5)	<1.5	3.2 (1.4-7.3)	0.9 (0.7-1.1)	2.3 (1.5-3.5)
Heart failure	8.3 (6.9-9.9)	16.5 (13.4-20.1)	5.4 (4.7-6.2)	17.5 (13.9-21.8)	9 (8.8-9.2)	19 (18.5-19.5)	9.1 (8.1-10.2)	20.9 (17.9-24.3)	7.8 (5.8-10.5)	5.5 (4.5-6.7)	<1.5	3.2 (1.4-7.3)	2.4 (2.1-2.8)	8.2 (6.6-10.1)
Myocardial infarction	3.3 (2.5-4.4)	7.1 (5.1-9.8)	1.5 (1.1-2)	4.6 (2.9-7.3)	2.3 (2.2-2.4)	5.4 (5.1-5.7)	3.7 (3.1-4.4)	8.9 (6.9-11.4)	2.8 (1.7-4.6)	1.5 (1-2.2)	0.0	<3.2	0.4 (0.3-0.6)	1.2 (0.7-2.1)
Prevalent heart disease	50.1 (47.4-52.8)	64.9 (60.5-69.0)	22.2 (20.8-23.6)	46.1 (40.9-51.3)	49.8 (49.5-50.1)	68.2 (67.6-68.8)	53.7 (51.9-55.5)	72.8 (69.1-76.2)	38.1 (34-42.4)	19.9 (18-22)	21.6 (17.6-26.3)	20.5 (14.9-27.5)	12.4 (11.7-13.2)	26.8 (24.1-29.7)
Prevalent hypertension	57.9 (55.2-60.5)	76 (72.0-79.6)	37.2 (35.6-38.8)	64.8 (59.7-69.6)	60.6 (60.3-60.9)	79.7 (79.2-80.2)	70.4 (68.7-72)	85.7 (82.7-88.3)	46.9 (42.6-51.3)	29.6 (27.4-31.9)	27.4 (22.9-32.4)	28.2 (21.7-35.7)	16 (15.2-16.8)	31.5 (28.6-34.5)
Prevalent T2DM	32.6 (30.1-35.2)	49.7 (45.2-54.2)	20.6 (19.3-22)	41.3 (36.3-46.5)	38.5 (38.2-38.8)	55.8 (55.2-56.4)	41.3 (39.5-43.1)	58.2 (54.2-62.1)	18.8 (15.6-22.5)	29.9 (27.7-32.2)	18.7 (14.9-23.2)	19.9 (14.4-26.9)	6.5 (6-7.1)	16.1 (13.9-18.6)

Other														
Anxiety	12.7 (11.0-14.6)	11.7 (9.1-14.9)	13.6 (12.5-14.8)	17.2 (13.6-21.5)	15.1 (14.9-15.3)	15.3 (14.8-15.8)	44.1 (42.3-45.9)	38.7 (34.9-42.6)	22.4 (19-26.3)	13.6 (12-15.4)	5.8 (3.8-8.8)	10.3 (6.4-16.1)	35.7 (34.6-36.8)	35.2 (32.2-38.3)
Depression	19.8 (17.8-22.0)	23.4 (19.8-27.4)	11.4 (10.4-12.5)	20.1 (16.2-24.6)	13.0 (12.8-13.2)	15.3 (14.8-15.8)	33.1 (31.4-34.8)	32.1 (28.5-35.9)	19.2 (16-22.9)	5.0 (4-6.2)	4.4 (2.7-7.1)	7.1 (4-12.2)	13.5 (12.7-14.3)	17.6 (15.3-20.1)
Prevalent CKD	19.6 (17.6-21.8)	33 (28.9-37.3)	8.4 (7.5-9.4)	25.5 (21.2-30.3)	17.2 (16.9-17.5)	31.9 (31.3-32.5)	19.3 (17.9-20.8)	32 (28.4-35.8)	16 (13.1-19.5)	7.6 (6.4-9)	12.8 (9.7-16.8)	10.3 (6.4-16.1)	4.5 (4.1-5)	16.3 (14.1-18.8)
Chronic Liver Disease	2.2 (1.5-3.1)	4.6 (3.1-6.9)	1.1 (0.8-1.5)	4 (2.4-6.6)	1.3 (1.2-1.4)	2.4 (2.2-2.6)	4.5 (3.8-5.3)	8.7 (6.7-11.2)	2.6 (1.5-4.4)	6.5 (5.4-7.8)	<1.5	0.0	1 (0.8-1.3)	1.5 (0.9-2.5)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort.

Prevalent = conditions defined using all person time otherwise within 365 days of index date. Depression = incident depression/major depressive disorder. N/A=Data not captured. CKD=Chronic kidney disease. T2DM=Type 2 diabetes mellitus. COPD=chronic obstructive pulmonary disease.

Supplementary table S5. Comorbidities in patients without asthma diagnosed and hospitalized with COVID-19.

Characteristic	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC % (95%CI)		HealthVerity % (95%CI)		IQVIA OpenClaims % (95%CI)		VA-OMOP % (95%CI)		STARR-OMOP % (95%CI)	HIRA % (95%CI)	CPRD % (95%CI)	IPCI % (95%CI)	SIDIAP % (95%CI)	
	(n = 7,181)	(n = 2,121)	(n = 35,194)	(n = 3,264)	(n = 379,863)	(n = 109,880)	(n = 21,659)	(n = 4,903)	(n = 2,827)	(n = 6,039)	(n = 1,993)	(n = 1,172)	(n = 114,522)	(n = 17,245)
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
<i>Respiratory/atopy related</i>														
Allergic disorder	2.3 (2-2.7)	1.6 (1.1-2.2)	4.2 (4-4.4)	4.1 (3.5-4.8)	5.6 (5.5-5.7)	4.6 (4.5-4.7)	10.8 (10.4-11.2)	9.9 (9.1-10.8)	3.7 (3.1-4.5)	61.1 (59.9-62.3)	0.6 (0.3-1)	7.6 (6.2-9.3)	14.1 (13.9-14.3)	14.3 (13.8-14.8)
Allergic rhinitis	1.8 (1.5-2.1)	1.2 (0.8-1.8)	3.4 (3.2-3.6)	3.2 (2.6-3.9)	4.5 (4.4-4.6)	3.6 (3.5-3.7)	9.3 (8.9-9.7)	8.2 (7.5-9)	3.5 (2.9-4.2)	53.3 (52-54.6)	0.5 (0.3-0.9)	2.2 (1.5-3.2)	10.7 (10.5-10.9)	10.5 (10.1-11)
Bronchiectasis	0.4 (0.3-0.6)	0.6 (0.3-1)	0.2 (0.2-0.3)	0.4 (0.2-0.7)	0.3 (0.3-0.3)	0.7 (0.7-0.8)	0.3 (0.2-0.4)	0.6 (0.4-0.9)	0.7 (0.5-1.1)	0.4 (0.3-0.6)	<0.3	<0.4	0.9 (0.8-1)	1.9 (1.7-2.1)
COPD	2.5 (2.2-2.9)	4.8 (4-5.8)	4.6 (4.4-4.8)	16.1 (14.9-17.4)	7.6 (7.5-7.7)	13.6 (13.4-13.8)	13.7 (13.2-14.2)	23.4 (22.2-24.6)	2.7 (2.2-3.4)	1.4 (1.1-1.7)	2.1 (1.6-2.8)	4.7 (3.6-6.1)	3.6 (3.5-3.7)	8.3 (7.9-8.7)
Eczema	0.7 (0.5-0.9)	0.3 (0.1-0.6)	0.8 (0.7-0.9)	0.7 (0.5-1)	1.1 (1.1-1.1)	1.0 (0.9-1.1)	2.2 (2-2.4)	2.4 (2-2.9)	0.8 (0.5-1.2)	5.8 (5.2-6.4)	0.6 (0.3-1)	2.2 (1.5-3.2)	4.5 (4.4-4.6)	3.7 (3.4-4)
Interstitial lung disease	0.5 (0.4-0.7)	1.2 (0.8-1.8)	0.4 (0.3-0.5)	1.8 (1.4-2.3)	0.9 (0.9-0.9)	3.0 (2.9-3.1)	1 (0.9-1.1)	1.6 (1.3-2)	0.8 (0.5-1.2)	0.1 (0-0.2)	<0.3	0.0	0.1 (0.1-0.1)	0.5 (0.4-0.6)
Obesity	34.9 (33.8-36)	42.6 (40.5-44.7)	11.6 (11.3-11.9)	17.9 (16.6-19.3)	29.8 (29.7-29.9)	34.4 (34.1-34.7)	44.5 (43.8-45.2)	50.9 (49.5-52.3)	31.7 (30-33.4)	N/A	38.9 (36.8-41.1)	19.7 (17.5-22.1)	29.4 (29.1-29.7)	45.6 (44.9-46.3)
Sleep apnoea	2.8 (2.4-3.2)	3.3 (2.6-4.1)	4.9 (4.7-5.1)	7.2 (6.4-8.1)	4.9 (4.8-5)	6.8 (6.7-7)	22.1 (21.6-22.7)	24.2 (23-25.4)	9.8 (8.8-11)	0.3 (0.2-0.5)	<0.3	1.3 (0.8-2.1)	2.6 (2.5-2.7)	5.3 (5-5.6)
Urticaria	0.3 (0.2-0.5)	<0.2	0.4 (0.3-0.5)	0.5 (0.3-0.8)	0.5 (0.5-0.5)	0.4 (0.4-0.4)	0.6 (0.5-0.7)	0.3 (0.2-0.5)	0.5 (0.3-0.8)	1.4 (1.1-1.7)	0.4 (0.2-0.8)	0.9 (0.5-1.6)	3.2 (3.1-3.3)	2.8 (2.6-3.1)
<i>Cardiometabolic</i>														
Atrial fibrillation	4.1 (3.7-4.6)	7 (6-8.2)	4 (3.8-4.2)	13.7 (12.6-14.9)	6.6 (6.5-6.7)	11.2 (11-11.4)	9.2 (8.8-9.6)	16.1 (15.1-17.2)	5 (4.3-5.9)	0.8 (0.6-1.1)	2.1 (1.6-2.8)	4.3 (3.3-5.6)	4.2 (4.1-4.3)	8.7 (8.3-9.1)
Cardiac arrhythmia	6.6 (6-7.2)	11.0 (9.7-12.4)	6.1 (5.9-6.4)	19.1 (17.8-20.5)	10.7 (10.6-10.8)	18.5 (18.3-18.7)	14.4 (13.9-14.9)	24.2 (23-25.4)	8.7 (7.7-9.8)	2.4 (2-2.8)	2.5 (1.9-3.3)	5.2 (4.1-6.6)	9.6 (9.4-9.8)	18.5 (17.9-19.1)
Cerebrovascular disease	3.1 (2.7-3.5)	4.9 (4.1-5.9)	2.5 (2.3-2.7)	7.1 (6.3-8)	4.6 (4.5-4.7)	7.7 (7.5-7.9)	4.6 (4.3-4.9)	8.3 (7.6-9.1)	2.5 (2-3.1)	2.9 (2.5-3.4)	1.5 (1.1-2.1)	3.6 (2.7-4.8)	1.4 (1.3-1.5)	2.5 (2.3-2.7)
Heart failure	4.5 (4-5)	9.1 (7.9-10.4)	4.8 (4.6-5)	18.4 (17.1-19.8)	9 (8.9-9.1)	17 (16.8-17.2)	9.6 (9.2-10)	19.9 (18.8-21)	3.9 (3.2-4.7)	3 (2.6-3.5)	1.4 (1-2)	2.6 (1.8-3.7)	2.9 (2.8-3)	6.3 (5.9-6.7)
Myocardial infarction	2 (1.7-2.4)	4.6 (3.8-5.6)	1.4 (1.3-1.5)	5.3 (4.6-6.1)	2.4 (2.4-2.4)	5.3 (5.2-5.4)	3.7 (3.5-4)	7.6 (6.9-8.4)	2.2 (1.7-2.8)	0.7 (0.5-0.9)	0.6 (0.3-1)	2 (1.3-3)	0.9 (0.8-1)	2.3 (2.1-2.5)
Prevalent heart disease	32.4 (31.3-33.5)	48.8 (46.7-50.9)	16.2 (15.8-16.6)	42.9 (41.2-44.6)	45.1 (44.9-45.3)	62.7 (62.4-63)	48.4 (47.7-49.1)	69.8 (68.5-71.1)	25 (23.4-26.6)	11.2 (10.4-12)	20 (18.3-21.8)	19.5 (17.3-21.9)	14.6 (14.4-14.8)	28.1 (27.4-28.8)
Prevalent hypertension	39.8 (38.7-40.9)	62.1 (60-64.1)	26.4 (25.9-26.9)	57.8 (56.1-59.5)	58.8 (58.6-59)	77.7 (77.5-77.9)	65.5 (64.9-66.1)	86.4 (85.4-87.3)	33.7 (32-35.5)	22.4 (21.4-23.5)	21.5 (19.8-23.4)	27.9 (25.4-30.5)	17.2 (17-17.4)	29.8 (29.1-30.5)

Prevalent T2DM	20.1 (19.2-21)	37.8 (35.8-39.9)	15.7 (15.3-16.1)	36.2 (34.6-37.9)	35.5 (35.3-35.7)	51.4 (51.1-51.7)	36.8 (36.2-37.4)	55.4 (54-56.8)	14.4 (13.2-15.7)	19.2 (18.2-20.2)	15.1 (13.6-16.7)	17.7 (15.6-20)	8.1 (7.9-8.3)	17.9 (17.3-18.5)
Other														
Anxiety	5.9 (5.4-6.5)	5.3 (4.4-6.3)	7.6 (7.3-7.9)	13.6 (12.5-14.8)	9.8 (9.7-9.9)	9.9 (9.7-10.1)	30.8 (30.2-31.4)	30.1 (28.8-31.4)	10.3 (9.2-11.5)	8.5 (7.8-9.2)	2.9 (2.2-3.7)	7.8 (6.4-9.5)	27.4 (27.1-27.7)	23.7 (23.1-24.3)
Depression	7.1 (6.5-7.7)	10.0 (8.8-11.3)	6.9 (6.6-7.2)	16.2 (15-17.5)	9.1 (9-9.2)	11.1 (10.9-11.3)	23.2 (22.6-23.8)	26.1 (24.9-27.3)	16.5 (15.2-17.9)	4.4 (3.9-4.9)	4.6 (3.8-5.6)	4.3 (3.3-5.6)	10.9 (10.7-11.1)	11.8 (11.3-12.3)
Prevalent CKD	11.9 (11.2-12.7)	22.7 (21-24.5)	7.1 (6.8-7.4)	25.7 (24.2-27.2)	18.6 (18.5-18.7)	32.4 (32.1-32.7)	21.4 (20.9-22)	38.9 (37.5-40.3)	10.3 (9.2-11.5)	4.8 (4.3-5.4)	13.5 (12.1-15.1)	9.9 (8.3-11.7)	6.8 (6.7-6.9)	14.7 (14.2-15.2)
Chronic Liver Disease	1.1 (0.9-1.4)	2.3 (1.7-3)	0.7 (0.6-0.8)	1.9 (1.5-2.4)	1.1 (18.5-18.7)	2 (1.9-2.1)	4.3 (4-4.6)	7.8 (7.1-8.6)	3 (2.4-3.7)	3.7 (3.3-4.2)	<0.3	0.0	1.1 (1-1.2)	1.9 (1.7-2.1)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort.

Prevalent = conditions defined using all person time otherwise within 365 days of index date. Depression = incident depression/major depressive disorder. N/A=Data not captured. CKD=Chronic kidney disease. T2DM=Type 2 diabetes mellitus. COPD=chronic obstructive pulmonary disease.

Supplementary table S6. Standardised mean differences for the comparison between diagnosed COVID-19 patients without asthma compared to diagnosed COVID-19 patients with asthma.

COVARIATE	SIDIAP	STARR-OMOP	VA-OMOP	CUIMC	HEALTHVERITY	IQVIA-OPENCLAIMS
AGE GROUP: 00-04	-0.02884	0.096417		0.012843	0.039687	0.029575
AGE GROUP: 05-09	0.042887	0.031893		0.103379	0.078905	0.063221
AGE GROUP: 10-14	0.09065	0.022877		0.077368	0.056296	0.069005
AGE GROUP: 15-19	0.068606	0.01853		0.112052	0.048542	0.06923
AGE GROUP: 20-24	0.062397	0.033604		0.074488	0.014803	0.05751
AGE GROUP: 25-29	0.032923	0.026918	-0.04151	-0.01265	-0.01889	0.029918
AGE GROUP: 30-34	0.014312	-0.06487	-0.02629	-0.07431	0	0.012295
AGE GROUP: 35-39	0.024846	0.027552	0.008747	-0.04708	0.002709	0.014853
AGE GROUP: 40-44	0.039876	-0.02028	0.063563	-0.01071	0.038466	0.031212
AGE GROUP: 45-49	0.031414	0.035669	0.075152	-0.01657	0.073019	0.039984
AGE GROUP: 50-54	0.025962	-0.01491	0.120203	0.059027	0.097539	0.049128
AGE GROUP: 55-59	-0.01279	0.031071	0.105962	0.024545	-0.04507	0.039778
AGE GROUP: 60-64	-0.03802	0.018393	0.041882	0.028949	-0.0662	0.002393
AGE GROUP: 65-69	-0.053	-0.05648	-0.0023	-0.01592	-0.05699	-0.04241
AGE GROUP: 70-74	-0.04608	-0.03484	-0.12903	-0.01683	0.002996	-0.057
AGE GROUP: 75-79	-0.06316	-0.03802	-0.10267	-0.04521	-0.07126	-0.0724
AGE GROUP: 80-84	-0.07347	-0.01931	-0.07494	-0.01699	-0.05116	-0.07533
ALLERGIC DISORDER	0.364823	0.220473	0.22997	0.234282	0.278388	0.2035
ALLERGIC RHINITIS	0.366483	0.193709	0.223303	0.22792	0.28233	0.202521
ANXIETY	0.126816	0.234742	0.196198	0.166606	0.138426	0.113751
AF	-0.04977	0.101449	-0.04888	0.046579	-0.03029	-0.03265
BRONCHIECTASIS	0.08	0.15	0.02	0.1	0.07	0.04
CARDIAC ARRHYTHMIA	-0.05062	0.12275	-0.03087	0.063273	0.008747	-0.00923
CVD	-0.03321	0.05285	-0.02818	0.015795	0.037768	-0.00339
CLD	-0.00696	-0.01708	0.006898	0.060968	0.030526	0.012904
CKD	-0.07056	0.119608	-0.03693	0.150264	0.034338	-0.02581
COPD	-0.00768	0.058246	0.075976	0.142118	0.041249	0.057663
DEPRESSION	0.055787	0.163153	0.093571	0.180014	0.097084	0.057983
ECZEMA	0.126958	0.072569	0.066773	0.079208	0.076696	0.056179
HEART DISEASE	-0.04553	0.201256	0.075028	0.25845	0.108028	0.066601
HEART FAILURE	-0.02201	0.118088	-0.01215	0.109953	0.01932	0
HYPERTENSION	-0.02278	0.191782	0.074339	0.260133	0.165127	0.025949
ILD	0.018291	0.040647	0.020057	0.071792	0.028453	0.026977
MI	-0.04282	0.027315	0	0.057562	0.005915	-0.00465
OBESITY	0.101198	0.239946	0.266942	0.308074	0.274888	0.239677
SLEEP APNOEA	0.044421	0.211738	0.211433	0.148566	0.155816	0.135553
SYSTEMIC CORTICOSTEROIDS	0.219023	0.262743	0.25	0.30255	0.361485	0.290719
T2DM	-0.04354	0.08374	0.065335	0.202787	0.089985	0.043918

SMD<0 = prevalence greater in COVID-19 patients without asthma. SMD>0 = prevalence greater in COVID-19 patients with asthma. SMD in bold = greater or less than 0.1 suggests significant imbalance between groups. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. T2DM=Type 2 diabetes mellitus. Top row=name of the database.

Supplementary table S7. Standardised mean differences for the comparison between hospitalised COVID-19 patients without asthma compared to hospitalised COVID-19 patients with asthma.

COVARIATE	CUIMC	HEALTHVERITY	IQVIA- OPENCLAIMS	HIRA	SIDIAP	VA- OMOP
AGE GROUP: 00-04	-0.01145		0.047643	0.117634		
AGE GROUP: 05-09	0.116224		0.063362	0.077911		
AGE GROUP: 10-14	0.100771		0.044497	0.037588		
AGE GROUP: 15-19	0.101593		0.060867	-0.06655	0.06	
AGE GROUP: 20-24	0.08229	0.081274	0.062593	-0.11666	0.02	
AGE GROUP: 25-29	0.089904		0.051705	-0.09763	0.04	
AGE GROUP: 30-34	0.008033	0.021313	0.057922	0.003236	-0.01	0.037261
AGE GROUP: 35-39	-0.04912	0.131966	0.036585	-0.01288	-0.01	-0.04027
AGE GROUP: 40-44	-0.05274	0.05925	0.061463	-0.00315	0.09	0.08572
AGE GROUP: 45-49	0.01376	0.120082	0.062631	-0.01329	0.07	0.106684
AGE GROUP: 50-54	0.043576	0.124868	0.06944	-0.03575	0.03	0.158299
AGE GROUP: 55-59	0.020869	0.057381	0.072061	0	0.02	0.114338
AGE GROUP: 60-64	0.007315	-0.00219	0.021888	0.08614	-0.01	0.078541
AGE GROUP: 65-69	-0.01113	-0.09113	-0.04324	0.065681	-0.05	0.040446
AGE GROUP: 70-74	-0.03028	0.005975	-0.06448	0.021044	-0.01	-0.13317
AGE GROUP: 75-79	-0.07874	-0.19042	-0.07871	0.059969	-0.02	-0.13662
AGE GROUP: 80-84	-0.03247	-0.0434	-0.08297	0.052199	-0.06	-0.04866
ALLERGIC DISORDER	0.24167	0.231497	0.176201	0.422476	0.31	0.209157
ALLERGIC RHINITIS	0.225682	0.237533	0.174225	0.459431	0.32	0.203605
ANXIETY	0.162924	0.07053	0.115391	0.115347	0.18	0.128369
AF	0.052105	-0.04245	-0.01822	0.034462	-0.02	-0.03146
BRONCHIECTASIS	0.14		0.04	0.07	0.11	0.05
CARDIAC ARRHYTHMIA	0.06826	-0.0348	0.003631	0.078431	-0.04	0
CVD	-0.02384	0.03946	-0.00266	0.056429	-0.01	-0.09706
CLD	0.089324	0.087933	0.019157	0.090258	-0.02	0.023091
CKD	0.163389	-0.00324	-0.00757	0.082203	-0.04	-0.10215
COPD	0.174419	-0.04152	0.096409	0.069131	-0.05	0.110294
DEPRESSION	0.141013	0.089362	0.072634	0.05	0.09	0.068322
ECZEMA		0.092802	0.047903	0.112732	0.04	0.03822
HEART DISEASE	0.232751	0.045528	0.081861	0.170931	-0.02	0.046926
HEART FAILURE	0.157295	-0.01657	0.036867	0.087904	0.05	0.017545
HYPERTENSION	0.214889	0.101833	0.034572	0.11652	0.03	-0.01426
ILD	0.118966	0.051675	0.027456	0.049379		0.03585
MI	0.075471	-0.02285	0.003129	0.053711	-0.06	0.033405
OBESITY	0.299305	0.286975	0.27579	0.038698	0.15	0.25776
SLEEP APNOEA	0.12684	0.146852	0.172139	0.048072	0.12	0.2339
SYSTEMIC CORTICOSTEROIDS	0.301188	0.268416	0.280436	0.330866	0.27	0.162708
T2DM	0.170658	0.074045	0.062412	0.177108	-0.03	0.039957

SMD<0 = prevalence greater in patients without asthma. SMD>0 = prevalence greater in patients with asthma. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD in bold = greater or less than 0.1 indicates significant imbalance between groups. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. T2DM=Type 2 diabetes mellitus. row=name of the database.

Supplementary tables S8. Treatments in patients with asthma 30 days before COVID-19 diagnosis or hospitalization.

Treatment	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC (% 95%CI)		HealthVerity (% 95%CI)		IQVIA OpenClaims (% 95%CI)		VA-OMOP (% 95%CI)		STARR- OMOP (% 95%CI)	HIRA (% 95%CI)	CPRD (% 95%CI)	IPCI (% 95%CI)	SIDIAP (% 95%CI)	
	N=1338 D	N=479 H	N=3367 D	N=349 H	N=86328 D	N=23211 H	N=2953 D	N=607 H	N=501 D	N=1560 H	N=343 D	N=156 D	N=7536 D	N=952 H
Asthma management														
Systemic corticosteroids	12.6 (10.9-14.5)	15 (12.1-18.5)	6.1 (5.3-7)	9.2 (6.6-12.7)	13.9 (13.7-14.1)	17.9 (17.4-18.4)	14.6 (13.4-15.9)	18.5 (15.6-21.8)	17.2 (14.1-20.8)	19.9 (18-22)	17.5 (13.8-21.9)	14.7 (10-21.1)	8.7 (8.1-9.4)	16.4 (14.2-18.9)
Inhaled corticosteroid	10.7 (9.2-12.5)	10.3 (7.9-13.3)	7.7 (6.8-8.6)	9.0 (6.4-12.5)	19.9 (19.6-20.2)	21.6 (21.1-22.1)	41.4 (39.6-43.2)	44.3 (40.4-48.3)	18.4 (15.3-22)	6.4 (5.3-7.7)	50.7 (45.4-56)	43.6 (36.1-51.4)	55.1 (54-56.2)	71.3 (68.3-74.1)
SABA	20.7 (18.6-23)	22.8 (19.3-26.8)	8.9 (8-9.9)	7.4 (5.1-10.6)	22.9 (22.6-23.2)	24.0 (23.5-24.6)	37.6 (35.9-39.4)	36.9 (33.2-40.8)	16.0 (13.1-19.5)	2.1 (1.5-2.9)	48.4 (43.2-53.7)	17.9 (12.7-24.7)	26.5 (25.5-27.5)	29.9 (27.1-32.9)
LABA	7.1 (5.8-8.6)	7.5 (5.5-10.2)	4.8 (4.1-5.6)	5.1 (3.2-7.9)	10.3 (10.1-10.5)	12.6 (12.2-13)	19.4 (18-20.9)	24.0 (20.8-27.6)	7.4 (5.4-10)	3.2 (2.4-4.2)	30.5 (25.9-35.6)	19.3 (13.9-26.2)	28.4 (27.4-29.4)	39.8 (36.7-42.9)
LTRA	4.9 (3.9-6.2)	4.8 (3.2-7.1)	3.7 (3.1-4.4)	3.4 (1.9-5.9)	9.4 (9.2-9.6)	10.5 (10.1-10.9)	9.1 (8.1-10.2)	8.4 (6.4-10.9)	3.2 (2-5.1)	8.8 (7.5-10.3)	7.6 (5.2-10.9)	3.2 (1.4-7.3)	6.8 (6.3-7.4)	9.0 (7.3-11)
Methylxanthines	<0.4	0.0	<0.1	0.0	0.1 (0.1-0.1)	0.2 (0.2-0.3)	0.3 (0.2-0.6)	<0.8	0.0	2.5 (1.8-3.4)	1.7 (0.8-3.7)	0.0	0.1	<0.5
Antibiotics														
Beta-lactam penicillins	3.1 (2.3-4.2)	4.2 (2.7-6.4)	1.2 (0.9-1.6)	<1.4	5.8 (5.6-6)	6.5 (6.2-6.8)	4.6 (3.9-5.4)	4.1 (2.8-6)	4.2 (2.8-6.3)	13.5 (11.9-15.3)	16.3 (12.8-20.6)	10.9 (6.9-16.8)	4.5 (4.1-5)	9.6 (7.9-11.6)
Fluoroquinolones	2.3 (1.6-3.3)	2.9 (1.7-4.8)	0.8 (0.6-1.2)	<1.4	3.3 (3.2-3.4)	4.5 (4.2-4.8)	1.5 (1.1-2)	2.5 (1.5-4.1)	1.5 (0.7-3)	6.9 (5.7-8.3)	<1.5	0.0	2.5 (2.2-2.9)	5.9 (4.6-7.6)
Macrolides	8.7 (7.3-10.3)	9.6 (7.3-12.6)	3.2 (2.7-3.8)	5.4 (3.5-8.3)	14.1 (13.9-14.3)	15.3 (14.8-15.8)	8.2 (7.3-9.2)	10.4 (8.2-13.1)	4.4 (2.9-6.6)	12.3 (10.8-14)	6.1 (4-9.2)	<3.2	3.1 (2.7-3.5)	9.6 (7.9-11.6)
Covid 19 Symptom management														
Acetaminophen	16.6 (14.7-18.7)	22.8 (19.3-26.8)	2.5 (2-3.1)	2.3 (1.2-4.5)	7.4 (7.2-7.6)	10.4 (10-10.8)	22.9 (21.4-24.5)	31.3 (27.7-35.1)	19.8 (16.5-23.5)	38.3 (35.9-40.7)	31.2 (26.5-36.3)	4.5 (2.2-9)	25.6 (24.6-26.6)	46.5 (43.4-49.7)
NSAIDs	10.2 (8.7-11.9)	13.2 (10.5-16.5)	3 (2.5-3.6)	5.2 (3.3-8.1)	22.2 (21.9-22.5)	26.8 (26.2-27.4)	44 (42.2-45.8)	49.9 (45.9-53.9)	13 (10.3-16.2)	28.1 (25.9-30.4)	10.5 (7.7-14.2)	7.7 (4.5-13)	12.4 (11.7-13.2)	14.2 (12.1-16.6)
Opioids	6.7 (5.5-8.2)	6.9 (5-9.5)	1.7 (1.3-2.2)	2.9 (1.6-5.2)	7.4 (7.2-7.6)	10.9 (10.5-11.3)	11.1 (10-12.3)	14.7 (12.1-17.7)	14.8 (12-18.2)	41.5 (39.1-44)	12.5 (9.4-16.4)	6.4 (3.5-11.4)	6.7 (6.2-7.3)	13.6 (11.6-15.9)
Other														
Nasal preparations	14.3 (12.5-16.3)	15.7 (12.7-19.2)	8.0 (7.1-9)	9.5 (6.8-13)	23.8 (23.5-24.1)	26.5 (25.9-27.1)	41.9 (40.1-43.7)	44.3 (40.4-48.3)	22.8 (19.3-26.7)	10.1 (8.7-11.7)	46.1 (40.9-51.4)	38.5 (31.2-46.3)	48.7 (47.6-49.8)	63.6 (60.5-66.6)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. LTRA=Leukotriene receptor antagonist. Nasal preparations= decongestants and other nasal preparations for topical use (ATC R01A).

D=Diagnosed cohort. H=hospitalized cohort. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort.

Supplementary table S9. Standardised mean differences for the comparison between diagnosed COVID-19 patients with asthma compared to hospitalised COVID-19 patients with asthma.

COVARIATE	CUIMC	HEALTHVERITY	IQVIA- OPENCLAIMS	SIDIAP	VA- OMOP
AGE GROUP: 00-04	0.012033		0		
AGE GROUP: 05-09	0.024941		-0.03211		
AGE GROUP: 10-14	0.043596		-0.06777		-0.11941
AGE GROUP: 15-19	0.014041		-0.07567	-0.09458	-0.1945
AGE GROUP: 20-24	-0.0043	-0.09779	-0.1036	-0.18684	-0.11383
AGE GROUP: 25-29	-0.03027		-0.10363	-0.16754	-0.0844
AGE GROUP: 30-34	-0.0992	-0.16403	-0.08838	-0.17602	-0.06389
AGE GROUP: 35-39	-0.15011	-0.07379	-0.08846	-0.20813	-0.06169
AGE GROUP: 40-44	-0.17473	-0.12675	-0.0713	-0.10554	0.02788
AGE GROUP: 45-49	-0.06417	-0.07809	-0.05418	-0.0745	0.101453
AGE GROUP: 50-54	-0.08039	-0.08844	-0.02895	-0.03569	0.10967
AGE GROUP: 55-59	-0.02965	0.06207	0.019978	0.053844	0.082052
AGE GROUP: 60-64	-0.01669	0.072648	0.058749	0.094962	0.107742
AGE GROUP: 65-69	0.090476	0.095645	0.076468	0.139041	-0.04123
AGE GROUP: 70-74	0.080571	0.207698	0.097675	0.202214	-0.04677
AGE GROUP: 75-79	0.095913	0.074744	0.099694	0.22533	-0.07753
AGE GROUP: 80-84	0.11163	0.201516	0.087131	0.173594	0.032992
ALLERGIC DISORDER	-0.02392	-0.05219	-0.05948	-0.04778	0.164529
ALLERGIC RHINITIS	-0.03316	-0.05411	-0.06091	-0.05277	0.05
ANXIETY	-0.02159	0.07053	0.003934	-0.00739	0.20737
ASTHMA EXACERBATION	0.017426	0.073527	0.056941	0.030327	0.038051
AF	0.095854	0.23133	0.128676	0.15995	0.119786
BRONCHIECTASIS	0.06		0.04	0.09	0.212625
CARDIAC ARRHYTHMIA	0.115082	0.239468	0.169874	0.188016	0.053479
CVD	0.025758	0.155573	0.092189	0.078612	-0.01915
CLD	0.093836	0.130453	0.05741	0.032272	0.265515
CKD	0.217534	0.330698	0.244986	0.103952	0.236667
COPD	0.118253	0.192896	0.177321	0.074541	0.082033
DEPRESSION	0.023781	0.151515	0.05149	-0.11712	0.053248
ECZEMA		0.009651	-0.01536	0.261656	0.152058
HEART DISEASE	0.213958	0.367885	0.269207	0.18453	0.082033
HEART FAILURE	0.177027	0.273677	0.205832	0.286563	0.207855
HYPERTENSION	0.276919	0.406158	0.301724		0.056975
ILD	0.102105	0.117119	0.108566	0.0639	0.026897
MI	0.121552	0.127831	0.113936	0.286563	0.242395
OBESITY	0.103998	0.136551	0.104967	0.208852	0.207855
SLEEP APNOEA	-0.0027	0.058409	0.093566	0.168808	0.056975
SYSTEMIC CORTICOSTEROIDS	0.035539	-0.06795	0.032625	0.173464	0.026897
T2DM	0.249174	0.324439	0.248624	0.217283	0.242395

SMD<0 = greater in asthma patients diagnosed with COVID-19. SMD>0 = greater in asthma patients hospitalized with COVID-19. SMD in bold = greater or less than 0.1. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. Top row=name of the database.

Supplementary table S10. Outcomes in COVID-19 patients with asthma in the diagnosed and hospitalized cohorts.

Characteristic	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC (% , 95%CI)		HealthVerity (% , 95%CI)		IQVIA OpenClaims (% , 95%CI)		VA-OMOP (% , 95%CI)		STARR-OMOP (% , 95%CI)	HIRA (% , 95%CI)	CPRD (% , 95%CI)	IPCI (% , 95%CI)	SIDIAP (% , 95%CI)	
	N=1338	N=479	N=3367	N=349	N=86328	N=23211	N=2953	N=607	N=501	N=1560	N=343	N=156	N=7536	N=952
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
Death	6.1 (4.9-7.5)	16.9 (13.8-20.5)	NA	NA	NA	NA	3.2 (2.6-3.9)	12.9 (10.5-15.8)	NA	3.7 (2.9-4.8)	7.3 (5-10.6)	9.6 (5.9-15.2)	2.1 (1.8-2.4)	7.7 (6.2-9.6)
Intensive services	NA	NA	0.7 (0.5-1)	7.4 (5.1-10.6)	3.7 (3.6-3.8)	10.1 (9.7-10.5)	2.9 (2.4-3.6)	17.6 (14.8-20.8)	3.2 (2-5.1)	2.7 (2-3.6)	NA	NA	NA	NA
ARDS	5.2 (4.1-6.5)	15.0 (12.1-18.5)	2.2 (1.8-2.8)	26.1 (21.8-31)	11.0 (10.8-11.2)	31.8 (31.2-32.4)	7.3 (6.4-8.3)	39.7 (35.9-43.6)	4.0 (2.6-6.1)	2.1 (1.5-2.9)	NA	NA	NA	NA
ARFS	4.9 (3.9-6.2)	14.0 (11.2-17.4)	1.8 (1.4-2.3)	16.0 (12.5-20.2)	5.8 (5.6-6)	18.8 (18.3-19.3)	7.2 (6.3-8.2)	29.7 (26.2-33.5)	2.2 (1.2-3.9)	1.5 (1-2.2)	2.3 (1.2-4.5)	<3.2	<0.1	0.5 (0.2-1.2)
Cardiac arrhythmia	4.6 (3.6-5.9)	8.4 (6.2-11.2)	2.4 (1.9-3)	14.3 (11-18.4)	5.5 (5.3-5.7)	14.7 (14.3-15.2)	9.1 (8.1-10.2)	29.7 (26.2-33.5)	10.0 (7.7-12.9)	3.5 (2.7-4.5)	<1.5	<3.2	7.7 (7.1-8.3)	17.0 (14.7-19.5)
Heart failure	2.3 (1.6-3.3)	7.5 (5.5-10.2)	0.9 (0.6-1.3)	7.2 (4.9-10.4)	2.0 (1.9-2.1)	6.0 (5.7-6.3)	3.9 (3.3-4.7)	19.8 (16.8-23.2)	3.8 (2.4-5.9)	3.4 (2.6-4.4)	0.0	0.0	1.5 (1.2-1.8)	4.9 (3.7-6.5)
Myocardial infarction	1.0 (0.6-1.7)	2.1 (1.1-3.8)	0.2 (0.1-0.4)	1.7 (0.8-3.7)	1.1 (1-1.2)	3.3 (3.1-3.5)	2.3 (1.8-2.9)	8.4 (6.4-10.9)	1 (0.4-2.3)	2.8 (2.1-3.7)	0.0	<3.2	0.4 (0.3-0.6)	1.2 (0.7-2.1)
Sepsis	1.9 (1.3-2.8)	4.6 (3.1-6.9)	2.1 (1.7-2.6)	17.2 (13.6-21.5)	6.8 (6.6-7)	20.5 (20-21)	4.0 (3.4-4.8)	18.1 (15.2-21.4)	2.8 (1.7-4.6)	2.8 (2.1-3.7)	<1.5	0.0	0.1 (0-0.2)	<0.5
Bleeding	2.5 (1.8-3.5)	5.0 (3.4-7.3)	1.0 (0.7-1.4)	5.4 (3.5-8.3)	1.8 (1.7-1.9)	4.4 (4.1-4.7)	2.0 (1.6-2.6)	6.8 (5.1-9.1)	3.1 (1.9-5)	2.6 (1.9-3.5)	0.0	<3.2	2.6 (2.3-3)	3.6 (2.6-5)
PE	0.7 (0.4-1.3)	1.5 (0.7-3)	0.3 (0.2-0.5)	1.7 (0.8-3.7)	0.8 (0.7-0.9)	1.9 (1.7-2.1)	1.1 (0.8-1.5)	4.1 (2.8-6)	<1.0	<0.3	0.0	0.0	0.2 (0.1-0.3)	2.2 (1.4-3.3)
Stroke	1.1 (0.7-1.8)	2.7 (1.6-4.6)	<0.1	2.0 (1-4.1)	0.6 (0.6-0.7)	1.7 (1.5-1.9)	0.5 (0.3-0.8)	2.3 (1.4-3.8)	<1.0	0.6 (0.3-1.1)	0.0	0.0	0.8 (0.6-1)	<0.5

US=United States. KR=South Korea. UK=United Kingdom. NL=Netherlands. ES=Spain. D=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. H=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. ARDS=Acute respiratory distress syndrome. ARFS=Acute renal failure syndrome. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. Heart failure = during hospitalization. NA=Data not captured.

Supplementary table S11. Outcomes in patients without asthma diagnosed and hospitalized with COVID-19.

Treatment	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC % (95%CI)		HealthVerity % (95%CI)		IQVIA OpenClaims % (95%CI)		VA-OMOP % (95%CI)		STARR-OMOP % (95%CI)	HIRA % (95%CI)	CPRD % (95%CI)	IPCI % (95%CI)	SIDIAP % (95%CI)	
	(n=7181)	(n=2121)	(n=35194)	(n =3264)	(n=379863)	(n=109880)	(n=21659)	(n= 903)	(n=2827)	(n=6039)	(n=1993)	(n=1172)	(n=114522)	(n=17245)
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
Death	6.3 (5.8-6.9)	20.7 (19-22.5)	NA	NA	NA	NA	5.2 (4.9-5.5)	17.6 (16.6-18.7)	NA	2.2 (1.9-2.6)	12.5 (11.1-14)	8.7 (7.2-10.5)	4.5 (4.4-4.6)	12.5 (12-13)
Intensive services	N/A	N/A	0.5 (0.4-0.6)	5.8 (5-6.7)	4 (3.9-4.1)	9.8 (9.6-10)	2.9 (2.7-3.1)	17.9 (16.9-19)	1 (0.7-1.4)	1.4 (1.1-1.7)	NA	NA	NA	NA
ARDS	4.8 (4.3-5.3)	17 (15.5-18.7)	2.1 (2-2.3)	24.5 (23.1-26)	12.2 (12.1-12.3)	32.3 (32-32.6)	8.3 (7.9-8.7)	44.3 (42.9-45.7)	1.9 (1.5-2.5)	0.8 (0.6-1.1)	NA	NA	NA	NA
ARFS	4.1 (3.7-4.6)	13.1 (11.7-14.6)	1.7 (1.6-1.8)	15.2 (14-16.5)	7.4 (7.3-7.5)	22.1 (21.9-22.3)	9 (8.6-9.4)	35.3 (34-36.6)	2.2 (1.7-2.8)	0.7 (0.5-0.9)	1.3 (0.9-1.9)	0.0	0.1 (0.1-0.1)	0.2 (0.1-0.3)
Cardiac arrhythmia	3.4 (3-3.8)	7.1 (6.1-8.3)	2.7 (2.5-2.9)	16.1 (14.9-17.4)	6.4 (6.3-6.5)	15.6 (15.4-15.8)	10.3 (9.9-10.7)	31.9 (30.6-33.2)	6.4 (5.6-7.4)	1.8 (1.5-2.2)	1 (0.6-1.5)	1.5 (0.9-2.4)	9.6 (9.4-9.8)	18.8 (18.2-19.4)
Heart failure	1.2 (1-1.5)	4.4 (3.6-5.4)	0.6 (0.5-0.7)	8.3 (7.4-9.3)	2.1 (2.1-2.1)	5.8 (5.7-5.9)	4 (3.7-4.3)	20.4 (19.3-21.6)	2.3 (1.8-2.9)	2.3 (2-2.7)	0.0	0.0	1.4 (1.3-1.5)	3.7 (3.4-4)
Myocardial infarction	0.7 (0.5-0.9)	1.9 (1.4-2.6)	0.5 (0.4-0.6)	3.6 (3-4.3)	1.4 (1.4-1.4)	3.8 (3.7-3.9)	2.9 (2.7-3.1)	11 (10.2-11.9)	1.6 (1.2-2.1)	3.5 (3.1-4)	<0.3	<0.4	1 (0.9-1.1)	2.3 (2.1-2.5)
Sepsis	2.2 (1.9-2.6)	6.3 (5.3-7.4)	1.7 (1.6-1.8)	15.4 (14.2-16.7)	7.9 (7.8-8)	21.7 (21.5-21.9)	5.4 (5.1-5.7)	22.8 (21.6-24)	1.7 (1.3-2.2)	1.9 (1.6-2.3)	0.4 (0.2-0.8)	0.0	0.2 (0.2-0.2)	0.4 (0.3-0.5)
Bleeding	1.6 (1.3-1.9)	3.4 (2.7-4.3)	0.7 (0.6-0.8)	3.8 (3.2-4.5)	1.7 (1.7-1.7)	4.1 (4-4.2)	2.5 (2.3-2.7)	7.8 (7.1-8.6)	3.5 (2.9-4.2)	2.5 (2.1-2.9)	0.3 (0.1-0.7)	1.4 (0.9-2.2)	2.3 (2.2-2.4)	3.4 (3.1-3.7)
PE	0.8 (0.6-1)	2.1 (1.6-2.8)	0.2 (0.2-0.3)	1.2 (0.9-1.6)	0.7 (0.7-0.7)	1.6 (1.5-1.7)	1.0 (0.9-1.1)	3.5 (3-4.1)	0.4 (0.2-0.7)	<0.1	0.4 (0.2-0.8)	0.4 (0.2-1)	0.1 (0.1-0.1)	1.7 (1.5-1.9)
Stroke	0.7 (0.5-0.9)	2.5 (1.9-3.3)	0.1 (0.1-0.1)	2.2 (1.8-2.8)	0.7 (0.7-0.7)	1.9 (1.8-2)	0.7 (0.6-0.8)	3.2 (2.7-3.7)	<0.4	0.7 (0.5-0.9)	0.0	0.0	0.0	0.2 (0.1-0.3)

US=United States. KR=South Korea. UK=United Kingdom. NL=Netherlands. ES=Spain. D=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. H=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. ARDS=Acute respiratory distress syndrome. ARFS=Acute renal failure syndrome. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. Heart failure = during hospitalization. N/A=Data not captured.

Appendix 1

1.1 Overview of Data Sources Screened for Eligibility and Contributing Results

Database Name	Country	Description	Contributed By
Clinical Practice Research Datalink	United Kingdom	The Clinical Practice Research Datalink (CPRD) is a governmental, not-for-profit research service, jointly funded by the NHS National Institute for Health Research (NIHR) and the Medicines and Healthcare products Regulatory Agency (MHRA), a part of the Department of Health, United Kingdom (UK). CPRD consists of data collected from UK primary care for all ages. This includes conditions, observations, measurements, and procedures that the general practitioner is made aware of in addition to any prescriptions as prescribed by the general practitioner. In addition to primary care, there are also linked secondary care records for a small number of people. The major data elements contained within this database are outpatient prescriptions given by the general practitioner (coded with Gemscript codes) and outpatient clinical, referral, immunization or test events that the general practitioner knows about (coded in Read or ICD10 or LOINC codes). The database also contains the patients' year of births and any date of deaths. The cohorts represented in this application were run on a COVID-specific cut of the CPRD database which included patients with a SARS-CoV-2 test, diagnosis, or related code.	Janssen Research & Development, Titusville, NJ, USA
Columbia University Irving Medical Center	United States	The clinical data warehouse of NewYork-Presbyterian Hospital/Columbia University Irving Medical Center, New York, NY, based on its current and previous electronic health record systems, with data spanning over 30 years and including over 6 million patients	Department of Biomedical Informatics, Columbia University Irving Medical Center, New York, NY 10032, USA
Daegu Catholic University Medical Center	South Korea	A teaching hospital in Daegu, South Korea, covered by Federated E-health Big Data for Evidence Renovation Network (FEEDER-NET).	Department of Biomedical Sciences, Ajou University Graduate School of Medicine, Suwon, Korea

HealthVerity	United States	This HealthVerity derived data set contains de-identified patient information with an antibody and/or diagnostic test for COVID-19 linked to all available Medical Claims and Pharmacy Data from select private data providers participating in the HealthVerity marketplace.	Janssen Research & Development, Titusville, NJ, USA
Health Insurance Review & Assessment Service (HIRA)	South Korea	National claim data from a single insurance service from South Korea. It contains the observational medical records (including both inpatient and outpatient) of a patient while they are qualified to get the national medical insurance.	Health Insurance Review & Assessment Service, 60 Hyeoksin-Rho, Wonju-Si, Gangwon-Do(Bangkok-Dong), 26465, Korea
HM Hospitals	Spain	Hospital de Madrid (HM) Hospitals data are made available through partnership with IDIAPJGol. The HM Hospitals database covers in-patient care delivered across a network of 17 private hospitals in Spain between 1st of March and 24th of April 2020. HM Hospitals database covers more than 2300 confirmed COVID-19 cases, and all in-patient hospital care, including the data of admission, conditions, procedures and medicines dispensed in hospital, date of discharge, and date of known death or date of end of follow-up in the database.	Fundacio Institut Universitari per a la recerca a l'Atencio Primaria de Salut Jordi Gol i Gurina (IDIAPJGol), Barcelona, Spain
Integrated Primary Care Information (IPCI)	Netherlands	The Integrated Primary Care Information (IPCI) database is a Dutch database containing the medical records of more than 2.5 million patients provided by more than 600 GPs geographically spread over the Netherlands. In the Netherlands, all citizens are registered with a GP practice which acts as a gatekeeper in a two-way exchange of information with secondary care.	Department of Medical Informatics, Erasmus University Medical Center, Rotterdam, The Netherlands
IQVIA Open Claims		A United States database of open, pre-adjudicated claims from January 2013 to May 2020. Data are reported at anonymized patient level collected from office-based physicians and specialists via office management software and clearinghouse switch sources for the purpose of reimbursement. A subset of medical claims data have adjudicated claims.	Real World Solutions, IQVIA Inc, Cambridge, MA, USA
Nanfang Hospital COVID-19 Research Database (NFHCRD)	China	The clinical data warehouse of The People's Hospital of Hong Huï Hubei China based on its current and previous electronic health record systems, with data spanning over 4 months and including over 400 patients.	Nanfang Hospital, Southern Medical University, Guangzhou, China; DHC Technologies

			Co. Ltd. Beijing, China
Optum EHR	United States	Optum© de-identified Electronic Health Record Dataset represents Humedica™s Electronic Health Record data a medical records database for patients receiving a COVID-19 diagnosis record or lab test for SARS-CoV-2. The medical record data includes clinical information, inclusive of prescriptions as prescribed and administered, lab results, vital signs, body measurements, diagnoses, procedures, and information derived from clinical Notes using Natural Language Processing (NLP).	Janssen Research & Development, Titusville, NJ, USA
Premier Healthcare Database	United States	The Premier Healthcare Database contains complete clinical coding, hospital cost, and patient billing data from approximately 700 hospitals throughout the United States representing 20% of inpatient hospital stays. Premier collects data from participating hospitals in its health care alliance. The Premier health care alliance was formed for hospitals to share knowledge, improve patient safety, and reduce risks. Participation in the Premier health care alliance is voluntary. Although the database excludes federally funded hospitals (e.g., Veterans Affairs), the hospitals included are nationally representative based on bed size, geographic region, location (urban/rural) and teaching hospital status. The database contains a date-stamped log of all billed items by cost-accounting department including medications; laboratory, diagnostic, and therapeutic services; and primary and secondary diagnoses for each patient's hospitalization.	Janssen Research & Development, Titusville, NJ, USA
Information System for Research in Primary Care (SIDIAP)	Spain	The Information System for Research in Primary Care (SIDIAP; www.sidiap.org) is a primary care records database that covers approximately 7 million people, equivalent to an 80% of the population of Catalonia, North-East Spain. Healthcare is universal and tax-payer funded in the region, and primary care physicians are gatekeepers for all care and responsible for repeat prescriptions.	Fundacio Institut Universitari per a la recerca a l'Atencio Primaria de Salut Jordi Gol i Gurina (IDIAPJGol), Barcelona, Spain

Information System for Research in Primary Care Hospitalization Linked Data (SIDIAP-H)	Spain	The Information System for Research in Primary Care (SIDIAP; www.sidiap.org) is a primary care records database from Catalonia, North-East Spain. The SIDIAP-H subset of the database includes around 2 million people out of the total 7 million in SIDIAP that are registered in primary care practices with linked hospital inpatient data available as obtained from the Catalan Institute of Health hospitals. Healthcare is universal and tax-payer funded in the region, and primary care physicians are gatekeepers for all care and responsible for repeat prescriptions.	Fundacio Institut Universitari per a la recerca a l'Atencio Primaria de Salut Jordi Gol i Gurina (IDIAPJGol), Barcelona, Spain
STanford medicine Research data Repository (STARR-OMOP)	United States	STanford medicine Research data Repository, a clinical data warehouse containing live Epic data from Stanford Health Care, the Stanford Children's Hospital, the University Healthcare Alliance and Packard Children's Health Alliance clinics and other auxiliary data from Hospital applications such as radiology PACS. STARR platform is developed and operated by Stanford Medicine Research IT team and is made possible by Stanford School of Medicine Research Office.	Department of Medicine, School of Medicine, Stanford University, Redwood City, CA USA
Tufts Research Data Warehouse (TRDW)	United States	Electronic medical record data on approximately 1 million patients who received care beginning in 2006 at Tufts Medical Center (TMC). TMC is an academic medical center that includes Tufts Medical Center's main downtown Boston hospital for adult patients, the Floating Hospital for Children, and associated primary and specialty care clinics. TRDW contains TMC's EHR data fused with data on the same patients from TMC's CoC accredited tumor registry, its oncology EHR, and death data from the Massachusetts State Registry of Vital Statistics. EHR data streams ingested into TRDW include controlled vocabulary data on all domains except cost, and select free text sources and devices.	Tufts Institute for Clinical Research and Health Policy Studies, Boston, MA, 02111, USA

United States Department of Veterans Affairs	United States	VA OMOP data reflects the national Department of Veterans Affairs health care system, which is the largest integrated provider of medical and mental health services in the United States. Care is provided at 170 VA Medical Centers and 1,063 outpatient sites serving more than 9 million enrolled Veterans each year.	VA Informatics and Computing Infrastructure, VA Salt Lake City Health Care System, Salt Lake City, UT, USA; Tennessee Valley Healthcare System, Veterans Affairs Medical Center, Nashville, TN, USA
--	---------------	---	---

Appendix 2. Definitions and codes used to identify COVID-19 cases

The below tables summarise the concepts used to identify patients diagnosed with COVID-19. The full description of the logic used is provided at <https://atlas.ohdsi.org/#/cohortdefinition/200> for COVID-19. Similarly, the full description of the logic used to identify patients hospitalized is provided at <https://atlas.ohdsi.org/#/cohortdefinition/197> for COVID-19.

2.1 COVID-19 condition codes

Concept id	Concept name	Vocabulary
756023	Acute bronchitis due to COVID-19	OMOP Extension
756044	Acute respiratory distress syndrome (ARDS) due to COVID-19	OMOP Extension
756061	Asymptomatic COVID-19	OMOP Extension
756031	Bronchitis due to COVID-19	OMOP Extension
439676	Coronavirus infection	SNOMED
37311061	Disease caused by 2019-nCoV	SNOMED
4100065	Disease due to Coronaviridae	SNOMED
37310284	Encephalopathy caused by 2019 novel coronavirus	SNOMED
37310283	Gastroenteritis caused by 2019 novel coronavirus	SNOMED
4248811	Healthcare associated severe acute respiratory syndrome	SNOMED
756081	Infection of lower respiratory tract due to COVID-19	OMOP Extension
37310286	Infection of upper respiratory tract caused by 2019 novel coronavirus	SNOMED
45763594	Middle East respiratory syndrome	SNOMED
37310287	Myocarditis caused by 2019 novel coronavirus	SNOMED
37310254	Otitis media caused by 2019 novel coronavirus	SNOMED
37310285	Pneumonia caused by 2019 novel coronavirus	SNOMED
37016927	Pneumonia caused by Human coronavirus	SNOMED
40479642	Pneumonia due to Severe acute respiratory syndrome coronavirus	SNOMED
756039	Respiratory infection due to COVID-19	OMOP Extension
320651	Severe acute respiratory syndrome	SNOMED
37396171	Severe acute respiratory syndrome of upper respiratory tract	SNOMED
37311060	Suspected disease caused by 2019-nCoV	SNOMED

2.2 COVID-19 specific testing - Positive

Concept id	Concept name	Vocabulary
37310282	2019 novel coronavirus detected	SNOMED

2.3 COVID-19 specific testing (note, these required a corresponding value as concept of: Detected, Positive, or Present)

Concept id	Concept name	Vocabulary
37310255	Detection of 2019 novel coronavirus using polymerase chain reaction technique	SNOMED
700360	Infectious agent detection by nucleic acid (DNA or RNA); severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Coronavirus disease [COVID-19]), amplified probe technique	CPT4
37310258	Measurement of 2019 novel coronavirus antibody	SNOMED
37310257	Measurement of 2019 novel coronavirus antigen	SNOMED
756055	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)	OMOP Extension
586310	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) Genetic material using Molecular method	OMOP Extension
704991	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Blood	OMOP Extension
756029	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Respiratory specimen	OMOP Extension
586307	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Saliva	OMOP Extension
705107	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Sample from nose	OMOP Extension
586309	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Specified specimen	OMOP Extension
756065	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in Unspecified specimen	OMOP Extension
704992	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Culture method	OMOP Extension
705001	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Nucleic acid amplification technique	OMOP Extension
705000	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Nucleic acid amplification technique in Blood	OMOP Extension
756085	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Nucleic acid amplification technique in Respiratory specimen	OMOP Extension
586308	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using	OMOP Extension

	Nucleic acid amplification technique in Saliva	
705106	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Nucleic acid amplification technique in Sample from nose	OMOP Extension
756084	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Nucleic acid amplification technique in Unspecified specimen	OMOP Extension
704993	Measurement of Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using Sequencing	OMOP Extension
586516	SARS-CoV-2 (COVID19) [Presence] in Unspecified specimen by Organism specific culture	LOINC
723480	SARS-CoV-2 (COVID19) Ab [Interpretation] in Serum or Plasma	LOINC
586515	SARS-CoV-2 (COVID19) Ab [Presence] in Serum or Plasma by Immunoassay	LOINC
586522	SARS-CoV-2 (COVID19) Ab [Units/volume] in Serum or Plasma by Immunoassay	LOINC
706179	SARS-CoV-2 (COVID19) Ab panel - Serum or Plasma by Immunoassay	LOINC
723477	SARS-CoV-2 (COVID19) Ag [Presence] in Respiratory specimen by Rapid immunoassay	LOINC
706166	SARS-CoV-2 (COVID19) E gene [Cycle Threshold #] in Unspecified specimen by NAA with probe detection	LOINC
586523	SARS-CoV-2 (COVID19) E gene [Presence] in Respiratory specimen by NAA with probe detection	LOINC
586518	SARS-CoV-2 (COVID19) E gene [Presence] in Serum or Plasma by NAA with probe detection	LOINC
706174	SARS-CoV-2 (COVID19) E gene [Presence] in Unspecified specimen by NAA with probe detection	LOINC
723473	SARS-CoV-2 (COVID19) IgA Ab [Presence] in Serum or Plasma by Immunoassay	LOINC
586521	SARS-CoV-2 (COVID19) IgA Ab [Presence] in Serum, Plasma or Blood by Rapid immunoassay	LOINC
723459	SARS-CoV-2 (COVID19) IgA Ab [Units/volume] in Serum or Plasma by Immunoassay	LOINC
757686	SARS-CoV-2 (COVID19) IgA+IgM [Presence] in Serum or Plasma by Immunoassay	LOINC
586527	SARS-CoV-2 (COVID19) IgG Ab [Presence] in DBS by Immunoassay	LOINC
723474	SARS-CoV-2 (COVID19) IgG Ab [Presence] in Serum or Plasma by Immunoassay	LOINC
706181	SARS-CoV-2 (COVID19) IgG Ab [Presence] in Serum, Plasma or Blood by Rapid immunoassay	LOINC
706177	SARS-CoV-2 (COVID19) IgG Ab [Units/volume] in Serum or Plasma by Immunoassay	LOINC
706176	SARS-CoV-2 (COVID19) IgG and IgM panel - Serum, Plasma or Blood by Rapid immunoassay	LOINC
723479	SARS-CoV-2 (COVID19) IgG+IgM Ab [Presence] in Serum or Plasma by Immunoassay	LOINC
723475	SARS-CoV-2 (COVID19) IgM Ab [Presence] in Serum or Plasma by Immunoassay	LOINC

706180	SARS-CoV-2 (COVID19) IgM Ab [Presence] in Serum, Plasma or Blood by Rapid immunoassay	LOINC
706178	SARS-CoV-2 (COVID19) IgM Ab [Units/volume] in Serum or Plasma by Immunoassay	LOINC
706167	SARS-CoV-2 (COVID19) N gene [Cycle Threshold #] in Unspecified specimen by NAA with probe detection	LOINC
706157	SARS-CoV-2 (COVID19) N gene [Cycle Threshold #] in Unspecified specimen by Nucleic acid amplification using CDC primer-probe set N1	LOINC
706155	SARS-CoV-2 (COVID19) N gene [Cycle Threshold #] in Unspecified specimen by Nucleic acid amplification using CDC primer-probe set N2	LOINC
715272	SARS-CoV-2 (COVID19) N gene [Presence] in Nasopharynx by NAA with probe detection	LOINC
757678	SARS-CoV-2 (COVID19) N gene [Presence] in Nose by NAA with probe detection	LOINC
706161	SARS-CoV-2 (COVID19) N gene [Presence] in Respiratory specimen by NAA with probe detection	LOINC
586524	SARS-CoV-2 (COVID19) N gene [Presence] in Respiratory specimen by Nucleic acid amplification using CDC primer-probe set N1	LOINC
586525	SARS-CoV-2 (COVID19) N gene [Presence] in Respiratory specimen by Nucleic acid amplification using CDC primer-probe set N2	LOINC
586520	SARS-CoV-2 (COVID19) N gene [Presence] in Serum or Plasma by NAA with probe detection	LOINC
706175	SARS-CoV-2 (COVID19) N gene [Presence] in Unspecified specimen by NAA with probe detection	LOINC
706156	SARS-CoV-2 (COVID19) N gene [Presence] in Unspecified specimen by Nucleic acid amplification using CDC primer-probe set N1	LOINC
706154	SARS-CoV-2 (COVID19) N gene [Presence] in Unspecified specimen by Nucleic acid amplification using CDC primer-probe set N2	LOINC
757680	SARS-CoV-2 (COVID19) neutralizing antibody [Presence] in Serum by pVNT	LOINC
757679	SARS-CoV-2 (COVID19) neutralizing antibody [Titer] in Serum by pVNT	LOINC
723469	SARS-CoV-2 (COVID19) ORF1ab region [Cycle Threshold #] in Respiratory specimen by NAA with probe detection	LOINC
706168	SARS-CoV-2 (COVID19) ORF1ab region [Cycle Threshold #] in Unspecified specimen by NAA with probe detection	LOINC
723478	SARS-CoV-2 (COVID19) ORF1ab region [Presence] in Respiratory specimen by NAA with probe detection	LOINC
723464	SARS-CoV-2 (COVID19) ORF1ab region [Presence] in Unspecified specimen by NAA with probe detection	LOINC
723471	SARS-CoV-2 (COVID19) RdRp gene [Cycle Threshold #] in Respiratory specimen by NAA with probe detection	LOINC
723470	SARS-CoV-2 (COVID19) RdRp gene [Cycle Threshold #] in Unspecified specimen by	LOINC

	NAA with probe detection	
706160	SARS-CoV-2 (COVID19) RdRp gene [Presence] in Respiratory specimen by NAA with probe detection	LOINC
706173	SARS-CoV-2 (COVID19) RdRp gene [Presence] in Unspecified specimen by NAA with probe detection	LOINC
586528	SARS-CoV-2 (COVID19) RNA [Cycle Threshold #] in Respiratory specimen by NAA with probe detection	LOINC
586529	SARS-CoV-2 (COVID19) RNA [Cycle Threshold #] in Unspecified specimen by NAA with probe detection	LOINC
715262	SARS-CoV-2 (COVID19) RNA [Log #/volume] (viral load) in Unspecified specimen by NAA with probe detection	LOINC
723476	SARS-CoV-2 (COVID19) RNA [Presence] in Nasopharynx by NAA with non-probe detection	LOINC
586526	SARS-CoV-2 (COVID19) RNA [Presence] in Nasopharynx by NAA with probe detection	LOINC
757677	SARS-CoV-2 (COVID19) RNA [Presence] in Nose by NAA with probe detection	LOINC
706163	SARS-CoV-2 (COVID19) RNA [Presence] in Respiratory specimen by NAA with probe detection	LOINC
715260	SARS-CoV-2 (COVID19) RNA [Presence] in Saliva (oral fluid) by NAA with probe detection	LOINC
715261	SARS-CoV-2 (COVID19) RNA [Presence] in Saliva (oral fluid) by Sequencing	LOINC
723463	SARS-CoV-2 (COVID19) RNA [Presence] in Serum or Plasma by NAA with probe detection	LOINC
706170	SARS-CoV-2 (COVID19) RNA [Presence] in Unspecified specimen by NAA with probe detection	LOINC
706158	SARS-CoV-2 (COVID19) RNA panel - Respiratory specimen by NAA with probe detection	LOINC
706169	SARS-CoV-2 (COVID19) RNA panel - Unspecified specimen by NAA with probe detection	LOINC
723467	SARS-CoV-2 (COVID19) S gene [Cycle Threshold #] in Respiratory specimen by NAA with probe detection	LOINC
723468	SARS-CoV-2 (COVID19) S gene [Cycle Threshold #] in Unspecified specimen by NAA with probe detection	LOINC
723465	SARS-CoV-2 (COVID19) S gene [Presence] in Respiratory specimen by NAA with probe detection	LOINC
586519	SARS-CoV-2 (COVID19) S gene [Presence] in Serum or Plasma by NAA with probe detection	LOINC
723466	SARS-CoV-2 (COVID19) S gene [Presence] in Unspecified specimen by NAA with probe detection	LOINC
586517	SARS-CoV-2 (COVID19) whole genome [Nucleotide sequence] in Isolate by Sequencing	LOINC

40218805	Testing for SARS-CoV-2 in CDC laboratory	HCPCS
40218804	Testing for SARS-CoV-2 in non-CDC laboratory	HCPCS

Appendix 3. Definitions and medications used to identify asthma patients

3.1 Asthma diagnosis

Group	Concept id	Concept name	Vocabulary
Asthma diagnosis	252658	Intrinsic asthma without status asthmaticus	SNOMED
	252942	Asthmatic pulmonary eosinophilia	SNOMED
	256448	Chronic asthmatic bronchitis	SNOMED
	257581	Exacerbation of asthma	SNOMED
	257583	Allergic bronchopulmonary aspergillosis	SNOMED
	312950	IgE-mediated allergic asthma	SNOMED
	313236	Cough variant asthma	SNOMED
	317009	Asthma	SNOMED
	443801	Exercise-induced asthma	SNOMED
	761844	Inhaled steroid-dependent asthma	SNOMED
	764677	Persistent asthma	SNOMED
	764949	Persistent asthma, well controlled	SNOMED
	2108536	Persistent asthma, preferred long term control medication or an acceptable alternative treatment, prescribed (NMA-No Measure Associated)	CPT4
	4022592	Millers' asthma	SNOMED
	4051466	Childhood asthma	SNOMED
	4057952	Meat-wrappers' asthma	SNOMED
	4075237	Brittle asthma	SNOMED
	4080516	Printers' asthma	SNOMED
	4081994	Tropical pulmonary eosinophilia	SNOMED
	4110051	Mixed asthma	SNOMED
	4119298	Late onset asthma	SNOMED
	4119300	Colophony asthma	SNOMED
	4120261	Sulfite-induced asthma	SNOMED
	4120262	Cryptogenic pulmonary eosinophilia	SNOMED
	4123253	Hay fever with asthma	SNOMED
	4125022	Acute asthma	SNOMED
	4138760	Exacerbation of intermittent asthma	SNOMED
	4141978	Intermittent asthma	SNOMED
	4142738	Moderate persistent asthma	SNOMED
	4143474	Bakers' asthma	SNOMED
	4143828	Mild persistent asthma	SNOMED
	4145356	Severe persistent asthma	SNOMED
	4145497	Intrinsic asthma	SNOMED
	4146581	Mild intermittent asthma	SNOMED
	4152913	Severe asthma	SNOMED
	4155468	Mild asthma	SNOMED
	4155469	Moderate asthma	SNOMED
	4155470	Occasional asthma	SNOMED
	4191479	Allergic asthma	SNOMED
	4206340	Asthma without status asthmaticus	SNOMED
	4211530	Asthma caused by wood dust	SNOMED
	4212099	Occupational asthma	SNOMED
	4217558	Detergent asthma	SNOMED
	4225553	Cheese-makers' asthma	SNOMED
	4225554	Isocyanate induced asthma	SNOMED
	4232595	Platinum asthma	SNOMED
	4233784	Asthmatic bronchitis	SNOMED
	4235703	Asthma management	SNOMED
	4244339	Drug-induced asthma	SNOMED
	4245292	Weavers' cough	SNOMED
	4245676	Chemical-induced asthma	SNOMED
	4250128	Aspirin-induced asthma	SNOMED
	4271333	Allergic asthma without status asthmaticus	SNOMED
	4277596	Simple pulmonary eosinophilia	SNOMED
	4279553	Eosinophilic asthma	SNOMED
	4301938	Tea-makers' asthma	SNOMED
	4309833	Non-IgE mediated allergic asthma	SNOMED
	4312524	Substance induced asthma	SNOMED

	35609846	Life threatening acute exacerbation of extrinsic asthma	SNOMED
	35609847	Life threatening acute exacerbation of non-allergic asthma	SNOMED
	36684328	Acute severe exacerbation of allergic asthma	SNOMED
	36684335	Exacerbation of allergic asthma due to infection	SNOMED
	37108580	Severe controlled persistent asthma	SNOMED
	37108581	Severe uncontrolled persistent asthma	SNOMED
	37109103	Oral steroid-dependent asthma	SNOMED
	37116845	Acute severe refractory exacerbation of asthma	SNOMED
	37206717	Near fatal asthma	SNOMED
	37208352	SAFS - severe asthma with fungal sensitisation	SNOMED
	37310241	Intermittent allergic asthma	SNOMED
	40481763	Acute exacerbation of chronic asthmatic bronchitis	SNOMED
	40483397	Seasonal asthma	SNOMED
	42535716	Asthma in pregnancy	SNOMED
	42536207	Life threatening acute exacerbation of asthma	SNOMED
	42536208	Moderate acute exacerbation of asthma	SNOMED
	42536649	Uncomplicated non-allergic asthma	SNOMED
	42538744	Exacerbation of allergic asthma	SNOMED
	42539549	Uncomplicated allergic asthma	SNOMED
	43530693	Acute exacerbation of chronic obstructive airways disease with asthma	SNOMED
	43530745	Asthma with irreversible airway obstruction	SNOMED
	44783610	Asthma self management	SNOMED
	44810117	Chronic asthma with fixed airflow obstruction	SNOMED
	44810118	Eosinophilic bronchitis	SNOMED
	45757063	Allergic bronchopulmonary mycosis	SNOMED
	45766727	Allergic asthma due to Dermatophagoides pteronyssinus	SNOMED
	45766728	Allergic asthma due to Dermatophagoides farinae	SNOMED
	45768910	Uncomplicated asthma	SNOMED
	45768911	Exacerbation of mild persistent asthma	SNOMED
	45768912	Exacerbation of severe persistent asthma	SNOMED
	45768963	Uncomplicated mild persistent asthma	SNOMED
	45768964	Uncomplicated moderate persistent asthma	SNOMED
	45768965	Uncomplicated severe persistent asthma	SNOMED
	45769350	Acute severe exacerbation of severe persistent asthma	SNOMED
	45769351	Acute severe exacerbation of moderate persistent asthma	SNOMED
	45769352	Acute severe exacerbation of mild persistent asthma	SNOMED
	45769438	Acute severe exacerbation of asthma	SNOMED
	45769441	Acute exacerbation of allergic asthma	SNOMED
	45769442	Acute severe exacerbation of immunoglobulin E-mediated allergic asthma	SNOMED
	45769443	Acute severe exacerbation of intrinsic asthma	SNOMED
	45771045	Acute exacerbation of asthma	SNOMED
	45772073	Asthma in mother complicating childbirth	SNOMED
	45772937	Exacerbation of moderate persistent asthma	SNOMED
	45773005	Acute exacerbation of intrinsic asthma	SNOMED
	46269767	Acute severe exacerbation of asthma co-occurrent with allergic rhinitis	SNOMED
	46269770	Severe persistent allergic asthma	SNOMED
	46269771	Acute severe exacerbation of severe persistent asthma co-occurrent with allergic rhinitis	SNOMED
	46269776	Mild persistent allergic asthma	SNOMED
	46269777	Acute severe exacerbation of mild persistent allergic asthma co-occurrent with allergic rhinitis	SNOMED
	46269784	Moderate persistent allergic asthma	SNOMED
	46269785	Acute severe exacerbation of moderate persistent asthma co-occurrent with allergic rhinitis	SNOMED
	46269801	Aspirin exacerbated respiratory disease	SNOMED
	46269802	Chronic obstructive asthma co-occurrent with acute exacerbation of asthma	SNOMED
	46270028	Severe persistent asthma co-occurrent with allergic rhinitis	SNOMED
	46270029	Mild persistent asthma co-occurrent with allergic rhinitis	SNOMED
	46270030	Intermittent asthma co-occurrent with allergic rhinitis	SNOMED
	46270082	Acute exacerbation of mild persistent asthma	SNOMED
	46270322	Intermittent asthma uncontrolled	SNOMED
	46273452	Acute exacerbation of asthma co-occurrent with allergic rhinitis	SNOMED
	46273454	Moderate persistent asthma co-occurrent with allergic rhinitis	SNOMED
	46273462	Acute severe exacerbation of moderate persistent allergic asthma	SNOMED
	46273487	Acute exacerbation of moderate persistent asthma	SNOMED

No COPD diagnosis	46273635	Steroid dependent asthma	SNOMED
	46274059	Acute severe exacerbation of severe persistent allergic asthma	SNOMED
	46274062	Asthma-chronic obstructive pulmonary disease overlap syndrome	SNOMED
	46274124	Acute severe exacerbation of mild persistent allergic asthma	SNOMED
	255573	Chronic obstructive lung disease	SNOMED
	257004	Acute exacerbation of chronic obstructive airways disease	SNOMED
	258780	Emphysematous bronchitis	SNOMED
	259043	Emphysematous bleb of lung	SNOMED
	261325	Pulmonary emphysema	SNOMED
	261895	Compensatory emphysema	SNOMED
	440748	Interstitial emphysema of lung	SNOMED
	3185549	Bronchiectasis with acute exacerbation	Nebraska Lexicon
	4046986	End stage chronic obstructive airways disease	SNOMED
	4050732	Pulmonary emphysema in alpha-1 PI deficiency	SNOMED
	4050733	Toxic emphysema	SNOMED
	4050734	Scar emphysema	SNOMED
	4050961	Giant bullous emphysema	SNOMED
	4056405	Obstructive emphysema	SNOMED
	4083395	Vanishing lung	SNOMED
	4104506	Cystic-bullous disease of the lung	SNOMED
	4110048	Chronic bullous emphysema	SNOMED
	4110056	Chronic obstructive pulmonary disease with acute lower respiratory infection	SNOMED
	4110635	Segmental bullous emphysema	SNOMED
	4112828	Zonal bullous emphysema	SNOMED
	4112836	Chronic emphysema due to chemical fumes	SNOMED
	4115044	Acute infective exacerbation of chronic obstructive airways disease	SNOMED
	4136683	Paraseptal emphysema	SNOMED
	4138392	Chronic obliterative bronchiolitis due to inhalation of chemical fumes AND/OR vapors	SNOMED
	4145496	Bullous emphysema with collapse	SNOMED
	4148124	Atrophic (senile) emphysema	SNOMED
	4166508	Congenital emphysema	SNOMED
	4166517	Chronic obliterative bronchiolitis	SNOMED
	4177944	Panacinar emphysema	SNOMED
	4193588	Moderate chronic obstructive pulmonary disease	SNOMED
	4196712	Mild chronic obstructive pulmonary disease	SNOMED
	4209097	Severe chronic obstructive pulmonary disease	SNOMED
	4246105	Hemolytic anemia with emphysema AND cutis laxa	SNOMED
	4278831	Chronic diffuse emphysema due to inhalation of chemical fumes AND/OR vapors	SNOMED
	4286497	Centriacinar emphysema	SNOMED
	4315386	Ruptured emphysematous bleb of lung	SNOMED
	43530693	Acute exacerbation of chronic obstructive airways disease with asthma	SNOMED
	44791725	Very severe chronic obstructive pulmonary disease	SNOMED
	44807895	Acute non-infective exacerbation of chronic obstructive pulmonary disease	SNOMED
	45769389	Pulmonary emphysema co-occurrent with fibrosis of lung	SNOMED
	46269701	Chronic obstructive lung disease co-occurrent with acute bronchitis	SNOMED
	46270376	Acute exacerbation of chronic obstructive bronchitis	SNOMED
	46274062	Asthma-chronic obstructive pulmonary disease overlap syndrome	SNOMED
No LAMA therapy	21603292	Anticholinergics	ATC

3.2 Medications used to define asthma diagnosis and treatments

	Concept id	Concept name	Vocabulary
Long-acting beta agonists	43024344	vilanterol Inhalation Powder	RxNorm Extension
	43180317	vilanterol Dry Powder Inhaler	RxNorm Extension
	1356189	salmeterol Metered Dose Inhaler	RxNorm
	783089	salmeterol Inhalation Solution	RxNorm Extension

	35158799	salmeterol Inhalation Powder	RxNorm Extension
	40167702	salmeterol Dry Powder Inhaler	RxNorm
	45775117	olodaterol Metered Dose Inhaler	RxNorm
	21174574	olodaterol Inhalant Solution	RxNorm Extension
	40746100	olodaterol Inhalant Powder	RxNorm Extension
	44055847	indacaterol Metered Dose Inhaler	RxNorm Extension
	1356211	indacaterol Inhalation Powder	RxNorm
	42479568	indacaterol Dry Powder Inhaler	RxNorm Extension
	1356187	formoterol Inhalation Solution	RxNorm
	1356191	formoterol Inhalation Powder	RxNorm
Short-acting beta agonists	36812414	Terbutaline Inhalation Solution	RxNorm Extension
	36813480	Terbutaline Inhalation Powder	RxNorm Extension
	40152687	pirbuterol Metered Dose Inhaler	RxNorm
	41205378	pirbuterol Dry Powder Inhaler	RxNorm Extension
	40143276	levalbuterol Metered Dose Inhaler	RxNorm
	1356103	levalbuterol Inhalation Solution	RxNorm
	40142703	albuterol Metered Dose Inhaler	RxNorm
	1356108	albuterol Inhalation Solution	RxNorm
	1356111	albuterol Inhalation Powder	RxNorm
	46234463	albuterol Dry Powder Inhaler	RxNorm
Long-acting muscarinic antagonist	41142750	umeclidinium Inhalant Solution	RxNorm Extension
	43285708	umeclidinium Inhalant Powder	RxNorm Extension
	45774869	umeclidinium Dry Powder Inhaler	RxNorm
	45774773	tiotropium Metered Dose Inhaler	RxNorm
	1356250	tiotropium Inhalation Powder	RxNorm
	42482607	tiotropium Inhalant Solution	RxNorm Extension
	42482075	tiotropium Dry Powder Inhaler	RxNorm Extension
	35149223	glycopyrronium Metered Dose Inhaler	RxNorm Extension
	1356202	glycopyrronium Inhalation Solution	RxNorm
	1356199	glycopyrronium Inhalation Powder	RxNorm
	43292583	glycopyrronium Inhalant Powder	RxNorm Extension
	43179057	glycopyrronium Dry Powder Inhaler	RxNorm Extension
	41236953	aclidinium Inhalant Solution	RxNorm Extension
	44069324	aclidinium Inhalant Powder	RxNorm Extension
	42873412	aclidinium Dry Powder Inhaler	RxNorm

Leukotriene receptor antagonists	1111706	zafirlukast	RxNorm
	43009065	pranlukast hydrate	RxNorm Extension
	1154161	montelukast	RxNorm
	43009091	ibudilast	RxNorm Extension
Inhaled corticosteroids	44817882	mometasone Metered Dose Inhaler	RxNorm
	40892816	Mometasone Inhalant Solution	RxNorm Extension
	36894464	Mometasone Inhalant Powder	RxNorm Extension
	40143326	mometasone Dry Powder Inhaler	RxNorm
	40144037	fluticasone Metered Dose Inhaler	RxNorm
	41080160	fluticasone Injectable Solution	RxNorm Extension
	35149212	fluticasone Inhalation Solution	RxNorm Extension
	35147990	fluticasone Inhalation Powder	RxNorm Extension
	40144035	fluticasone Dry Powder Inhaler	RxNorm
	44120754	Budesonide Metered Dose Inhaler	RxNorm Extension
	1356140	budesonide Inhalation Suspension	RxNorm
	35135829	Budesonide Inhalation Solution	RxNorm Extension
	1356143	budesonide Inhalation Powder	RxNorm
	40142920	budesonide Dry Powder Inhaler	RxNorm
	40142784	beclomethasone Metered Dose Inhaler	RxNorm
	35130061	Beclomethasone Inhalation Solution	RxNorm Extension
	36883710	Beclomethasone Inhalant Powder	RxNorm Extension
	42480194	Beclomethasone Dry Powder Inhaler	RxNorm Extension
Combo-therapy	40223712	formoterol / mometasone Metered Dose Inhaler	RxNorm
	41267401	fluticasone / vilanterol Inhalant Solution	RxNorm Extension
	43291091	fluticasone / vilanterol Inhalant Powder	RxNorm Extension
	43532281	fluticasone / vilanterol Dry Powder Inhaler	RxNorm
	37592046	fluticasone / vilanterol / vilanterol Dry Powder Inhaler	RxNorm Extension
	40755794	fluticasone / umeclidinium / vilanterol Inhalant Powder	RxNorm Extension
	792484	fluticasone / umeclidinium / vilanterol Dry Powder Inhaler	RxNorm
	40144024	fluticasone / salmeterol Metered Dose Inhaler	RxNorm
	42482744	fluticasone / salmeterol Inhalant Solution	RxNorm Extension
	36882733	fluticasone / salmeterol Inhalant Powder	RxNorm Extension
	40144020	fluticasone / salmeterol Dry Powder Inhaler	RxNorm
	21089505	fluticasone / formoterol Inhalant Solution	RxNorm Extension
	40754973	fluticasone / formoterol Inhalant Powder	RxNorm Extension

41048760	fluticasone / formoterol Dry Powder Inhaler	RxNorm Extension
36787269	Budesonide / salmeterol Inhalant Powder	RxNorm Extension
40142910	budesonide / formoterol Metered Dose Inhaler	RxNorm
783228	Budesonide / formoterol Inhalation Solution	RxNorm Extension
35133500	Budesonide / formoterol Inhalation Powder	RxNorm Extension
42479684	Budesonide / formoterol Dry Powder Inhaler	RxNorm Extension
21090035	Beclomethasone / formoterol Inhalant Solution	RxNorm Extension
36894458	Beclomethasone / formoterol Inhalant Powder	RxNorm Extension
21158944	Beclomethasone / formoterol Dry Powder Inhaler	RxNorm Extension
36787954	Beclomethasone / formoterol / glycopyrronium Inhalant Solution	RxNorm Extension
40745353	Beclomethasone / formoterol / glycopyrronium Inhalant Powder	RxNorm Extension
36421291	Beclomethasone / formoterol / glycopyrronium Dry Powder Inhaler	RxNorm Extension
36250078	azelastine / fluticasone Metered Dose Nasal Spray	RxNorm
36812530	Albuterol / Beclomethasone Inhalation Powder	RxNorm Extension
42483138	Albuterol / Beclomethasone Dry Powder Inhaler	RxNorm Extension

Characteristics and outcomes of COVID-19 patients with and without asthma from the United States, South Korea, and Europe

SUPPLEMENTARY TABLES

Supplementary table S1. Prevalence of asthma exacerbation at presentation among patients diagnosed and hospitalized with COVID-19.

Cohort	US CUIMC	US HealthVerity	US IQVIA OpenClaims	US STARR-OMOP	US VA-OMOP	KR HIRA	UK CPRD	ES SIDIAP
Diagnosed COVID-19 (%) (95%CI)	5.3 (4.2-6.6)	2.7 (2.2-3.3)	3.9 (3.8-4.0)	5.2 (3.6-7.5)	1.6 (1.2-2.1)	-	1.7 (0.8-3.7)	1.6 (1.3-1.9)
Hospitalized COVID-19 (%) (95%CI)	4.6 (3.1-6.9)	8.6 (6.1-12.0)	6.1 (5.8-6.4)	-	3.3 (2.1-5.0)	0.8 (0.5-1.4)	-	2.1 (1.4-3.2)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. Grey=US databases. Red=South Korean database. Orange=European databases. Grey=US databases. Red=South Korean database. Orange=European databases. 95%CI = 95% Confidence Interval. IPCI data excluded as not recorded.

Supplementary table S2. Age and gender distribution of asthma patients diagnosed and hospitalized with COVID-19.

Characteristic	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC		HealthVerity		IQVIA OpenClaims		VA-OMOP		STARR-OMOP	HIRA	CPRD	IPCI	SIDIAP	
	N=1338	N=479	N=3367	N=349	N=86328	N=23211	N=2953	N=607	N=501	N=1560	N=343	N=156	N=7536	N=952
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
age group: 00-04	1.3%	1.5%	0.4%	0.0%	1.1%	1.1%	0.0%	0.0%	2.2%	1.9%	0.8%	0.0%	0.0%	0.0%
age group: 05-09	1.8%	2.3%	1.1%	<1.4%	1.5%	1.0%	0.0%	0.0%	1.0%	1.3%	1.7%	0.0%	0.0%	0.0%
age group: 10-14	1.3%	2.1%	1.1%	0.0%	1.6%	0.6%	0.0%	0.0%	1.0%	1.6%	2.4%	0.0%	<1.5%	<0.5%
age group: 15-19	2.2%	2.5%	1.8%	0.0%	2.4%	1.0%	0.0%	0.0%	2.6%	2.2%	2.5%	<1.2%	0.0%	0.80%
age group: 20-24	2.8%	2.7%	4.0%	1.7%	4.3%	1.8%	<0.2%	0.0%	4.2%	8.7%	5.3%	<1.2%	<1.5%	0.80%
age group: 25-29	5.1%	4.2%	5.0%	<1.4%	5.2%	2.4%	1.5%	<0.8%	5.0%	8.3%	6.5%	1.4%	3.8%	1.80%
age group: 30-34	6.3%	3.3%	6.7%	2.0%	5.8%	3.2%	4.5%	1.6%	4.0%	5.1%	6.8%	1.4%	6.7%	1.80%
age group: 35-39	7.0%	2.5%	7.4%	4.9%	6.3%	3.6%	6.4%	1.2%	7.6%	4.9%	9.4%	2.2%	4.7%	2.50%
age group: 40-44	7.3%	2.1%	9.1%	4.6%	7.2%	4.8%	7.5%	3.8%	6.0%	5.3%	12.4%	6.2%	5.8%	7.90%
age group: 45-49	6.7%	4.6%	11.6%	8.3%	8.4%	6.4%	8.3%	5.3%	7.8%	7.4%	11.9%	8.2%	7.9%	8.70%
age group: 50-54	10.3%	7.1%	15.1%	10.9%	10.1%	8.9%	13.1%	10.2%	8.6%	9.0%	10.5%	8.2%	12.5%	9.00%
age group: 55-59	9.6%	8.4%	10.1%	12.9%	11.0%	11.9%	14.1%	11.2%	12.2%	9.6%	8.1%	8.7%	10.5%	10.30%
age group: 60-64	10.1%	9.4%	8.6%	11.7%	9.7%	12.3%	14.1%	15.5%	11.0%	11.5%	5.6%	8.7%	10.8%	9.10%
age group: 65-69	7.4%	11.1%	6.3%	10.0%	6.9%	9.9%	10.5%	15.3%	8.0%	7.1%	2.9%	4.8%	6.4%	7.20%
age group: 70-74	6.5%	9.6%	6.0%	14.9%	5.6%	9.2%	9.9%	15.0%	8.2%	4.6%	2.9%	12.0%	5.2%	9.80%
age group: 75-79	4.3%	7.5%	2.4%	4.3%	4.2%	7.5%	4.8%	7.6%	5.6%	5.1%	2.5%	12.0%	6.4%	10.20%
age group: 80-84	4.3%	8.1%	2.2%	8.6%	3.4%	6.0%	2.1%	4.9%	3.2%	3.3%	2.2%	10.6%	7.6%	7.40%
age group: 85-89	2.8%	5.8%	0.0%	0.0%	5.3%	8.3%	1.9%	4.6%	1.8%	2.2%	3.0%	6.2%	6.7%	7.70%
age group: 90-94	2.2%	4.4%	1.2%	3.4%	0.0%	0.0%	0.8%	2.3%	<1.0%	1.0%	1.8%	6.2%	2.0%	4.00%
age group: 95-99	0.4%	<1.0%	0.0%	0.0%	0.0%	0.0%	0.4%	<0.8%	0.0%	<0.3%	0.6%	1.2%	<1.5%	0.80%
gender = female	68.0%	62.4%	66.1%	63.9%	64.2%	60.8%	22.7%	11.9%	65.3%	64.9%	66.1%	69.2%	60.3%	64.20%
gender = male	32.0%	37.6%	33.9%	36.1%	35.8%	39.2%	77.3%	88.1%	34.7%	35.1%	33.9%	30.8%	39.7%	35.80%

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. VA-OMOP population predominantly male.

Supplementary table S3. Age and gender distribution of patients without asthma diagnosed and hospitalized with COVID-19.

Characteristic	US CUIMC		US HealthVerity		US IQVIA OpenClaims		US VA-OMOP		US STARR- OMOP	KR HIRA	UK CPRD	NL IPCI	ES SIDIAP	
	(n = 7,181)	(n = 2,121)	(n = 35,194)	(n = 3,264)	(n = 379,863)	(n = 109,880)	(n = 21,659)	(n = 4,903)	(n = 2,827)	(n = 6,039)	(n = 1,993)	(n = 1,172)	(n = 114,522)	(n = 17,245)
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
age group: 00-04	1.1%	1.7%	0.1%	<0.2%	0.7%	0.5%	0.0%	0.0%	0.6%	0.2%	0.4%	<0.4%	1.2%	0.1%
age group: 05-09	0.3%	0.4%	0.2%	0.0%	0.6%	0.3%	0.0%	0.0%	0.6%	0.3%	0.5%	<0.4%	1.0%	0.0%
age group: 10-14	0.3%	0.5%	0.4%	0.0%	0.6%	0.2%	0.4%	0.0%	0.7%	1.0%	<0.3%	0.5%	0.8%	0.1%
age group: 15-19	0.4%	0.7%	1.0%	<0.2%	1.1%	0.3%	2.3%	0.0%	2.2%	3.8%	0.5%	0.8%	1.2%	0.2%
age group: 20-24	1.3%	1.1%	3.6%	0.5%	2.8%	0.8%	5.3%	0.1%	3.3%	13.9%	1.4%	3.3%	3.5%	0.6%
age group: 25-29	5.5%	2.0%	5.6%	0.9%	4.3%	1.4%	6.1%	0.4%	4.2%	12.5%	2.4%	4.4%	5.4%	1.1%
age group: 30-34	9.1%	3.1%	6.7%	1.6%	5.4%	1.9%	5.3%	1.0%	6.0%	5.0%	3.4%	4.7%	6.3%	1.9%
age group: 35-39	8.8%	3.7%	7.3%	1.6%	5.8%	2.7%	5.6%	1.9%	6.6%	5.3%	4.7%	4.9%	8.4%	2.8%
age group: 40-44	7.7%	3.3%	7.6%	3.0%	6.1%	3.1%	7.9%	1.8%	6.7%	5.4%	5.3%	7.2%	10.6%	4.8%
age group: 45-49	7.3%	4.2%	8.5%	4.2%	6.9%	4.4%	9.3%	2.4%	6.5%	7.9%	6.7%	10.2%	10.5%	6.0%
age group: 50-54	7.9%	5.6%	10.5%	6.0%	8.1%	6.3%	12.1%	4.4%	9.2%	10.5%	8.6%	9.4%	9.4%	7.8%
age group: 55-59	8.6%	7.6%	12.1%	10.3%	9.3%	8.8%	10.6%	6.6%	10.8%	9.6%	9.9%	10.2%	8.6%	9.4%
age group: 60-64	8.9%	9.1%	11.4%	11.8%	9.6%	11.3%	16.0%	11.7%	10.2%	7.9%	8.0%	9.5%	6.9%	9.5%
age group: 65-69	8.0%	11.6%	8.4%	14.2%	8.5%	11.8%	8.4%	13.3%	10.3%	4.9%	5.2%	6.4%	4.3%	9.0%
age group: 70-74	7.1%	10.9%	5.9%	14.6%	7.6%	12.0%	3.9%	22.3%	9.6%	4.0%	7.4%	5.7%	4.1%	10.4%
age group: 75-79	5.7%	10.7%	4.2%	11.5%	6.5%	10.7%	3.6%	13.5%	6.9%	3.4%	7.9%	7.6%	4.1%	11.2%
age group: 80-84	4.8%	9.4%	3.4%	10.4%	5.6%	9.1%	2.2%	6.5%	3.7%	2.1%	9.5%	5.2%	4.0%	9.8%
age group: 85-89	3.6%	7.2%	0.0%	9.3%	10.5%	14.3%	0.9%	6.8%	1.8%	1.7%	8.2%	6.1%	4.8%	9.1%
age group: 90-94	2.5%	5.3%	3.0%	0.0%	0.0%	0.0%	0.1%	4.8%	<0.4%	0.6%	6.9%	2.6%	3.5%	4.7%
age group: 95-99	0.7%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	0.1%	2.7%	0.7%	1.3%	1.3%
gender = female	43.6%	44.6%	45.3%	47.2%	47.4%	45.1%	15.4%	4.8%	50.7%	57.7%	43.8%	59.5%	57.3%	44.1%
gender = male	56.4%	55.3%	54.7%	52.8%	52.6%	54.9%	84.6%	95.2%	49.3%	42.3%	56.2%	40.5%	42.7%	55.9%

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. VA-OMOP population predominantly male.

Supplementary table S4. Comorbidities in COVID-19 patients with asthma in the diagnosed and hospitalized cohorts.

Characteristic (% 95%CI)	US CUIMC (% 95%CI)		US HealthVerity (% 95%CI)		US IQVIA OpenClaims (% 95%CI)		US VA-OMOP (% 95%CI)		US STARR- OMOP (% 95%CI)	KR HIRA (% 95%CI)	UK CPRD (% 95%CI)	NL IPCI (% 95%CI)	ES SIDIAP (% 95%CI)	
	N=1338	N=479	N=3367	N=349	N=86328	N=23211	N=2953	N=607	N=501	N=1560	N=343	N=156	N=7536	N=952
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
<i>Asthma/atopy related</i>														
Allergic disorder	10.2 (8.7-11.9)	9.2 (6.9-12.1)	15.8 (14.6-17.1)	13.2 (10-17.2)	14.1 (13.9-14.3)	11.3 (10.9-11.7)	22.8 (21.3-24.3)	20.4 (17.4-23.8)	12 (9.4-15.1)	86.3 (84.5-87.9)	<1.5	16 (11.1-22.6)	35.7 (34.6-36.8)	32.5 (29.6-35.5)
Allergic rhinitis	9.0 (7.6-10.7)	7.7 (5.6-10.4)	14.6 (13.4-15.8)	12 (9-15.8)	12.4 (12.2-12.6)	9.7 (9.3-10.1)	20.4 (19-21.9)	17.8 (15-21)	10.4 (8-13.4)	82.2 (80.2-84)	<1.5	8.3 (4.9-13.7)	31.1 (30.1-32.2)	27.7 (25-30.6)
Bronchiectasis	2.0 (1.4-2.9)	3.3 (2.0-5.3)	0.9 (0.6-1.3)	<1.4	0.7 (0.6-0.8)	1.2 (1.1-1.3)	0.5 (0.3-0.8)	1.2 (0.6-2.4)	3.8 (2.4-5.9)	1.2 (0.8-1.9)	<1.5	<3.2	2.3 (2-2.7)	4.7 (3.5-6.2)
COPD	6.7 (5.5-8.2)	11.5 (8.9-14.7)	5.9 (5.2-6.7)	14.0 (10.8-18)	9.9 (9.7-10.1)	18.6 (18.1-19.1)	17.6 (16.3-19)	30.3 (26.8-34.1)	4.2 (2.8-6.3)	2.8 (2.1-3.7)	2.3 (1.2-4.5)	4.5 (2.2-9)	3.4 (3-3.8)	6.6 (5.2-8.4)
Eczema	2.0 (1.4-2.9)	<1	2.1 (1.7-2.6)	2.3 (1.2-4.5)	2.1 (2-2.2)	1.8 (1.6-2)	3.8 (3.2-4.6)	3.3 (2.1-5)	2 (1.1-3.6)	10.1 (8.7-11.7)	<1.5	3.2 (1.4-7.3)	9 (8.4-9.7)	4.8 (3.6-6.3)
Exacerbation of asthma	8.5 (7.1-10.1)	9.2 (6.9-12.1)	14.0 (12.9-15.2)	17.8 (14.1-22.2)	10.6 (10.4-10.8)	13.2 (12.8-13.6)	6.5 (5.7-7.4)	7.7 (5.8-10.1)	12.4 (9.8-15.6)	1.3 (0.8-2)	4.7 (2.9-7.5)	0.0	1.7 (1.4-2)	23 (20.4-25.8)
Interstitial lung disease	1.5 (1.0-2.3)	3.8 (2.4-5.9)	0.7 (0.5-1)	2.9 (1.6-5.2)	1.3 (1.2-1.4)	3.7 (3.5-4)	1.3 (1-1.8)	2.3 (1.4-3.8)	1.4 (0.7-2.9)	0.5 (0.3-1)	0.0	0.0	0.2 (0.1-0.3)	<0.5
Obesity	56.1 (53.4-58.7)	63.3 (58.9-67.5)	26.6 (25.1-28.1)	35.5 (30.7-40.7)	46 (45.7-46.3)	53.4 (52.8-54)	63 (61.2-64.7)	68.5 (64.7-72.1)	48.1 (43.8-52.5)	N/A	58.6 (53.3-63.7)	30.1 (23.5-37.7)	36.1 (35-37.2)	55.9 (52.7-59)
Sleep apnoea	7.4 (6.1-8.9)	7.3 (5.3-10.0)	10.8 (9.8-11.9)	13.5 (10.3-17.5)	9.9 (9.7-10.1)	14.2 (13.8-14.7)	35.5 (33.8-37.2)	39.4 (35.6-43.3)	20.4 (17.1-24.1)	0.8 (0.5-1.4)	<1.5	<3.2	3.7 (3.3-4.2)	9.6 (7.9-11.6)
Urticaria	1.3 (0.8-2.1)	<1	1.3 (1-1.7)	<1.4	1.2 (1.1-1.3)	0.9 (0.8-1)	1 (0.7-1.4)	1.2 (0.6-2.4)	2 (1.1-3.6)	18.5 (16.7-20.5)	<1.5	<3.2	5.3 (4.8-5.8)	4.4 (3.3-5.9)
<i>Cardiometabolic</i>														
Atrial fibrillation	5.5 (4.4-6.9)	9 (6.8-11.9)	3.2 (2.7-3.8)	11.7 (8.7-15.5)	5.5 (5.3-5.7)	10.4 (10-10.8)	7.3 (6.4-8.3)	14.5 (11.9-17.5)	8.6 (6.4-11.4)	1.3 (0.8-2)	<1.5	3.2 (1.4-7.3)	2.9 (2.5-3.3)	8.0 (6.4-9.9)
Cardiac arrhythmia	9.0 (7.6-10.7)	14.2 (11.4-17.6)	6.4 (5.6-7.3)	17.2 (13.6-21.5)	10.3 (10.1-10.5)	18.7 (10-10.8)	12.9 (11.7-14.2)	24.2 (21-27.8)	14.2 (11.4-17.5)	4.4 (3.5-5.5)	1.7 (0.8-3.7)	4.5 (2.2-9)	7.6 (7-8.2)	16.1 (13.9-18.6)
Cerebrovascular disease	3.5 (2.6-4.6)	4.2 (2.7-6.4)	3.4 (2.8-4.1)	8.6 (6.1-12)	4.5 (4.4-4.6)	7.6 (7.3-7.9)	3.8 (3.2-4.6)	4.9 (3.4-6.9)	3.8 (2.4-5.9)	4.4 (3.5-5.5)	<1.5	3.2 (1.4-7.3)	0.9 (0.7-1.1)	2.3 (1.5-3.5)
Heart failure	8.3 (6.9-9.9)	16.5 (13.4-20.1)	5.4 (4.7-6.2)	17.5 (13.9-21.8)	9 (8.8-9.2)	19 (18.5-19.5)	9.1 (8.1-10.2)	20.9 (17.9-24.3)	7.8 (5.8-10.5)	5.5 (4.5-6.7)	<1.5	3.2 (1.4-7.3)	2.4 (2.1-2.8)	8.2 (6.6-10.1)
Myocardial infarction	3.3 (2.5-4.4)	7.1 (5.1-9.8)	1.5 (1.1-2)	4.6 (2.9-7.3)	2.3 (2.2-2.4)	5.4 (5.1-5.7)	3.7 (3.1-4.4)	8.9 (6.9-11.4)	2.8 (1.7-4.6)	1.5 (1-2.2)	0.0	<3.2	0.4 (0.3-0.6)	1.2 (0.7-2.1)
Prevalent heart disease	50.1 (47.4-52.8)	64.9 (60.5-69.0)	22.2 (20.8-23.6)	46.1 (40.9-51.3)	49.8 (49.5-50.1)	68.2 (67.6-68.8)	53.7 (51.9-55.5)	72.8 (69.1-76.2)	38.1 (34-42.4)	19.9 (18-22)	21.6 (17.6-26.3)	20.5 (14.9-27.5)	12.4 (11.7-13.2)	26.8 (24.1-29.7)
Prevalent hypertension	57.9 (55.2-60.5)	76 (72.0-79.6)	37.2 (35.6-38.8)	64.8 (59.7-69.6)	60.6 (60.3-60.9)	79.7 (79.2-80.2)	70.4 (68.7-72)	85.7 (82.7-88.3)	46.9 (42.6-51.3)	29.6 (27.4-31.9)	27.4 (22.9-32.4)	28.2 (21.7-35.7)	16 (15.2-16.8)	31.5 (28.6-34.5)
Prevalent T2DM	32.6 (30.1-35.2)	49.7 (45.2-54.2)	20.6 (19.3-22)	41.3 (36.3-46.5)	38.5 (38.2-38.8)	55.8 (55.2-56.4)	41.3 (39.5-43.1)	58.2 (54.2-62.1)	18.8 (15.6-22.5)	29.9 (27.7-32.2)	18.7 (14.9-23.2)	19.9 (14.4-26.9)	6.5 (6-7.1)	16.1 (13.9-18.6)

Other														
Anxiety	12.7 (11.0-14.6)	11.7 (9.1-14.9)	13.6 (12.5-14.8)	17.2 (13.6-21.5)	15.1 (14.9-15.3)	15.3 (14.8-15.8)	44.1 (42.3-45.9)	38.7 (34.9-42.6)	22.4 (19-26.3)	13.6 (12-15.4)	5.8 (3.8-8.8)	10.3 (6.4-16.1)	35.7 (34.6-36.8)	35.2 (32.2-38.3)
Depression	19.8 (17.8-22.0)	23.4 (19.8-27.4)	11.4 (10.4-12.5)	20.1 (16.2-24.6)	13.0 (12.8-13.2)	15.3 (14.8-15.8)	33.1 (31.4-34.8)	32.1 (28.5-35.9)	19.2 (16-22.9)	5.0 (4-6.2)	4.4 (2.7-7.1)	7.1 (4-12.2)	13.5 (12.7-14.3)	17.6 (15.3-20.1)
Prevalent CKD	19.6 (17.6-21.8)	33 (28.9-37.3)	8.4 (7.5-9.4)	25.5 (21.2-30.3)	17.2 (16.9-17.5)	31.9 (31.3-32.5)	19.3 (17.9-20.8)	32 (28.4-35.8)	16 (13.1-19.5)	7.6 (6.4-9)	12.8 (9.7-16.8)	10.3 (6.4-16.1)	4.5 (4.1-5)	16.3 (14.1-18.8)
Chronic Liver Disease	2.2 (1.5-3.1)	4.6 (3.1-6.9)	1.1 (0.8-1.5)	4 (2.4-6.6)	1.3 (1.2-1.4)	2.4 (2.2-2.6)	4.5 (3.8-5.3)	8.7 (6.7-11.2)	2.6 (1.5-4.4)	6.5 (5.4-7.8)	<1.5	0.0	1 (0.8-1.3)	1.5 (0.9-2.5)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort.

Prevalent = conditions defined using all person time otherwise within 365 days of index date. Depression = incident depression/major depressive disorder. N/A=Data not captured. CKD=Chronic kidney disease. T2DM=Type 2 diabetes mellitus. COPD=chronic obstructive pulmonary disease.

Supplementary table S5. Comorbidities in patients without asthma diagnosed and hospitalized with COVID-19.

Characteristic	US CUIMC % (95%CI)		US HealthVerity % (95%CI)		US IQVIA OpenClaims % (95%CI)		US VA-OMOP % (95%CI)		US STARR-OMOP % (95%CI)	KR HIRA % (95%CI)	UK CPRD % (95%CI)	NL IPCI % (95%CI)	ES SIDIAP % (95%CI)	
	(n = 7,181)	(n = 2,121)	(n = 35,194)	(n = 3,264)	(n = 379,863)	(n = 109,880)	(n = 21,659)	(n = 4,903)	(n = 2,827)	(n = 6,039)	(n = 1,993)	(n = 1,172)	(n = 114,522)	(n = 17,245)
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
<i>Respiratory/atopy related</i>														
Allergic disorder	2.3 (2-2.7)	1.6 (1.1-2.2)	4.2 (4-4.4)	4.1 (3.5-4.8)	5.6 (5.5-5.7)	4.6 (4.5-4.7)	10.8 (10.4-11.2)	9.9 (9.1-10.8)	3.7 (3.1-4.5)	61.1 (59.9-62.3)	0.6 (0.3-1)	7.6 (6.2-9.3)	14.1 (13.9-14.3)	14.3 (13.8-14.8)
Allergic rhinitis	1.8 (1.5-2.1)	1.2 (0.8-1.8)	3.4 (3.2-3.6)	3.2 (2.6-3.9)	4.5 (4.4-4.6)	3.6 (3.5-3.7)	9.3 (8.9-9.7)	8.2 (7.5-9)	3.5 (2.9-4.2)	53.3 (52-54.6)	0.5 (0.3-0.9)	2.2 (1.5-3.2)	10.7 (10.5-10.9)	10.5 (10.1-11)
Bronchiectasis	0.4 (0.3-0.6)	0.6 (0.3-1)	0.2 (0.2-0.3)	0.4 (0.2-0.7)	0.3 (0.3-0.3)	0.7 (0.7-0.8)	0.3 (0.2-0.4)	0.6 (0.4-0.9)	0.7 (0.5-1.1)	0.4 (0.3-0.6)	<0.3	<0.4	0.9 (0.8-1)	1.9 (1.7-2.1)
COPD	2.5 (2.2-2.9)	4.8 (4-5.8)	4.6 (4.4-4.8)	16.1 (14.9-17.4)	7.6 (7.5-7.7)	13.6 (13.4-13.8)	13.7 (13.2-14.2)	23.4 (22.2-24.6)	2.7 (2.2-3.4)	1.4 (1.1-1.7)	2.1 (1.6-2.8)	4.7 (3.6-6.1)	3.6 (3.5-3.7)	8.3 (7.9-8.7)
Eczema	0.7 (0.5-0.9)	0.3 (0.1-0.6)	0.8 (0.7-0.9)	0.7 (0.5-1)	1.1 (1.1-1.1)	1.0 (0.9-1.1)	2.2 (2-2.4)	2.4 (2-2.9)	0.8 (0.5-1.2)	5.8 (5.2-6.4)	0.6 (0.3-1)	2.2 (1.5-3.2)	4.5 (4.4-4.6)	3.7 (3.4-4)
Interstitial lung disease	0.5 (0.4-0.7)	1.2 (0.8-1.8)	0.4 (0.3-0.5)	1.8 (1.4-2.3)	0.9 (0.9-0.9)	3.0 (2.9-3.1)	1 (0.9-1.1)	1.6 (1.3-2)	0.8 (0.5-1.2)	0.1 (0-0.2)	<0.3	0.0	0.1 (0.1-0.1)	0.5 (0.4-0.6)
Obesity	34.9 (33.8-36)	42.6 (40.5-44.7)	11.6 (11.3-11.9)	17.9 (16.6-19.3)	29.8 (29.7-29.9)	34.4 (34.1-34.7)	44.5 (43.8-45.2)	50.9 (49.5-52.3)	31.7 (30-33.4)	N/A	38.9 (36.8-41.1)	19.7 (17.5-22.1)	29.4 (29.1-29.7)	45.6 (44.9-46.3)
Sleep apnoea	2.8 (2.4-3.2)	3.3 (2.6-4.1)	4.9 (4.7-5.1)	7.2 (6.4-8.1)	4.9 (4.8-5)	6.8 (6.7-7)	22.1 (21.6-22.7)	24.2 (23-25.4)	9.8 (8.8-11)	0.3 (0.2-0.5)	<0.3	1.3 (0.8-2.1)	2.6 (2.5-2.7)	5.3 (5-5.6)
Urticaria	0.3 (0.2-0.5)	<0.2	0.4 (0.3-0.5)	0.5 (0.3-0.8)	0.5 (0.5-0.5)	0.4 (0.4-0.4)	0.6 (0.5-0.7)	0.3 (0.2-0.5)	0.5 (0.3-0.8)	1.4 (1.1-1.7)	0.4 (0.2-0.8)	0.9 (0.5-1.6)	3.2 (3.1-3.3)	2.8 (2.6-3.1)
<i>Cardiometabolic</i>														
Atrial fibrillation	4.1 (3.7-4.6)	7 (6-8.2)	4 (3.8-4.2)	13.7 (12.6-14.9)	6.6 (6.5-6.7)	11.2 (11-11.4)	9.2 (8.8-9.6)	16.1 (15.1-17.2)	5 (4.3-5.9)	0.8 (0.6-1.1)	2.1 (1.6-2.8)	4.3 (3.3-5.6)	4.2 (4.1-4.3)	8.7 (8.3-9.1)
Cardiac arrhythmia	6.6 (6-7.2)	11.0 (9.7-12.4)	6.1 (5.9-6.4)	19.1 (17.8-20.5)	10.7 (10.6-10.8)	18.5 (18.3-18.7)	14.4 (13.9-14.9)	24.2 (23-25.4)	8.7 (7.7-9.8)	2.4 (2-2.8)	2.5 (1.9-3.3)	5.2 (4.1-6.6)	9.6 (9.4-9.8)	18.5 (17.9-19.1)
Cerebrovascular disease	3.1 (2.7-3.5)	4.9 (4.1-5.9)	2.5 (2.3-2.7)	7.1 (6.3-8)	4.6 (4.5-4.7)	7.7 (7.5-7.9)	4.6 (4.3-4.9)	8.3 (7.6-9.1)	2.5 (2-3.1)	2.9 (2.5-3.4)	1.5 (1.1-2.1)	3.6 (2.7-4.8)	1.4 (1.3-1.5)	2.5 (2.3-2.7)
Heart failure	4.5 (4-5)	9.1 (7.9-10.4)	4.8 (4.6-5)	18.4 (17.1-19.8)	9 (8.9-9.1)	17 (16.8-17.2)	9.6 (9.2-10)	19.9 (18.8-21)	3.9 (3.2-4.7)	3 (2.6-3.5)	1.4 (1-2)	2.6 (1.8-3.7)	2.9 (2.8-3)	6.3 (5.9-6.7)
Myocardial infarction	2 (1.7-2.4)	4.6 (3.8-5.6)	1.4 (1.3-1.5)	5.3 (4.6-6.1)	2.4 (2.4-2.4)	5.3 (5.2-5.4)	3.7 (3.5-4)	7.6 (6.9-8.4)	2.2 (1.7-2.8)	0.7 (0.5-0.9)	0.6 (0.3-1)	2 (1.3-3)	0.9 (0.8-1)	2.3 (2.1-2.5)
Prevalent heart disease	32.4 (31.3-33.5)	48.8 (46.7-50.9)	16.2 (15.8-16.6)	42.9 (41.2-44.6)	45.1 (44.9-45.3)	62.7 (62.4-63)	48.4 (47.7-49.1)	69.8 (68.5-71.1)	25 (23.4-26.6)	11.2 (10.4-12)	20 (18.3-21.8)	19.5 (17.3-21.9)	14.6 (14.4-14.8)	28.1 (27.4-28.8)
Prevalent hypertension	39.8 (38.7-40.9)	62.1 (60-64.1)	26.4 (25.9-26.9)	57.8 (56.1-59.5)	58.8 (58.6-59)	77.7 (77.5-77.9)	65.5 (64.9-66.1)	86.4 (85.4-87.3)	33.7 (32-35.5)	22.4 (21.4-23.5)	21.5 (19.8-23.4)	27.9 (25.4-30.5)	17.2 (17-17.4)	29.8 (29.1-30.5)

Prevalent T2DM	20.1 (19.2-21)	37.8 (35.8-39.9)	15.7 (15.3-16.1)	36.2 (34.6-37.9)	35.5 (35.3-35.7)	51.4 (51.1-51.7)	36.8 (36.2-37.4)	55.4 (54-56.8)	14.4 (13.2-15.7)	19.2 (18.2-20.2)	15.1 (13.6-16.7)	17.7 (15.6-20)	8.1 (7.9-8.3)	17.9 (17.3-18.5)
Other														
Anxiety	5.9 (5.4-6.5)	5.3 (4.4-6.3)	7.6 (7.3-7.9)	13.6 (12.5-14.8)	9.8 (9.7-9.9)	9.9 (9.7-10.1)	30.8 (30.2-31.4)	30.1 (28.8-31.4)	10.3 (9.2-11.5)	8.5 (7.8-9.2)	2.9 (2.2-3.7)	7.8 (6.4-9.5)	27.4 (27.1-27.7)	23.7 (23.1-24.3)
Depression	7.1 (6.5-7.7)	10.0 (8.8-11.3)	6.9 (6.6-7.2)	16.2 (15-17.5)	9.1 (9-9.2)	11.1 (10.9-11.3)	23.2 (22.6-23.8)	26.1 (24.9-27.3)	16.5 (15.2-17.9)	4.4 (3.9-4.9)	4.6 (3.8-5.6)	4.3 (3.3-5.6)	10.9 (10.7-11.1)	11.8 (11.3-12.3)
Prevalent CKD	11.9 (11.2-12.7)	22.7 (21-24.5)	7.1 (6.8-7.4)	25.7 (24.2-27.2)	18.6 (18.5-18.7)	32.4 (32.1-32.7)	21.4 (20.9-22)	38.9 (37.5-40.3)	10.3 (9.2-11.5)	4.8 (4.3-5.4)	13.5 (12.1-15.1)	9.9 (8.3-11.7)	6.8 (6.7-6.9)	14.7 (14.2-15.2)
Chronic Liver Disease	1.1 (0.9-1.4)	2.3 (1.7-3)	0.7 (0.6-0.8)	1.9 (1.5-2.4)	1.1 (18.5-18.7)	2 (1.9-2.1)	4.3 (4-4.6)	7.8 (7.1-8.6)	3 (2.4-3.7)	3.7 (3.3-4.2)	<0.3	0.0	1.1 (1-1.2)	1.9 (1.7-2.1)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort.

Prevalent = conditions defined using all person time otherwise within 365 days of index date. Depression = incident depression/major depressive disorder. N/A=Data not captured. CKD=Chronic kidney disease. T2DM=Type 2 diabetes mellitus. COPD=chronic obstructive pulmonary disease.

Supplementary table S6. Standardised mean differences for the comparison between diagnosed COVID-19 patients without asthma compared to diagnosed COVID-19 patients with asthma.

COVARIATE	SIDIAP	STARR-OMOP	VA-OMOP	CUIMC	HEALTHVERITY	IQVIA-OPENCLAIMS
AGE GROUP: 00-04	-0.02884	0.096417		0.012843	0.039687	0.029575
AGE GROUP: 05-09	0.042887	0.031893		0.103379	0.078905	0.063221
AGE GROUP: 10-14	0.09065	0.022877		0.077368	0.056296	0.069005
AGE GROUP: 15-19	0.068606	0.01853		0.112052	0.048542	0.06923
AGE GROUP: 20-24	0.062397	0.033604		0.074488	0.014803	0.05751
AGE GROUP: 25-29	0.032923	0.026918	-0.04151	-0.01265	-0.01889	0.029918
AGE GROUP: 30-34	0.014312	-0.06487	-0.02629	-0.07431	0	0.012295
AGE GROUP: 35-39	0.024846	0.027552	0.008747	-0.04708	0.002709	0.014853
AGE GROUP: 40-44	0.039876	-0.02028	0.063563	-0.01071	0.038466	0.031212
AGE GROUP: 45-49	0.031414	0.035669	0.075152	-0.01657	0.073019	0.039984
AGE GROUP: 50-54	0.025962	-0.01491	0.120203	0.059027	0.097539	0.049128
AGE GROUP: 55-59	-0.01279	0.031071	0.105962	0.024545	-0.04507	0.039778
AGE GROUP: 60-64	-0.03802	0.018393	0.041882	0.028949	-0.0662	0.002393
AGE GROUP: 65-69	-0.053	-0.05648	-0.0023	-0.01592	-0.05699	-0.04241
AGE GROUP: 70-74	-0.04608	-0.03484	-0.12903	-0.01683	0.002996	-0.057
AGE GROUP: 75-79	-0.06316	-0.03802	-0.10267	-0.04521	-0.07126	-0.0724
AGE GROUP: 80-84	-0.07347	-0.01931	-0.07494	-0.01699	-0.05116	-0.07533
ALLERGIC DISORDER	0.364823	0.220473	0.22997	0.234282	0.278388	0.2035
ALLERGIC RHINITIS	0.366483	0.193709	0.223303	0.22792	0.28233	0.202521
ANXIETY	0.126816	0.234742	0.196198	0.166606	0.138426	0.113751
AF	-0.04977	0.101449	-0.04888	0.046579	-0.03029	-0.03265
BRONCHIECTASIS	0.08	0.15	0.02	0.1	0.07	0.04
CARDIAC ARRHYTHMIA	-0.05062	0.12275	-0.03087	0.063273	0.008747	-0.00923
CVD	-0.03321	0.05285	-0.02818	0.015795	0.037768	-0.00339
CLD	-0.00696	-0.01708	0.006898	0.060968	0.030526	0.012904
CKD	-0.07056	0.119608	-0.03693	0.150264	0.034338	-0.02581
COPD	-0.00768	0.058246	0.075976	0.142118	0.041249	0.057663
DEPRESSION	0.055787	0.163153	0.093571	0.180014	0.097084	0.057983
ECZEMA	0.126958	0.072569	0.066773	0.079208	0.076696	0.056179
HEART DISEASE	-0.04553	0.201256	0.075028	0.25845	0.108028	0.066601
HEART FAILURE	-0.02201	0.118088	-0.01215	0.109953	0.01932	0
HYPERTENSION	-0.02278	0.191782	0.074339	0.260133	0.165127	0.025949
ILD	0.018291	0.040647	0.020057	0.071792	0.028453	0.026977
MI	-0.04282	0.027315	0	0.057562	0.005915	-0.00465
OBESITY	0.101198	0.239946	0.266942	0.308074	0.274888	0.239677
SLEEP APNOEA	0.044421	0.211738	0.211433	0.148566	0.155816	0.135553
SYSTEMIC CORTICOSTEROIDS	0.219023	0.262743	0.25	0.30255	0.361485	0.290719
T2DM	-0.04354	0.08374	0.065335	0.202787	0.089985	0.043918

SMD<0 = prevalence greater in COVID-19 patients without asthma. SMD>0 = prevalence greater in COVID-19 patients with asthma. SMD in bold = greater or less than 0.1 suggests significant imbalance between groups. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. T2DM=Type 2 diabetes mellitus. Top row=name of the database.

Supplementary table S7. Standardised mean differences for the comparison between hospitalised COVID-19 patients without asthma compared to hospitalised COVID-19 patients with asthma.

COVARIATE	CUIMC	HEALTHVERITY	IQVIA- OPENCLAIMS	HIRA	SIDIAP	VA- OMOP
AGE GROUP: 00-04	-0.01145		0.047643	0.117634		
AGE GROUP: 05-09	0.116224		0.063362	0.077911		
AGE GROUP: 10-14	0.100771		0.044497	0.037588		
AGE GROUP: 15-19	0.101593		0.060867	-0.06655	0.06	
AGE GROUP: 20-24	0.08229	0.081274	0.062593	-0.11666	0.02	
AGE GROUP: 25-29	0.089904		0.051705	-0.09763	0.04	
AGE GROUP: 30-34	0.008033	0.021313	0.057922	0.003236	-0.01	0.037261
AGE GROUP: 35-39	-0.04912	0.131966	0.036585	-0.01288	-0.01	-0.04027
AGE GROUP: 40-44	-0.05274	0.05925	0.061463	-0.00315	0.09	0.08572
AGE GROUP: 45-49	0.01376	0.120082	0.062631	-0.01329	0.07	0.106684
AGE GROUP: 50-54	0.043576	0.124868	0.06944	-0.03575	0.03	0.158299
AGE GROUP: 55-59	0.020869	0.057381	0.072061	0	0.02	0.114338
AGE GROUP: 60-64	0.007315	-0.00219	0.021888	0.08614	-0.01	0.078541
AGE GROUP: 65-69	-0.01113	-0.09113	-0.04324	0.065681	-0.05	0.040446
AGE GROUP: 70-74	-0.03028	0.005975	-0.06448	0.021044	-0.01	-0.13317
AGE GROUP: 75-79	-0.07874	-0.19042	-0.07871	0.059969	-0.02	-0.13662
AGE GROUP: 80-84	-0.03247	-0.0434	-0.08297	0.052199	-0.06	-0.04866
ALERGIC DISORDER	0.24167	0.231497	0.176201	0.422476	0.31	0.209157
ALLERGIC RHINITIS	0.225682	0.237533	0.174225	0.459431	0.32	0.203605
ANXIETY	0.162924	0.07053	0.115391	0.115347	0.18	0.128369
AF	0.052105	-0.04245	-0.01822	0.034462	-0.02	-0.03146
BRONCHIECTASIS	0.14		0.04	0.07	0.11	0.05
CARDIAC ARRHYTHMIA	0.06826	-0.0348	0.003631	0.078431	-0.04	0
CVD	-0.02384	0.03946	-0.00266	0.056429	-0.01	-0.09706
CLD	0.089324	0.087933	0.019157	0.090258	-0.02	0.023091
CKD	0.163389	-0.00324	-0.00757	0.082203	-0.04	-0.10215
COPD	0.174419	-0.04152	0.096409	0.069131	-0.05	0.110294
DEPRESSION	0.141013	0.089362	0.072634	0.05	0.09	0.068322
ECZEMA		0.092802	0.047903	0.112732	0.04	0.03822
HEART DISEASE	0.232751	0.045528	0.081861	0.170931	-0.02	0.046926
HEART FAILURE	0.157295	-0.01657	0.036867	0.087904	0.05	0.017545
HYPERTENSION	0.214889	0.101833	0.034572	0.11652	0.03	-0.01426
ILD	0.118966	0.051675	0.027456	0.049379		0.03585
MI	0.075471	-0.02285	0.003129	0.053711	-0.06	0.033405
OBESITY	0.299305	0.286975	0.27579	0.038698	0.15	0.25776
SLEEP APNOEA	0.12684	0.146852	0.172139	0.048072	0.12	0.2339
SYSTEMIC CORTICOSTEROIDS	0.301188	0.268416	0.280436	0.330866	0.27	0.162708
T2DM	0.170658	0.074045	0.062412	0.177108	-0.03	0.039957

SMD<0 = prevalence greater in patients without asthma. SMD>0 = prevalence greater in patients with asthma. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD in bold = greater or less than 0.1 indicates significant imbalance between groups. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. T2DM=Type 2 diabetes mellitus. row=name of the database.

Supplementary tables S8. Treatments in patients with asthma 30 days before COVID-19 diagnosis or hospitalization.

Treatment	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC (% 95%CI)		HealthVerity (% 95%CI)		IQVIA OpenClaims (% 95%CI)		VA-OMOP (% 95%CI)		STARR- OMOP (% 95%CI)	HIRA (% 95%CI)	CPRD (% 95%CI)	IPCI (% 95%CI)	SIDIAP (% 95%CI)	
	N=1338 D	N=479 H	N=3367 D	N=349 H	N=86328 D	N=23211 H	N=2953 D	N=607 H	N=501 D	N=1560 H	N=343 D	N=156 D	N=7536 D	N=952 H
Asthma management														
Systemic corticosteroids	12.6 (10.9-14.5)	15 (12.1-18.5)	6.1 (5.3-7)	9.2 (6.6-12.7)	13.9 (13.7-14.1)	17.9 (17.4-18.4)	14.6 (13.4-15.9)	18.5 (15.6-21.8)	17.2 (14.1-20.8)	19.9 (18-22)	17.5 (13.8-21.9)	14.7 (10-21.1)	8.7 (8.1-9.4)	16.4 (14.2-18.9)
Inhaled corticosteroid	10.7 (9.2-12.5)	10.3 (7.9-13.3)	7.7 (6.8-8.6)	9.0 (6.4-12.5)	19.9 (19.6-20.2)	21.6 (21.1-22.1)	41.4 (39.6-43.2)	44.3 (40.4-48.3)	18.4 (15.3-22)	6.4 (5.3-7.7)	50.7 (45.4-56)	43.6 (36.1-51.4)	55.1 (54-56.2)	71.3 (68.3-74.1)
SABA	20.7 (18.6-23)	22.8 (19.3-26.8)	8.9 (8-9.9)	7.4 (5.1-10.6)	22.9 (22.6-23.2)	24.0 (23.5-24.6)	37.6 (35.9-39.4)	36.9 (33.2-40.8)	16.0 (13.1-19.5)	2.1 (1.5-2.9)	48.4 (43.2-53.7)	17.9 (12.7-24.7)	26.5 (25.5-27.5)	29.9 (27.1-32.9)
LABA	7.1 (5.8-8.6)	7.5 (5.5-10.2)	4.8 (4.1-5.6)	5.1 (3.2-7.9)	10.3 (10.1-10.5)	12.6 (12.2-13)	19.4 (18-20.9)	24.0 (20.8-27.6)	7.4 (5.4-10)	3.2 (2.4-4.2)	30.5 (25.9-35.6)	19.3 (13.9-26.2)	28.4 (27.4-29.4)	39.8 (36.7-42.9)
LTRA	4.9 (3.9-6.2)	4.8 (3.2-7.1)	3.7 (3.1-4.4)	3.4 (1.9-5.9)	9.4 (9.2-9.6)	10.5 (10.1-10.9)	9.1 (8.1-10.2)	8.4 (6.4-10.9)	3.2 (2-5.1)	8.8 (7.5-10.3)	7.6 (5.2-10.9)	3.2 (1.4-7.3)	6.8 (6.3-7.4)	9.0 (7.3-11)
Methylxanthines	<0.4	0.0	<0.1	0.0	0.1 (0.1-0.1)	0.2 (0.2-0.3)	0.3 (0.2-0.6)	<0.8	0.0	2.5 (1.8-3.4)	1.7 (0.8-3.7)	0.0	0.1	<0.5
Antibiotics														
Beta-lactam penicillins	3.1 (2.3-4.2)	4.2 (2.7-6.4)	1.2 (0.9-1.6)	<1.4	5.8 (5.6-6)	6.5 (6.2-6.8)	4.6 (3.9-5.4)	4.1 (2.8-6)	4.2 (2.8-6.3)	13.5 (11.9-15.3)	16.3 (12.8-20.6)	10.9 (6.9-16.8)	4.5 (4.1-5)	9.6 (7.9-11.6)
Fluoroquinolones	2.3 (1.6-3.3)	2.9 (1.7-4.8)	0.8 (0.6-1.2)	<1.4	3.3 (3.2-3.4)	4.5 (4.2-4.8)	1.5 (1.1-2)	2.5 (1.5-4.1)	1.5 (0.7-3)	6.9 (5.7-8.3)	<1.5	0.0	2.5 (2.2-2.9)	5.9 (4.6-7.6)
Macrolides	8.7 (7.3-10.3)	9.6 (7.3-12.6)	3.2 (2.7-3.8)	5.4 (3.5-8.3)	14.1 (13.9-14.3)	15.3 (14.8-15.8)	8.2 (7.3-9.2)	10.4 (8.2-13.1)	4.4 (2.9-6.6)	12.3 (10.8-14)	6.1 (4-9.2)	<3.2	3.1 (2.7-3.5)	9.6 (7.9-11.6)
Covid 19 Symptom management														
Acetaminophen	16.6 (14.7-18.7)	22.8 (19.3-26.8)	2.5 (2-3.1)	2.3 (1.2-4.5)	7.4 (7.2-7.6)	10.4 (10-10.8)	22.9 (21.4-24.5)	31.3 (27.7-35.1)	19.8 (16.5-23.5)	38.3 (35.9-40.7)	31.2 (26.5-36.3)	4.5 (2.2-9)	25.6 (24.6-26.6)	46.5 (43.4-49.7)
NSAIDs	10.2 (8.7-11.9)	13.2 (10.5-16.5)	3 (2.5-3.6)	5.2 (3.3-8.1)	22.2 (21.9-22.5)	26.8 (26.2-27.4)	44 (42.2-45.8)	49.9 (45.9-53.9)	13 (10.3-16.2)	28.1 (25.9-30.4)	10.5 (7.7-14.2)	7.7 (4.5-13)	12.4 (11.7-13.2)	14.2 (12.1-16.6)
Opioids	6.7 (5.5-8.2)	6.9 (5-9.5)	1.7 (1.3-2.2)	2.9 (1.6-5.2)	7.4 (7.2-7.6)	10.9 (10.5-11.3)	11.1 (10-12.3)	14.7 (12.1-17.7)	14.8 (12-18.2)	41.5 (39.1-44)	12.5 (9.4-16.4)	6.4 (3.5-11.4)	6.7 (6.2-7.3)	13.6 (11.6-15.9)
Other														
Nasal preparations	14.3 (12.5-16.3)	15.7 (12.7-19.2)	8.0 (7.1-9)	9.5 (6.8-13)	23.8 (23.5-24.1)	26.5 (25.9-27.1)	41.9 (40.1-43.7)	44.3 (40.4-48.3)	22.8 (19.3-26.7)	10.1 (8.7-11.7)	46.1 (40.9-51.4)	38.5 (31.2-46.3)	48.7 (47.6-49.8)	63.6 (60.5-66.6)

US=United States. KR=South Korea. ES=Spain. UK=United Kingdom. NL=the Netherlands. LTRA=Leukotriene receptor antagonist. Nasal preparations= decongestants and other nasal preparations for topical use (ATC R01A).

D=Diagnosed cohort. H=hospitalized cohort. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort.

Supplementary table S9. Standardised mean differences for the comparison between diagnosed COVID-19 patients with asthma compared to hospitalised COVID-19 patients with asthma.

COVARIATE	CUIMC	HEALTHVERITY	IQVIA- OPENCLAIMS	SIDIAP	VA- OMOP
AGE GROUP: 00-04	0.012033		0		
AGE GROUP: 05-09	0.024941		-0.03211		
AGE GROUP: 10-14	0.043596		-0.06777		-0.11941
AGE GROUP: 15-19	0.014041		-0.07567	-0.09458	-0.1945
AGE GROUP: 20-24	-0.0043	-0.09779	-0.1036	-0.18684	-0.11383
AGE GROUP: 25-29	-0.03027		-0.10363	-0.16754	-0.0844
AGE GROUP: 30-34	-0.0992	-0.16403	-0.08838	-0.17602	-0.06389
AGE GROUP: 35-39	-0.15011	-0.07379	-0.08846	-0.20813	-0.06169
AGE GROUP: 40-44	-0.17473	-0.12675	-0.0713	-0.10554	0.02788
AGE GROUP: 45-49	-0.06417	-0.07809	-0.05418	-0.0745	0.101453
AGE GROUP: 50-54	-0.08039	-0.08844	-0.02895	-0.03569	0.10967
AGE GROUP: 55-59	-0.02965	0.06207	0.019978	0.053844	0.082052
AGE GROUP: 60-64	-0.01669	0.072648	0.058749	0.094962	0.107742
AGE GROUP: 65-69	0.090476	0.095645	0.076468	0.139041	-0.04123
AGE GROUP: 70-74	0.080571	0.207698	0.097675	0.202214	-0.04677
AGE GROUP: 75-79	0.095913	0.074744	0.099694	0.22533	-0.07753
AGE GROUP: 80-84	0.11163	0.201516	0.087131	0.173594	0.032992
ALERGIC DISORDER	-0.02392	-0.05219	-0.05948	-0.04778	0.164529
ALLERGIC RHINITIS	-0.03316	-0.05411	-0.06091	-0.05277	0.05
ANXIETY	-0.02159	0.07053	0.003934	-0.00739	0.20737
ASTHMA EXACERBATION	0.017426	0.073527	0.056941	0.030327	0.038051
AF	0.095854	0.23133	0.128676	0.15995	0.119786
BRONCHIECTASIS	0.06		0.04	0.09	0.212625
CARDIAC ARRHYTHMIA	0.115082	0.239468	0.169874	0.188016	0.053479
CVD	0.025758	0.155573	0.092189	0.078612	-0.01915
CLD	0.093836	0.130453	0.05741	0.032272	0.265515
CKD	0.217534	0.330698	0.244986	0.103952	0.236667
COPD	0.118253	0.192896	0.177321	0.074541	0.082033
DEPRESSION	0.023781	0.151515	0.05149	-0.11712	0.053248
ECZEMA		0.009651	-0.01536	0.261656	0.152058
HEART DISEASE	0.213958	0.367885	0.269207	0.18453	0.082033
HEART FAILURE	0.177027	0.273677	0.205832	0.286563	0.207855
HYPERTENSION	0.276919	0.406158	0.301724		0.056975
ILD	0.102105	0.117119	0.108566	0.0639	0.026897
MI	0.121552	0.127831	0.113936	0.286563	0.242395
OBESITY	0.103998	0.136551	0.104967	0.208852	0.207855
SLEEP APNOEA	-0.0027	0.058409	0.093566	0.168808	0.056975
SYSTEMIC CORTICOSTEROIDS	0.035539	-0.06795	0.032625	0.173464	0.026897
T2DM	0.249174	0.324439	0.248624	0.217283	0.242395

SMD<0 = greater in asthma patients diagnosed with COVID-19. SMD>0 = greater in asthma patients hospitalized with COVID-19. SMD in bold = greater or less than 0.1. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. Top row=name of the database.

Supplementary table S10. Outcomes in COVID-19 patients with asthma in the diagnosed and hospitalized cohorts.

Characteristic	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC (% , 95%CI)		HealthVerity (% , 95%CI)		IQVIA OpenClaims (% , 95%CI)		VA-OMOP (% , 95%CI)		STARR-OMOP (% , 95%CI)	HIRA (% , 95%CI)	CPRD (% , 95%CI)	IPCI (% , 95%CI)	SIDIAP (% , 95%CI)	
	N=1338	N=479	N=3367	N=349	N=86328	N=23211	N=2953	N=607	N=501	N=1560	N=343	N=156	N=7536	N=952
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
Death	6.1 (4.9-7.5)	16.9 (13.8-20.5)	NA	NA	NA	NA	3.2 (2.6-3.9)	12.9 (10.5-15.8)	NA	3.7 (2.9-4.8)	7.3 (5-10.6)	9.6 (5.9-15.2)	2.1 (1.8-2.4)	7.7 (6.2-9.6)
Intensive services	NA	NA	0.7 (0.5-1)	7.4 (5.1-10.6)	3.7 (3.6-3.8)	10.1 (9.7-10.5)	2.9 (2.4-3.6)	17.6 (14.8-20.8)	3.2 (2-5.1)	2.7 (2-3.6)	NA	NA	NA	NA
ARDS	5.2 (4.1-6.5)	15.0 (12.1-18.5)	2.2 (1.8-2.8)	26.1 (21.8-31)	11.0 (10.8-11.2)	31.8 (31.2-32.4)	7.3 (6.4-8.3)	39.7 (35.9-43.6)	4.0 (2.6-6.1)	2.1 (1.5-2.9)	NA	NA	NA	NA
ARFS	4.9 (3.9-6.2)	14.0 (11.2-17.4)	1.8 (1.4-2.3)	16.0 (12.5-20.2)	5.8 (5.6-6)	18.8 (18.3-19.3)	7.2 (6.3-8.2)	29.7 (26.2-33.5)	2.2 (1.2-3.9)	1.5 (1-2.2)	2.3 (1.2-4.5)	<3.2	<0.1	0.5 (0.2-1.2)
Cardiac arrhythmia	4.6 (3.6-5.9)	8.4 (6.2-11.2)	2.4 (1.9-3)	14.3 (11-18.4)	5.5 (5.3-5.7)	14.7 (14.3-15.2)	9.1 (8.1-10.2)	29.7 (26.2-33.5)	10.0 (7.7-12.9)	3.5 (2.7-4.5)	<1.5	<3.2	7.7 (7.1-8.3)	17.0 (14.7-19.5)
Heart failure	2.3 (1.6-3.3)	7.5 (5.5-10.2)	0.9 (0.6-1.3)	7.2 (4.9-10.4)	2.0 (1.9-2.1)	6.0 (5.7-6.3)	3.9 (3.3-4.7)	19.8 (16.8-23.2)	3.8 (2.4-5.9)	3.4 (2.6-4.4)	0.0	0.0	1.5 (1.2-1.8)	4.9 (3.7-6.5)
Myocardial infarction	1.0 (0.6-1.7)	2.1 (1.1-3.8)	0.2 (0.1-0.4)	1.7 (0.8-3.7)	1.1 (1-1.2)	3.3 (3.1-3.5)	2.3 (1.8-2.9)	8.4 (6.4-10.9)	1 (0.4-2.3)	2.8 (2.1-3.7)	0.0	<3.2	0.4 (0.3-0.6)	1.2 (0.7-2.1)
Sepsis	1.9 (1.3-2.8)	4.6 (3.1-6.9)	2.1 (1.7-2.6)	17.2 (13.6-21.5)	6.8 (6.6-7)	20.5 (20-21)	4.0 (3.4-4.8)	18.1 (15.2-21.4)	2.8 (1.7-4.6)	2.8 (2.1-3.7)	<1.5	0.0	0.1 (0-0.2)	<0.5
Bleeding	2.5 (1.8-3.5)	5.0 (3.4-7.3)	1.0 (0.7-1.4)	5.4 (3.5-8.3)	1.8 (1.7-1.9)	4.4 (4.1-4.7)	2.0 (1.6-2.6)	6.8 (5.1-9.1)	3.1 (1.9-5)	2.6 (1.9-3.5)	0.0	<3.2	2.6 (2.3-3)	3.6 (2.6-5)
PE	0.7 (0.4-1.3)	1.5 (0.7-3)	0.3 (0.2-0.5)	1.7 (0.8-3.7)	0.8 (0.7-0.9)	1.9 (1.7-2.1)	1.1 (0.8-1.5)	4.1 (2.8-6)	<1.0	<0.3	0.0	0.0	0.2 (0.1-0.3)	2.2 (1.4-3.3)
Stroke	1.1 (0.7-1.8)	2.7 (1.6-4.6)	<0.1	2.0 (1-4.1)	0.6 (0.6-0.7)	1.7 (1.5-1.9)	0.5 (0.3-0.8)	2.3 (1.4-3.8)	<1.0	0.6 (0.3-1.1)	0.0	0.0	0.8 (0.6-1)	<0.5

US=United States. KR=South Korea. UK=United Kingdom. NL=Netherlands. ES=Spain. D=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. H=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. ARDS=Acute respiratory distress syndrome. ARFS=Acute renal failure syndrome. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. Heart failure = during hospitalization. NA=Data not captured.

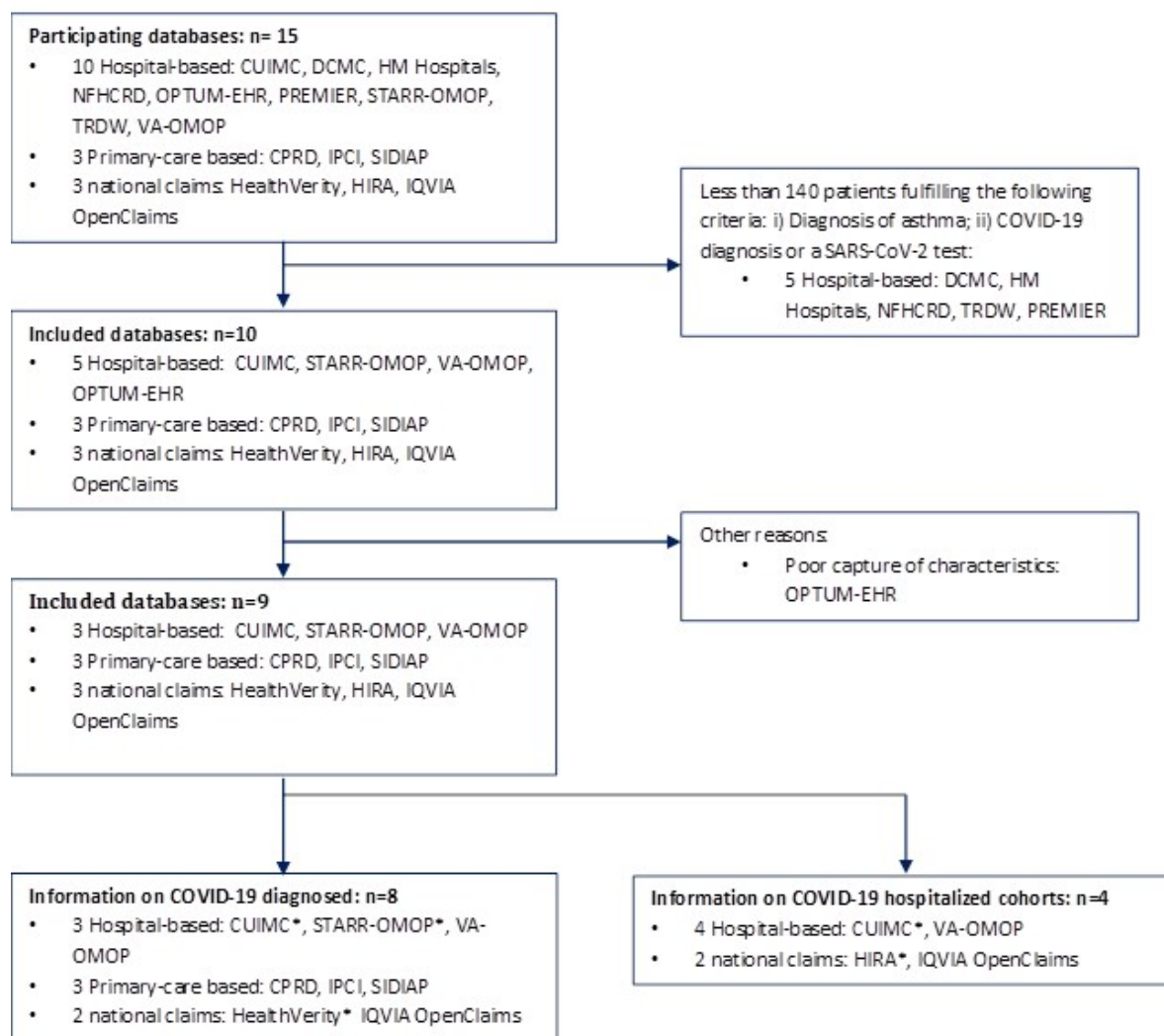
Supplementary table S11. Outcomes in patients without asthma diagnosed and hospitalized with COVID-19.

Treatment	US		US		US		US		US	KR	UK	NL	ES	
	CUIMC % (95%CI)		HealthVerity % (95%CI)		IQVIA OpenClaims % (95%CI)		VA-OMOP % (95%CI)		STARR-OMOP % (95%CI)	HIRA % (95%CI)	CPRD % (95%CI)	IPCI % (95%CI)	SIDIAP % (95%CI)	
	(n=7181)	(n=2121)	(n=35194)	(n=3264)	(n=379863)	(n=109880)	(n=21659)	(n=903)	(n=2827)	(n=6039)	(n=1993)	(n=1172)	(n=114522)	(n=17245)
	D	H	D	H	D	H	D	H	D	H	D	D	D	H
Death	6.3 (5.8-6.9)	20.7 (19-22.5)	NA	NA	NA	NA	5.2 (4.9-5.5)	17.6 (16.6-18.7)	NA	2.2 (1.9-2.6)	12.5 (11.1-14)	8.7 (7.2-10.5)	4.5 (4.4-4.6)	12.5 (12-13)
Intensive services	N/A	N/A	0.5 (0.4-0.6)	5.8 (5-6.7)	4 (3.9-4.1)	9.8 (9.6-10)	2.9 (2.7-3.1)	17.9 (16.9-19)	1 (0.7-1.4)	1.4 (1.1-1.7)	NA	NA	NA	NA
ARDS	4.8 (4.3-5.3)	17 (15.5-18.7)	2.1 (2-2.3)	24.5 (23.1-26)	12.2 (12.1-12.3)	32.3 (32-32.6)	8.3 (7.9-8.7)	44.3 (42.9-45.7)	1.9 (1.5-2.5)	0.8 (0.6-1.1)	NA	NA	NA	NA
ARFS	4.1 (3.7-4.6)	13.1 (11.7-14.6)	1.7 (1.6-1.8)	15.2 (14-16.5)	7.4 (7.3-7.5)	22.1 (21.9-22.3)	9 (8.6-9.4)	35.3 (34-36.6)	2.2 (1.7-2.8)	0.7 (0.5-0.9)	1.3 (0.9-1.9)	0.0	0.1 (0.1-0.1)	0.2 (0.1-0.3)
Cardiac arrhythmia	3.4 (3-3.8)	7.1 (6.1-8.3)	2.7 (2.5-2.9)	16.1 (14.9-17.4)	6.4 (6.3-6.5)	15.6 (15.4-15.8)	10.3 (9.9-10.7)	31.9 (30.6-33.2)	6.4 (5.6-7.4)	1.8 (1.5-2.2)	1 (0.6-1.5)	1.5 (0.9-2.4)	9.6 (9.4-9.8)	18.8 (18.2-19.4)
Heart failure	1.2 (1-1.5)	4.4 (3.6-5.4)	0.6 (0.5-0.7)	8.3 (7.4-9.3)	2.1 (2.1-2.1)	5.8 (5.7-5.9)	4 (3.7-4.3)	20.4 (19.3-21.6)	2.3 (1.8-2.9)	2.3 (2-2.7)	0.0	0.0	1.4 (1.3-1.5)	3.7 (3.4-4)
Myocardial infarction	0.7 (0.5-0.9)	1.9 (1.4-2.6)	0.5 (0.4-0.6)	3.6 (3-4.3)	1.4 (1.4-1.4)	3.8 (3.7-3.9)	2.9 (2.7-3.1)	11 (10.2-11.9)	1.6 (1.2-2.1)	3.5 (3.1-4)	<0.3	<0.4	1 (0.9-1.1)	2.3 (2.1-2.5)
Sepsis	2.2 (1.9-2.6)	6.3 (5.3-7.4)	1.7 (1.6-1.8)	15.4 (14.2-16.7)	7.9 (7.8-8)	21.7 (21.5-21.9)	5.4 (5.1-5.7)	22.8 (21.6-24)	1.7 (1.3-2.2)	1.9 (1.6-2.3)	0.4 (0.2-0.8)	0.0	0.2 (0.2-0.2)	0.4 (0.3-0.5)
Bleeding	1.6 (1.3-1.9)	3.4 (2.7-4.3)	0.7 (0.6-0.8)	3.8 (3.2-4.5)	1.7 (1.7-1.7)	4.1 (4-4.2)	2.5 (2.3-2.7)	7.8 (7.1-8.6)	3.5 (2.9-4.2)	2.5 (2.1-2.9)	0.3 (0.1-0.7)	1.4 (0.9-2.2)	2.3 (2.2-2.4)	3.4 (3.1-3.7)
PE	0.8 (0.6-1)	2.1 (1.6-2.8)	0.2 (0.2-0.3)	1.2 (0.9-1.6)	0.7 (0.7-0.7)	1.6 (1.5-1.7)	1.0 (0.9-1.1)	3.5 (3-4.1)	0.4 (0.2-0.7)	<0.1	0.4 (0.2-0.8)	0.4 (0.2-1)	0.1 (0.1-0.1)	1.7 (1.5-1.9)
Stroke	0.7 (0.5-0.9)	2.5 (1.9-3.3)	0.1 (0.1-0.1)	2.2 (1.8-2.8)	0.7 (0.7-0.7)	1.9 (1.8-2)	0.7 (0.6-0.8)	3.2 (2.7-3.7)	<0.4	0.7 (0.5-0.9)	0.0	0.0	0.0	0.2 (0.1-0.3)

US=United States. KR=South Korea. UK=United Kingdom. NL=Netherlands. ES=Spain. D=Persons with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. H=Persons hospitalized with a COVID-19 diagnosis or a SARS-CoV-2 positive test with at least 365 days prior observation. ARDS=Acute respiratory distress syndrome. ARFS=Acute renal failure syndrome. Grey=US databases. Red=South Korean database. Orange=European databases. D=diagnosed cohort. H=Hospitalized cohort. Heart failure = during hospitalization. N/A=Data not captured.

Characteristics and outcomes of COVID-19 patients with and without asthma from the United States, South Korea, and Europe

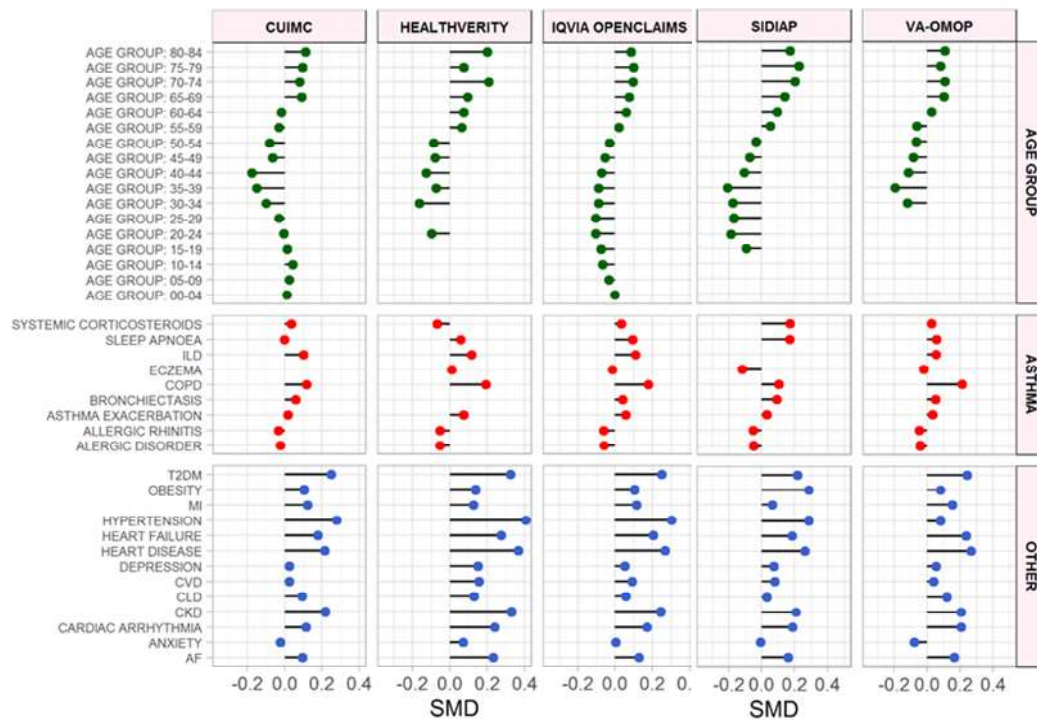
SUPPLEMENTARY FIGURES



Clinical Practice Research Datalink (CPRD), Daegu Catholic University Medical Center (DCMC), Health Insurance Review & Assessment Service (HIRA), Information System for Research in Primary Care (SIDIAP), Tufts Research Data Warehouse (TRDW), Department of Veterans Affairs (VA-OMOP), Integrated Primary Care Information (IPCI), Columbia University Irving Medical Center (CUIMC)

*No prior observation period available.

Supplementary figure S1. Flow chart showing database selection.



Supplementary figure S2. Standardised mean differences of characteristics between asthma patients diagnosed with COVID-19 and asthma patients hospitalized with COVID-19.

SMD<0 = greater in asthma patients diagnosed with COVID-19. SMD>0 = greater in asthma patients hospitalized with COVID-19. SMD greater or less than 0.1 indicates significant imbalance between groups. Only databases providing sufficient comparative information included. Asthma=Conditions related to asthma. SMD=Standardised mean difference. ILD=Interstitial lung disease. COPD=Chronic Obstructive Pulmonary Disease. CVD=Cerebrovascular disease. CLD=Chronic liver disease. CKD=Chronic kidney disease. AF=Atrial fibrillation. Asthma=asthma related comorbidities. Other=non-asthma related comorbidities. Top row=name of the database.