

Further learning

# ACE in the hole?

SUPPORTING DOCUMENTATION

## JAMA | Original Investigation

# Effect of Discontinuing vs Continuing Angiotensin-Converting Enzyme Inhibitors and Angiotensin II Receptor Blockers on Days Alive and Out of the Hospital in Patients Admitted With COVID-19

## A Randomized Clinical Trial

Renato D. Lopes, MD, PhD; Ariane V. S. Macedo, MD, MSc; Pedro G. M. de Barros E Silva, MD, PhD; Renata J. Moll-Bernardes, MD, PhD; Tiago M. dos Santos, MSc; Lilian Mazza, RT; André Feldman, MD, PhD; Guilherme D'Andréa Saba Arruda, MD; Denilson C. de Albuquerque, MD, PhD; Angelina S. Camiletti, RN, MSc; Andréa S. de Sousa, MD, PhD; Thiago C. de Paula, MD; Karla G. D. Giusti, MD; Rafael A. M. Domiciano, MD; Márcia M. Noya-Rabelo, MD, MHS, PhD; Alan M. Hamilton, MD; Vitor A. Loures, MD; Rodrigo M. Dionísio, MD; Thyago A. B. Furquim, MD; Fábio A. De Luca, MD, MBA, PhD; Ítalo B. dos Santos Sousa, MD; Bruno S. Bandeira, MD; Cleverton N. Zukowski, MD, PhD; Ricardo G. G. de Oliveira, MD; Noara B. Ribeiro, MD; Jeffer L. de Moraes, MD; João L. F. Petriz, MD, MHS, PhD; Adriana M. Pimentel, MD, PhD; Jacqueline S. Miranda, MD; Bárbara E. de Jesus Abufaiad, MD; C. Michael Gibson, MD; Christopher B. Granger, MD; John H. Alexander, MD, MHS; Olga F. de Souza, MD, PhD; for the BRACE CORONA Investigators

**IMPORTANCE** It is unknown whether angiotensin-converting enzyme inhibitors (ACEIs) or angiotensin II receptor blockers (ARBs) have a positive, neutral, or negative effect on clinical outcomes in patients with coronavirus disease 2019 (COVID-19).

**OBJECTIVE** To determine whether discontinuation compared with continuation of ACEIs or ARBs changed the number of days alive and out of the hospital through 30 days.

**DESIGN, SETTING, AND PARTICIPANTS** A randomized clinical trial of 659 patients hospitalized in Brazil with mild to moderate COVID-19 who were taking ACEIs or ARBs prior to hospitalization (enrolled: April 9-June 26, 2020; final follow-up: July 26, 2020).

**INTERVENTIONS** Discontinuation (n = 334) or continuation (n = 325) of ACEIs or ARBs.

**MAIN OUTCOMES AND MEASURES** The primary outcome was the number of days alive and out of the hospital through 30 days. Secondary outcomes included death, cardiovascular death, and COVID-19 progression.

**RESULTS** Among 659 patients, the median age was 55.1 years (interquartile range [IQR], 46.1-65.0 years), 14.7% were aged 70 years or older, 40.4% were women, and 100% completed the trial. The median time from symptom onset to hospital admission was 6 days (IQR, 4-9 days) and 27.2% of patients had an oxygen saturation of less than 94% of room air at baseline. In terms of clinical severity, 57.1% of patients were considered mild at hospital admission and 42.9% were considered moderate. There was no significant difference in the number of days alive and out of the hospital in patients in the discontinuation group (mean, 21.9 days [SD, 8 days]) vs patients in the continuation group (mean, 22.9 days [SD, 7.1 days]) and the mean ratio was 0.95 (95% CI, 0.90-1.01). There also was no statistically significant difference in death (2.7% for the discontinuation group vs 2.8% for the continuation group; odds ratio [OR], 0.97 [95% CI, 0.38-2.52]), cardiovascular death (0.6% vs 0.3%, respectively; OR, 1.95 [95% CI, 0.19-42.12]), or COVID-19 progression (38.3% vs 32.3%; OR, 1.30 [95% CI, 0.95-1.80]). The most common adverse events were respiratory failure requiring invasive mechanical ventilation (9.6% in the discontinuation group vs 7.7% in the continuation group), shock requiring vasopressors (8.4% vs 7.1%, respectively), acute myocardial infarction (7.5% vs 4.6%), new or worsening heart failure (4.2% vs 4.9%), and acute kidney failure requiring hemodialysis (3.3% vs 2.8%).

**CONCLUSIONS AND RELEVANCE** Among patients hospitalized with mild to moderate COVID-19 and who were taking ACEIs or ARBs before hospital admission, there was no significant difference in the mean number of days alive and out of the hospital for those assigned to discontinue vs continue these medications. These findings do not support routinely discontinuing ACEIs or ARBs among patients hospitalized with mild to moderate COVID-19 if there is an indication for treatment.

**TRIAL REGISTRATION** ClinicalTrials.gov Identifier: [NCT04364893](https://clinicaltrials.gov/ct2/show/study/NCT04364893)

JAMA. 2021;325(3):254-264. doi:10.1001/jama.2020.25864

[+ Visual Abstract](#)

[+ Supplemental content](#)

**Author Affiliations:** Author affiliations are listed at the end of this article.

**Group Information:** A list of the BRACE CORONA Investigators appears in Supplement 2.

**Corresponding Author:** Renato D. Lopes, MD, PhD, Duke Clinical Research Institute, 200 Morris St, Durham, NC 27701 ([renato.lopes@dm.duke.edu](mailto:renato.lopes@dm.duke.edu)).

**M**embrane-bound angiotensin-converting enzyme 2 (ACE2), an enzyme that physiologically counters renin-angiotensin-aldosterone system (RAAS) activation, is the functional receptor for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus responsible for the coronavirus disease 2019 (COVID-19) pandemic.<sup>1</sup> Select preclinical investigations have shown upregulation of ACE2 expression by RAAS inhibitors, such as angiotensin-converting enzyme inhibitors (ACEIs) and angiotensin II receptor blockers (ARBs), raising concerns about their safety in patients with COVID-19.<sup>2</sup>

Conversely, observational data have demonstrated an association between use of ACEIs or ARBs and better outcomes in patients with COVID-19, leading to speculation that ACEIs or ARBs decrease acute lung damage and prevent angiotensin II-mediated pulmonary permeability, inflammation, and fibrosis.<sup>3,4</sup> Therefore, there are conflicting mechanistic hypotheses and observational findings about the effect of ACEIs and ARBs on patients with COVID-19.<sup>5</sup> Given the impossibility of obtaining reliable estimates of comparative effectiveness in observational studies, this clinical question needs to be answered in a randomized clinical trial.<sup>6,7</sup>

A multicenter randomized clinical trial conducted during a pandemic should follow the general standards used in clinical research.<sup>8</sup> However, the urgent need for assessing new treatments requires leveraging more efficient research processes to address new challenges in conducting clinical research. Prospective, registry-based randomized clinical trials are a reliable tool for managing cost-effective and efficient research, and might be an attractive approach in critical circumstances like the current COVID-19 pandemic.<sup>9</sup>

The COVID-19 Registry is a clinical study including patients with suspected or confirmed COVID-19 hospitalized at 35 sites in Brazil.<sup>10</sup> Combining the capacity to randomize patients to various therapies within this structure enabled a streamlined process to provide reliable answers to important clinical questions. Thus, the BRACE CORONA (Blockers of Angiotensin Receptor and Angiotensin-Converting Enzyme inhibitors suspension in hospitalized patients with coronavirus infection) trial was conducted to evaluate whether the discontinuation of ACEIs or ARBs has an effect on the number of days alive and out of the hospital through 30 days in patients hospitalized with COVID-19.

## Methods

### Trial Oversight, Design, and Population

The trial protocol (Supplement 1) and all amendments were approved by the Brazilian Ministry of Health National Commission for Research Ethics and by institutional review boards or ethics committees at participating sites. All patients provided informed consent before enrollment. An independent data and safety monitoring board reviewed safety and efficacy data on an ongoing basis with access to unblinded data. An independent clinical events classification committee (whose members were blinded to the treatment assignment) adjudicated the causes of death and clinical outcomes described as secondary outcomes.

## Key Points

**Question** Does discontinuation compared with continuation of angiotensin-converting enzyme inhibitors (ACEIs) or angiotensin II receptor blockers (ARBs) change the number of days alive and out of the hospital through 30 days in patients hospitalized with mild to moderate coronavirus disease 2019 (COVID-19)?

**Findings** In this randomized clinical trial that included 659 patients hospitalized with mild to moderate COVID-19 and who were taking ACEIs or ARBs before hospital admission, the mean number of days alive and out of the hospital for those assigned to discontinue vs continue these medications was 21.9 vs 22.9, respectively, a difference that was not statistically significant.

**Meaning** These findings do not support routinely discontinuing ACEIs or ARBs among patients hospitalized with mild to moderate COVID-19.

The rationale and design for this trial have been published.<sup>10</sup> In brief, this was a multicenter, registry-based, open-label randomized clinical trial with blinded end-point assessment that included patients hospitalized with COVID-19 who were taking ACEIs or ARBs prior to hospital admission to determine whether discontinuation of these drugs compared with continuation of these drugs affects the number of days alive and out of the hospital.

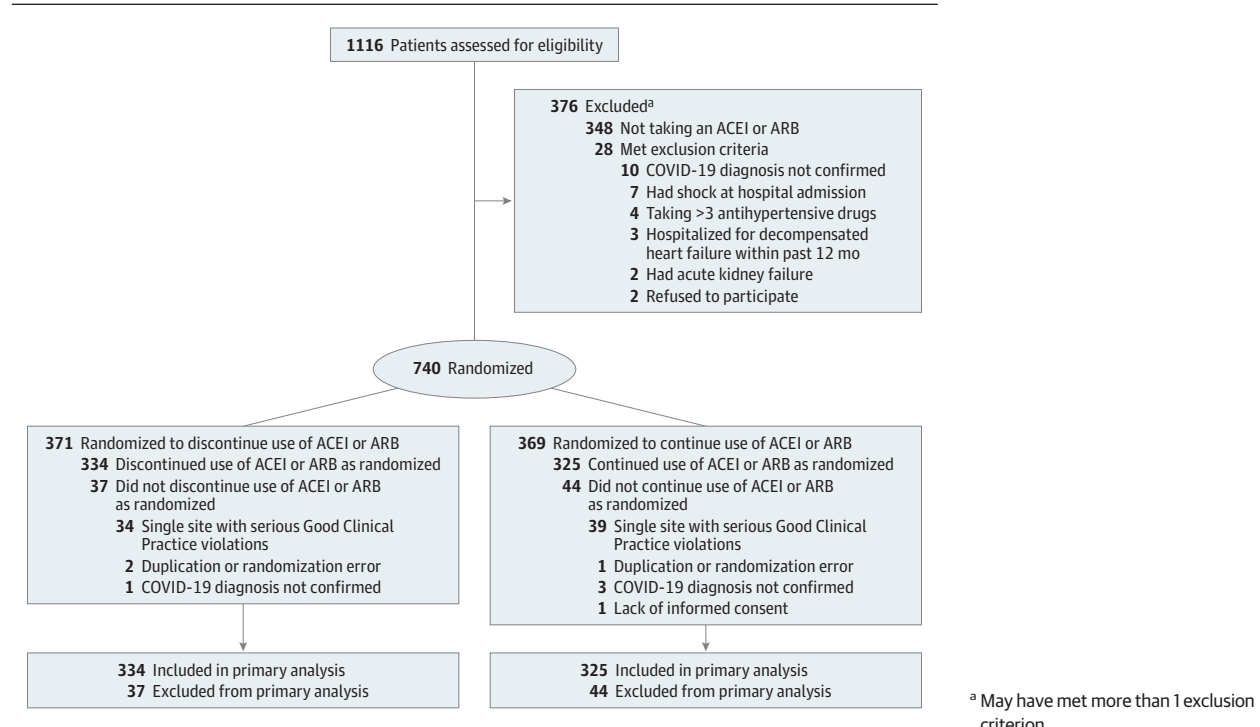
Patients with a suspected diagnosis of COVID-19 hospitalized at 29 centers in Brazil were included in the registry and followed up until the diagnosis of COVID-19 was confirmed. Patients aged 18 years or older with a confirmed diagnosis of COVID-19 who were taking ACEIs or ARBs prior to hospital admission were eligible for the trial. Patients taking more than 3 antihypertensive agents, those taking sacubitril/valsartan for heart failure, and those hospitalized for heart failure within the last 12 months were not eligible. Patients with a clinical indication to stop ACEI or ARB treatment (eg, those with hypotension, acute kidney injury, or shock) also were excluded. The full list of inclusion and exclusion criteria appears in the eMethods in Supplement 2.

### Trial Interventions

Eligible patients were randomized using a 1:1 allocation ratio to either discontinue or continue ACEI or ARB therapy for 30 days (Figure 1). Randomization was performed using block sizes of 4. A centralized, web-based automated randomization system was used to conceal allocation. For patients randomized to the ACEI or ARB discontinuation group, other drugs could replace these agents at the discretion of the treating physician.  $\beta$ -Blockers were maintained in patients already taking them for heart failure.

The study protocol did not recommend any specific treatment modification beyond discontinuing or continuing use of ACEIs or ARBs. The study team provided oversight on drug replacement, and those decisions were made based on current treatment guidelines. Patients were treated for COVID-19 according to current local standards of supportive care without

**Figure 1. Study Enrollment and Analysis in the BRACE CORONA Trial on the Use of Angiotensin-Converting Enzyme Inhibitors (ACEIs) or Angiotensin II Receptor Blockers (ARBs) Among Patients Hospitalized With Coronavirus Disease 2019 (COVID-19)**



the systematic use of investigational therapies. Treatment adherence was assessed based on medical prescriptions recorded in the chart throughout hospitalization and in the electronic health record after discharge.

### Outcomes

The primary outcome was the number of days alive and out of the hospital from randomization through 30 days. This outcome was calculated for each patient by subtracting the number of days in the hospital and the number of days from death until the end of follow-up from 30 days.<sup>11</sup> The secondary outcomes included: length of hospital stay (days), death (during the 30-day follow-up period), in-hospital death, cardiovascular death, COVID-19 progression (worsening of clinical severity during hospitalization in relation to baseline severity), acute myocardial infarction, new heart failure or worsening of preexisting heart failure, hypertensive crisis, transient ischemic attack, stroke, myocarditis, pericarditis, thromboembolic phenomena, arrhythmias requiring treatment, respiratory failure requiring mechanical ventilation, shock requiring vasopressors, kidney failure requiring hemodialysis, troponin level above the upper limit of normal in patients with normal values at baseline, B-type natriuretic peptide level above the upper limit of normal in patients with normal values at baseline, and D-dimer level above the upper limit of normal in patients with normal values at baseline. Detailed definitions of the secondary outcomes appear in the eMethods in Supplement 2.

### Sample Size

The initial planned sample size of the trial was 500 patients (additional information appears in Supplement 3). Based on the Coalition Covid-19 Brazil I trial,<sup>12</sup> and assuming a mean number of days alive and out of the hospital of 24 days (SD, 4 days), 500 patients would provide 90% power to detect a mean ratio of at least 1.10. This mean ratio of 1.10 represents a difference of approximately 2 days and was considered clinically relevant by the BRACE CORONA investigators and the members of the executive committee. The treatment effect considered relevant in this trial (2 days) represented half of the difference in days of hospitalization between remdesivir and placebo (4 days) in ACTT-1 (Adaptive COVID-19 Treatment Trial).<sup>13</sup> Two interim analyses were prespecified after 150 and 250 patients had completed the study follow-up. Because enrollment occurred more quickly than anticipated, and to allow for the interim analyses to be performed, the final sample size exceeded the initial planned number of patients allowed by the trial protocol. The increased sample size by more than 30% led to a final statistical power of 94.5% to detect a minimal between-group difference for days alive and out of the hospital of 2 days.

### Statistical Analysis

The primary analysis is expressed as the mean ratio for the number of days alive and out of the hospital at 30 days. The comparison between groups was made using generalized additive models for location, scale, and shape

with zero-inflated  $\beta$  binomial distribution (eFigure 1 in Supplement 2).<sup>14</sup> The results are presented as mean ratios (95% CIs). A mean ratio greater than 1.0 indicates that patients randomized to discontinuation of ACEIs or ARBs had more days alive and out of the hospital over the 30-day follow-up. A mean ratio less than 1.0 indicates that patients randomized to continuation of ACEIs or ARBs had more days alive and out of the hospital. The primary outcome is also presented as a mean (SD), mean difference (95% CI), median (interquartile range [IQR]), and difference in medians (95% CI).

Subgroup analyses were performed using the same generalized additive models for location, scale, and shape with  $\beta$  binomial distribution inflated at zero that was used for the main outcome, including interaction terms between each subgroup and study treatments. Interaction tests were done for specific subgroups, including age (<65 years or  $\geq$ 65 years), obesity (yes vs no), previous use of an ACEI (yes vs no), previous use of an ARB (yes vs no), oxygen saturation (<94% of room air vs  $\geq$ 94% of room air), time from symptom onset to randomization (divided in tertiles), degree of lung involvement assessed by chest computed tomographic scan at hospital admission ( $\leq$ 25%, 26%-50%, >50%), and clinical severity of COVID-19 (mild or moderate).

The primary analysis followed the intention-to-treat principle. A sensitivity analysis was performed in which patients who died received zero days alive and out of the hospital, regardless of when death occurred. Given the large variability in the number of patients randomized among sites (eFigure 2 in Supplement 2), another sensitivity analysis was performed using site as a random effect. An on-treatment analysis for the primary outcome was also performed including only patients who were adherent to the study intervention until time of death or through 30 days.

The secondary end points of death and cardiovascular events at 30 days were compared using log binomial models and are reported as relative risks and odds ratios (ORs) with respective 95% CIs. Continuous variables are reported as median (IQR) or mean (SD) according to normality of the distribution. The medians were compared using the Kruskal-Wallis test and the means were compared using the *t* test. Categorical variables are reported as absolute and relative frequencies and the proportions were compared using the  $\chi^2$  test.  $P < .05$  was considered statistically significant and 2-sided tests were performed. Because of the potential for type I error due to multiple comparisons, the findings for the analyses of secondary end points should be interpreted as exploratory. All analyses were performed using R version 3.6.0 (R Foundation for Statistical Computing).<sup>15</sup>

## Results

From March 10 to June 26, 2020, 1352 patients from 35 sites were enrolled in the COVID-19 Registry. At the 29 sites participating in this study, 1116 patients were enrolled in the COVID-19 Registry from the start of the trial on April 9, 2020, to the end

of enrollment on June 26, 2020. Final follow-up was completed on July 26, 2020.

Of these 1116 patients, 740 were randomized in this trial; however, 81 were excluded from the primary analysis (Figure 1). During routine onsite monitoring, it was discovered that the research coordinator at 1 site randomized 73 patients, but did not obtain informed consent, apply the study intervention, or conduct the protocol-specified follow-up. The site personnel entered falsified information into the clinical trial database regarding the study intervention and follow-up. Because of these Good Clinical Practice violations, the decision was made before unblinding the results to exclude all trial data from this site. Critical variables, including patient identification and informed consent, key eligibility criteria, including COVID-19 status and current use of an ACEI or ARB, randomization and adherence to the study intervention, and the total duration of hospitalization and vital status at 30 days were verified for 100% of the source data to mitigate the risk of similar behavior at other sites.

Therefore, a total of 659 randomized patients from 29 hospitals (28% being academic hospitals) in Brazil were included in the primary analysis, with 334 patients assigned to discontinue use of ACEIs or ARBs and 325 patients assigned to continue use of ACEIs or ARBs. The 30-day follow-up was completed for 100% of patients and no data were missing for the primary outcome. For the baseline variables, there were missing data for less than 10% and the missing data did not affect any of the analyses of the primary or secondary outcomes.

The median number of patients per site was 11 (IQR, 4-24 patients). During the peak of the pandemic (April-June for this study), the median number of beds available at all 29 centers was 166 (IQR, 139-202 beds) for patients with COVID-19 or without COVID-19. During the peak of the pandemic, the median percentage of beds with COVID-19 patients was 32.8% (IQR, 18.7%-41.5%) (eTable 1 and eFigure 2 in Supplement 2).

### Baseline Characteristics

The 2 groups were well matched with respect to baseline characteristics (Table 1 and eTable 2 in Supplement 2). The median age was 55.1 years (IQR, 46.1-65.0 years), 14.7% were aged 70 years or older, 40.4% of patients were women, and 52.2% were obese. Hypertension was present in 100% of the patients and 1.4% had heart failure. A total of 16.7% were taking an ACEI and 83.3% were taking an ARB for a median of 5 years (IQR, 3-8 years) prior to randomization.  $\beta$ -Blockers were taken by 14.6% of patients, diuretics by 31.3%, and calcium channel blockers by 18.4%.

Cough, fever, and shortness of breath were the most common symptoms at hospital admission. The median time from symptom onset to hospital admission was 6 days (IQR, 4-9 days) and 27.2% of patients had an oxygen saturation of less than 94% of room air at baseline. A total of 50.7% of patients had lung involvement of 25% or less on the chest computed tomographic scan, 37.9% had lung involvement of 26% to 50%, and 11.4% had lung involvement greater than 50%. In terms of clinical severity of COVID-19, 57.1% of patients were considered mild at hospital admission and 42.9% were moderate.

Table 1. Baseline Patient Characteristics<sup>a</sup>

	ACEI or ARB	
	Discontinue use (n = 334)	Continue use (n = 325)
Randomized at academic centers, No. (%)	131 (39.2)	127 (39.1)
Age, median (IQR), y	55 (46.1-63.1)	56 (46.1-66.1)
Aged >70 y, No. (%)	41 (12.3)	56 (17.2)
Sex, No. (%)		
Female	136 (40.7)	130 (40)
Male	198 (59.3)	195 (60)
Body mass index <sup>b</sup>		
Median (IQR)	30.5 (27.0-34.0)	29.8 (26.8-33.6)
>30, No./total (%)	183/331 (55.3)	158/322 (49.1)
Medical history, No. (%)		
Hypertension	334 (100)	325 (100)
Never smoker, No./total (%)	249/309 (80.6)	232/295 (78.6)
Diabetes	111 (33.2)	99 (30.5)
Coronary heart disease	16 (4.8)	14 (4.3)
Asthma	15 (4.5)	11 (3.4)
Cancer	7 (2.1)	3 (0.9)
Kidney disease	5 (1.5)	4 (1.2)
Heart failure	2 (0.6)	7 (2.2)
Clinical characteristics at hospital admission		
Symptom duration, median (IQR), d	6.5 (4.0-9.0)	6.0 (4.0-9.0)
Fever with temperature >37.5°C, No./total (%)	216/326 (66.3)	233/320 (72.8)
Heart rate		
No. of patients	333	325
Median (IQR), /min	91.0 (81.0-104.0)	89.0 (80.0-101.0)
Systolic blood pressure, median (IQR), mm Hg	139.0 (125.0-149.0)	135.0 (125.0-149.0)
Respiratory rate		
No. of patients	331	323
Median (IQR), breaths/min	19.0 (17.0-20.0)	19.0 (18.0-20.0)
Oxygen saturation <94% on room air, No./total (%)	88/327 (26.9)	85/310 (27.4)
Cough, No. (%)	246 (73.7)	217 (66.8)
Dyspnea, No. (%)	181 (54.2)	173 (53.2)
COVID-19 clinical severity within first 24 h of hospital admission, No. (%) <sup>c</sup>		
Mild	193 (57.8)	183 (56.3)
Moderate	141 (42.2)	142 (43.7)
Lung involvement on initial chest CT scan, No./total (%) <sup>d</sup>		
≤25%	164/317 (51.7)	153/308 (49.7)
26%-50%	112/317 (35.3)	125/308 (40.6)
>50%	41/317 (12.9)	30/308 (9.7)
Medication use at hospital admission, No. (%)		
ARB	264 (79)	285 (87.7)
ACEI	70 (21)	40 (12.3)
Diuretic <sup>e</sup>	105 (31.4)	101 (31.1)
Statin	75 (22.5)	64 (19.7)
Calcium channel blocker	59 (17.7)	62 (19.1)
β-Blocker	44 (13.2)	52 (16)
Antiplatelet <sup>f</sup>	33 (9.9)	33 (10.2)
Insulin	14 (4.2)	13 (4.0)
Oral anticoagulant <sup>g</sup>	10 (3.0)	8 (2.5)

(continued)

Table 1. Baseline Patient Characteristics<sup>a</sup> (continued)

	ACEI or ARB	
	Discontinue use (n = 334)	Continue use (n = 325)
Duration of ACEI or ARB use		
No. of patients	324	310
Median (IQR), y	5.0 (2.0-8.0)	5.0 (3.0-8.0)
Laboratory values at hospital admission <sup>h</sup>		
Lymphocytes		
No. of patients	302	300
Median (IQR), ×10 <sup>9</sup> /L	1.2 (0.9-1.7)	1.2 (0.8-1.6)
Creatinine		
No. of patients	325	312
Median (IQR), μmol/L	88.4 (70.7-97.2)	88.4 (70.7-106.1)
C-reactive protein		
No. of patients	318	297
Median (IQR), mg/L	4.3 (1.6-8.9)	4.2 (1.4-7.4)
Potassium		
No. of patients	276	264
Median (IQR), mmol/L	4.0 (3.7-4.4)	4.0 (3.7-4.4)
Time from hospital admission to randomization, median (IQR), d	2.0 (1.0-3.0)	2.0 (1.0-3.0)
Concomitant therapy, No. (%)		
Azithromycin	301 (90.1)	296 (91.1)
Anticoagulation <sup>i</sup>	222 (66.5)	218 (67.1)
Antiviral <sup>j</sup>	142 (42.5)	135 (41.5)
Chloroquine or hydroxychloroquine	72 (21.6)	58 (17.8)
Tocilizumab	17 (5.1)	7 (2.2)
Corticosteroid <sup>k</sup>	169 (50.6)	157 (48.3)

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; COVID-19, coronavirus disease 2019; CT, computed tomographic; IQR, interquartile range.

SI conversion factor: To convert creatinine to mg/dL, divide by 88.4.

<sup>a</sup> Additional information appears in eTable 1, eTable 2, and eFigure 2 in Supplement 2.

<sup>b</sup> Calculated as weight in kilograms divided by height in meters squared

<sup>c</sup> Mild defined as blood oxygen saturation of 94% or greater and lung infiltrates less than or equal to 50%; moderate, blood oxygen saturation less than 94%, or lung infiltrates greater than 50%, or ratio of partial pressure of arterial oxygen to fraction of inspired oxygen less than 300; and severe, invasive mechanical ventilation or hemodynamic instability or multiple organ dysfunction or failure.

<sup>d</sup> Estimated by visual assessment performed by a radiologist.

<sup>e</sup> Furosemide, hydrochlorothiazide, or spironolactone.

<sup>f</sup> Aspirin, clopidogrel, or ticagrelor.

<sup>g</sup> Warfarin, rivaroxaban, apixaban, dabigatran, or edoxaban.

<sup>h</sup> Reference ranges: 1000 to 5000 × 10<sup>9</sup>/L for lymphocytes; 61.88 to 106.08 μmol/L for creatinine; less than 10 mg/L for C-reactive protein; and 3.5 to 5.0 mmol/L for potassium.

<sup>i</sup> Enoxaparin, unfractionated heparin, warfarin, rivaroxaban, apixaban, dabigatran, or edoxaban. The differentiation between therapeutic and prophylactic anticoagulation was based on the dose.

<sup>j</sup> Oseltamivir, ribavirin, or lopinavir-ritonavir.

<sup>k</sup> Prednisone, dexamethasone, hydrocortisone, or methylprednisolone.

The median time from hospital admission to randomization was 2 days (IQR, 1-3 days) in both groups.

The in-hospital adherence rate to the study intervention (calculated based on the number of doses of ACEIs or ARBs) was 96.4% in the discontinuation group and 94.8% in the continuation group. At the end of the study, the ACEI or ARB persistence rates, assessed via a phone call, were 71% for the discontinuation group and 92.9% for the continuation group.

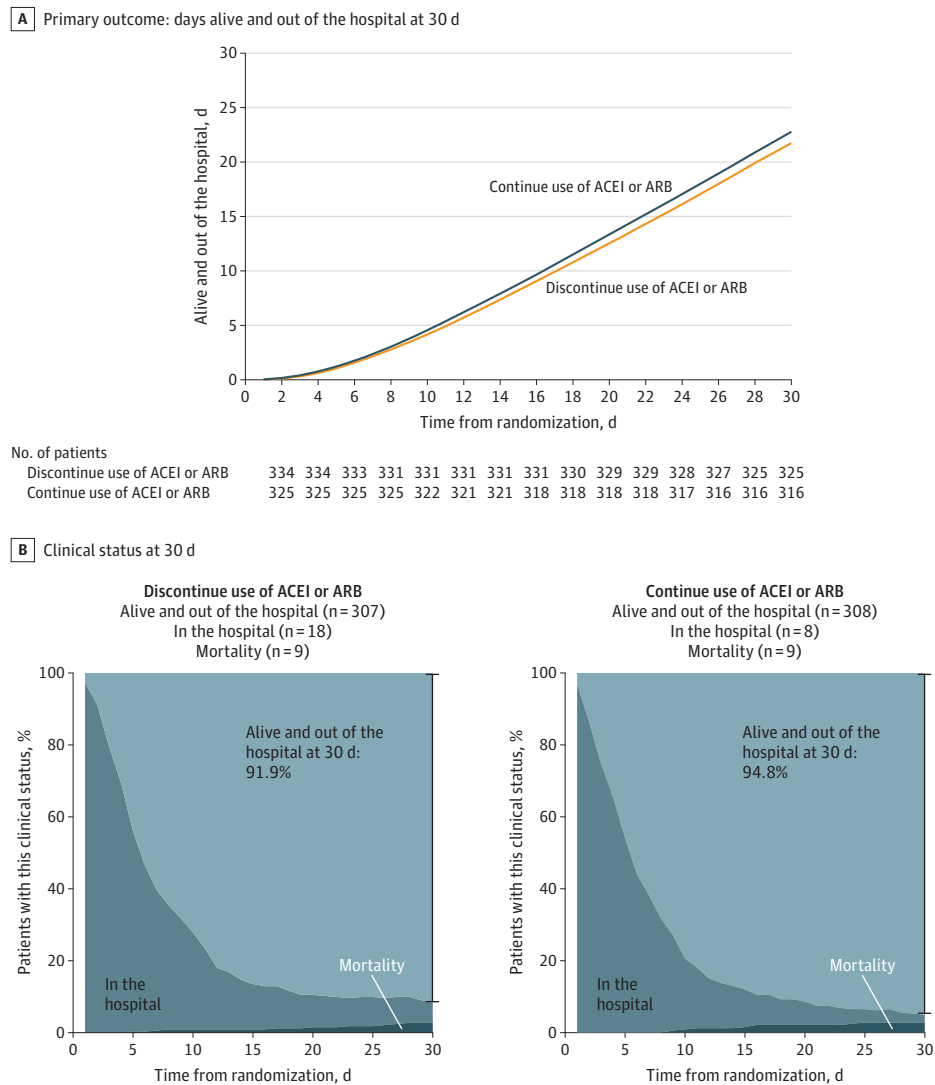
### Primary Outcome

The mean number of days alive and out of the hospital for patients randomized to discontinue use of ACEIs or ARBs was 21.9 days (SD, 8.0 days) vs 22.9 days (SD, 7.1 days) for those randomized to continue use of ACEIs or ARBs (Figure 2A). For days alive and out of the hospital, the between-group mean ratio

was 0.95 (95% CI, 0.90 to 1.01;  $P = .09$ ) and the between-group mean difference was -1.10 days (95% CI, -2.30 to 0.13 days). The median number of days alive and out of the hospital at 30 days was 25 days for both groups and the between-group median difference was 0 days (95% CI, -1 to 1 days). The proportion of patients alive and out of the hospital at 30 days was 91.9% in the discontinuation group and 94.8% in the continuation group (Figure 2B).

From the overall population, 7.5% of patients in the discontinuation group had 0 days alive and out of the hospital compared with 4.6% in the continuation group (eFigure 3 in Supplement 2). The mortality rate at 30 days for patients discontinuing ACEIs or ARBs was 2.7% vs 2.8% for patients continuing ACEI or ARBs (OR, 0.97 [95% CI, 0.38-2.52]; eFigure 4 in Supplement 2).

Figure 2. Primary Outcome and Clinical Status at 30 Days



For the primary outcome, the mean number of days alive and out of the hospital was 21.9 days (SD, 8.0 days) in the discontinue use of angiotensin-converting enzyme inhibitor (ACEI) or angiotensin II receptor blocker (ARB) group vs 22.9 days (SD, 7.1 days) in the continue use of ACEI or ARB group (median, 25.0 days

[interquartile range, 20.0-27.0 days] vs 25.0 days [interquartile range, 21.0-27.0 days], respectively) and the between-group mean ratio was 0.95 (95% CI, 0.90-1.01;  $P = .09$ ).

In a sensitivity analysis in which patients who died received 0 days alive and out of the hospital (regardless of when death occurred), there was no significant between-group difference for the primary outcome (mean ratio, 0.95 [95% CI, 0.89-1.01]). When site was used as a random effect, the between-group mean ratio of days alive and out of the hospital was 0.94 (95% CI, 0.89-0.997;  $P = .04$ ).

In the on-treatment analysis, 9.7% of patients in the discontinuation group had 0 days alive and out of the hospital compared with 3.0% in the continuation group; the between-group mean ratio was 0.91 (95% CI, 0.84 to 0.96).

**Secondary Outcomes**

The secondary outcomes appear in Table 2 and eTable 3 in Supplement 2. For the number of days in the hospital, the be-

tween-group mean ratio was 1.21 (95% CI, 1.02 to 1.42). No other significant between-group differences were seen for cardiovascular events, biomarkers, or COVID-19 progression. The most common adverse events were respiratory failure requiring invasive mechanical ventilation (9.6% in the discontinue ACEIs or ARBs group vs 7.7% in the continue ACEIs or ARBs group), shock requiring vasopressors (8.4% vs 7.1%, respectively), acute myocardial infarction (7.5% vs 4.6%), new or worsening heart failure (4.2% vs 4.9%), and acute kidney failure requiring hemodialysis (3.3% vs 2.8%). The secondary outcomes according to the on-treatment analysis appear in eTable 4 in Supplement 2.

**Subgroup Analysis**

Overall, the effect on the primary outcome was consistent across major predefined subgroups, including age, obesity, type



Table 2. Primary and Secondary Outcomes at 30 Days<sup>a</sup>

	ACEI or ARB		Absolute difference (95% CI)	Effect size (95% CI) <sup>b</sup>
	Discontinue use (n = 334)	Continue use (n = 325)		
<b>Primary outcome</b>				
Days alive and out of the hospital				
Mean (SD)	21.9 (8.0)	22.9 (7.1)	-1.10 (-2.30 to 0.13)	MR, 0.95 (0.90 to 1.01)
Median (IQR)	25.0 (20.0 to 27.0)	25.0 (21.0 to 27.0)		
<b>Secondary outcomes</b>				
Length of hospitalization, d				
Mean (SD)	7.8 (7.4)	6.7 (6.3)	1.46 (0.12 to 2.67)	MR, 1.21 (1.02 to 1.42)
Median (IQR)	5.0 (3.0 to 10.0)	5.0 (3.0 to 9.0)		
Death at 30 d, No. (%)	9 (2.7)	9 (2.8)	-0.07 (-2.56 to 2.41)	OR, 0.97 (0.38 to 2.52)
In-hospital death, No. (%)	9 (2.7)	7 (2.2)	0.54 (-1.81 to 2.89)	OR, 1.26 (0.46 to 3.56)
Cardiovascular death, No. (%)	2 (0.6)	1 (0.3)	0.29 (-0.73 to 1.31)	OR, 1.95 (0.19 to 42.12)
COVID-19 progression, No. (%) <sup>c</sup>	128 (38.3)	105 (32.3)	6.02 (-1.27 to 13.30)	OR, 1.30 (0.95 to 1.80)
Respiratory failure requiring invasive mechanical ventilation, No. (%) <sup>d</sup>	32 (9.6)	25 (7.7)	1.89 (-2.40 to 6.17)	RR, 1.25 (0.76 to 2.07)
Shock requiring vasopressors, No. (%)	28 (8.4)	23 (7.1)	1.31 (-2.77 to 5.38)	RR, 1.19 (0.70 to 2.03)
Cardiovascular outcomes, No. (%)				
Acute myocardial infarction	25 (7.5)	15 (4.6)	2.87 (-0.76 to 6.50)	RR, 1.62 (0.88 to 3.09)
New or worsening heart failure	14 (4.2)	16 (4.9)	-0.73 (-3.92 to 2.45)	RR, 0.85 (0.42 to 1.72)
Other outcomes, No. (%)				
Acute kidney failure requiring hemodialysis	11 (3.3)	9 (2.8)	0.52 (-2.09 to 3.14)	RR, 1.19 (0.50 to 2.91)
Thromboembolic events	6 (1.8)	4 (1.2)	0.57 (-1.30 to 2.43)	RR, 1.46 (0.42 to 5.67)
Stroke or TIA	3 (0.9)	3 (0.9)	-0.02 (-1.48 to 1.43)	RR, 0.97 (0.18 to 5.23)

Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; COVID-19, coronavirus disease 2019; IQR, interquartile range; MR, mean ratio; OR, odds ratio; RR, relative risk; TIA, transient ischemic attack.

<sup>a</sup> Additional information appears in eTable 3 and eTable 4 in Supplement 2.

<sup>b</sup> Comparisons were made using generalized additive models for the primary outcome and log binomial models for the secondary outcomes.

<sup>c</sup> Defined as change in clinical severity status during hospitalization. Mild

defined as blood oxygen saturation of 94% or greater and lung infiltrates less than or equal to 50%; moderate, blood oxygen saturation less than 94%, or lung infiltrates greater than 50%, or ratio of partial pressure of arterial oxygen to fraction of inspired oxygen less than 300; and severe, invasive mechanical ventilation or hemodynamic instability or multiple organ dysfunction or failure.

<sup>d</sup> The decision for intubation was based on clinical judgment.

of RAAS inhibitor (ACEI or ARB), days of symptoms to randomization, and opacities on the chest computed tomographic scan (Figure 3). However, there was a significant interaction among the treatment effect, oxygen saturation, and COVID-19 clinical severity at hospital admission, with the results slightly favoring the group continuing ACEI or ARB therapy among patients with lower oxygen saturation and greater disease severity at presentation.

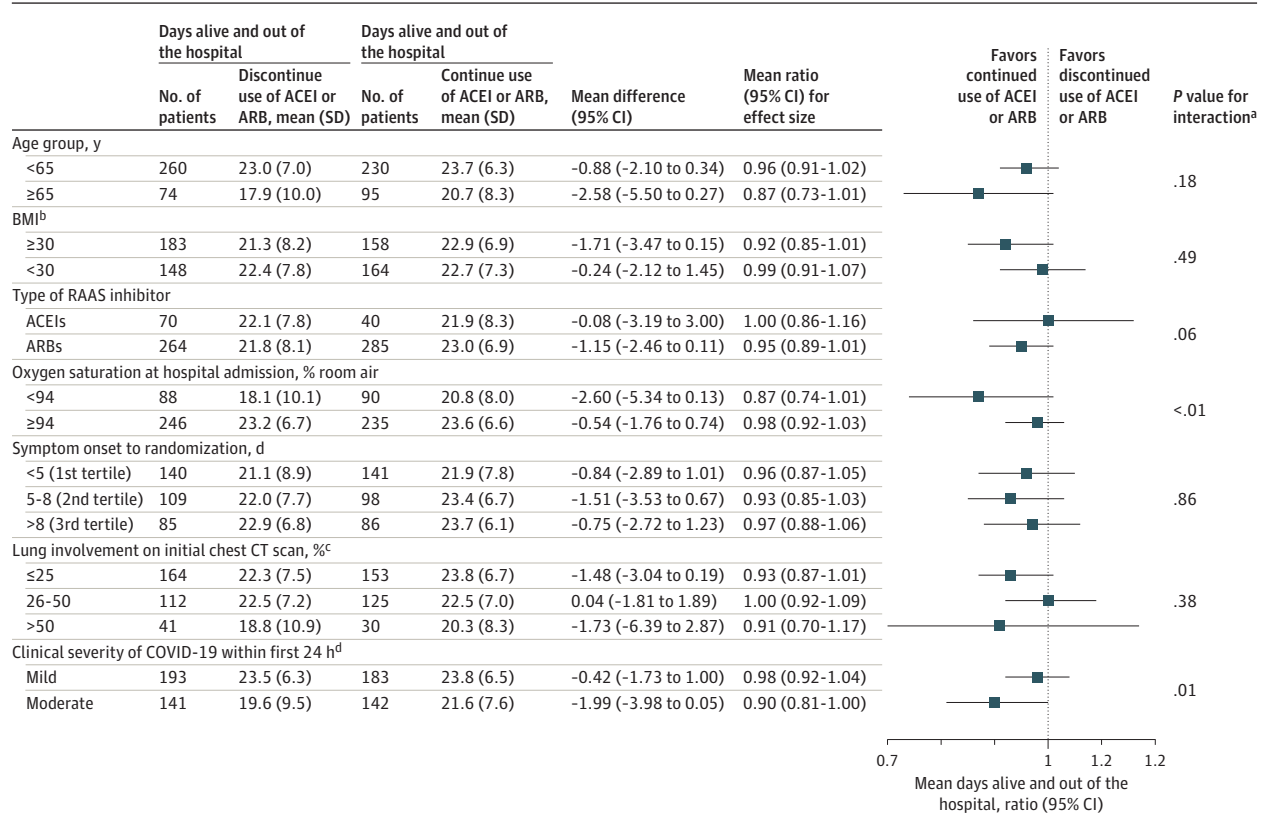
## Discussion

In this pragmatic, registry-based randomized clinical trial, discontinuing ACEI or ARB therapy for 30 days did not affect the number of days alive and out of the hospital in patients hospitalized with mild to moderate COVID-19. These results were generally consistent across major subgroups. There were no significant between-group differences in death, cardiovascular outcomes, or COVID-19 progression.

The interplay between SARS-CoV-2 and the RAAS has led to competing speculation about the effect of RAAS

inhibitors on the course of COVID-19.<sup>16</sup> Because animal models found that ACEIs and ARBs upregulated expression of ACE2, a receptor involved in the SARS-CoV-2 infection of host target cells, it was theorized that these medications could enhance viral binding and cell entry.<sup>2</sup> Conversely, RAAS inhibitors could benefit patients with COVID-19 through effects on angiotensin II expression and subsequent increases in angiotensin 1-7 and 1-9, which have vasodilatory and anti-inflammatory effects that might attenuate lung injury.<sup>16</sup> Animal data suggest an inherent protective effect of ARBs against COVID-19 pneumonia by limiting lung damage in mice infected with SARS-CoV, a close viral relative of SARS-CoV-2.<sup>17</sup> Uncertainty around the role of RAAS inhibitors in patients with COVID-19 has intensified due to observational data and a systematic review.<sup>18-31</sup> Scientific societies have recommended that patients should not discontinue ACEI or ARB therapy during the COVID-19 pandemic.<sup>32,33</sup> To date, randomized clinical trials designed to determine whether ACEIs or ARBs are beneficial, harmful, or neutral with respect to clinical outcomes in patients with COVID-19 have been lacking.

Figure 3. Subgroup Analysis for the Primary Outcome



ACEI indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; BMI, body mass index; CT, computed tomographic; RAAS, renin-angiotensin-aldosterone system.

<sup>a</sup> The subgroup analyses were performed using the same generalized additive model of location, scale, and shape with beta binomial distribution inflated at zero that was used for the primary outcome, including interaction terms between each subgroup and study treatments.

<sup>b</sup> Calculated as weight in kilograms divided by height in meters squared.

<sup>c</sup> Estimated by visual assessment performed by a radiologist.

<sup>d</sup> Defined as change in clinical severity status during hospitalization. Mild defined as blood oxygen saturation of 94% or greater and lung infiltrates less than or equal to 50%; moderate, blood oxygen saturation less than 94%, or lung infiltrates greater than 50%, or ratio of partial pressure of arterial oxygen to fraction of inspired oxygen less than 300; and severe, invasive mechanical ventilation or hemodynamic instability or multiple organ dysfunction or failure.

Hypertension is an important comorbidity in patients with COVID-19. Recent data have postulated that immune dysfunction may contribute to poor outcomes in patients with COVID-19 and hypertension.<sup>28</sup> Considering the importance of treating hypertension, it has been shown that when use of long-term medications is discontinued during hospitalization, the medications often are not restarted due to clinical inertia, thereby worsening long-term outcomes.<sup>34</sup> The results of this trial support the continued use of ACEIs or ARBs in patients hospitalized with COVID-19. In this study, all patients had hypertension and more than 50% were obese, both comorbidities that increase the risk of poor outcomes with COVID-19.<sup>35,36</sup>

In addition, in multicenter trials, site effect may play an important role in study outcomes. The sensitivity analysis that treated site as a random effect found a statistically significant result favoring the group that continued ACEIs or ARBs. These results were similar in the on-treatment analysis. There were also statistically significant interactions between treatment effect and some subgroups, such as

patients with lower oxygen saturation and greater disease severity at hospital admission, in which continuing ACEIs or ARBs may be beneficial. The primary analyses with the null results but wide 95% CIs suggest that the study might have been underpowered to detect a statistically significant benefit of continuing ACEIs or ARBs.

In this study, 14.7% of patients were aged 70 years or older. Other studies<sup>12,37-39</sup> that included hospitalized patients with COVID-19 had median or mean ages very similar to the population in this trial (median, 58.0 years [IQR, 49.0-68.0 years]<sup>37</sup>; median, 59.8 years [IQR, 50.6-70.1 years]<sup>38</sup>; median, 52 years [IQR, 32-62 years]<sup>39</sup>; and mean, 50.3 years [SD, 14.6 years]).<sup>12</sup> The relatively younger age of the population in COVID-19 trials compared with hypertension or heart failure trials may be a specific characteristic of this infection.

**Limitations**

This study has several limitations. First, this was an open-label study; therefore, some inherent bias in the treatment of patients could have occurred.

Second, the in-hospital study setting with randomization a median of 2 days after hospitalization may limit the generalizability of these results to patients with COVID-19 in other settings and with earlier modification of the therapy. However, the intervention in the study (discontinuing or continuing ACEIs or ARBs) was continued from randomization through 30 days, and most participants adhered to the study intervention through 30 days.

Third, the relatively small number of patients taking ACEIs with a diagnosis of heart failure might limit the extension of these results to a broader population. Nonetheless, prescription of ARBs has increased worldwide, and the results presented reflect this trend.<sup>40</sup>

Fourth, the effect of ACEIs or ARBs on the susceptibility to COVID-19 was not studied because the focus was only on clinical outcomes in patients already infected.

Fifth, data on race, ethnicity, chronic obstructive pulmonary disease, immunosuppression, and use of mineralocorticoid receptor antagonists were not systematically collected.

## Conclusions

Among patients hospitalized with mild to moderate COVID-19 and who were taking ACEIs or ARBs before hospital admission, there was no significant difference in the mean number of days alive and out of the hospital for those assigned to discontinue vs continue these medications. These findings do not support routinely discontinuing ACEIs or ARBs among patients hospitalized with mild to moderate COVID-19 if there is an indication for treatment.

### ARTICLE INFORMATION

**Accepted for Publication:** December 13, 2020.

**Author Affiliations:** D'Or Institute for Research and Education, Rio de Janeiro, Brazil (Lopes, Macedo, Moll-Bernardes, Feldman, D'Andrea Saba Arruda, de Albuquerque, Camiletti, de Sousa, de Souza); Duke Clinical Research Institute, Duke University Medical Center, Durham, North Carolina (Lopes, Granger, Alexander); Brazilian Clinical Research Institute, São Paulo, Brazil (Lopes, de Barros E Silva, dos Santos, Mazza); Rede D'Or São Luiz, São Paulo, Brazil (Lopes, Camiletti, de Souza); Hospital São Luiz Jabaquara, São Paulo, Brazil (Macedo, de Paula); Santa Casa de São Paulo, São Paulo, Brazil (Macedo); Insper Institute of Education and Research, São Paulo, Brazil (dos Santos); Hospital São Luiz Anália Franco, São Paulo, Brazil (Feldman, Domiciano, Loures); Hospital São Luiz São Caetano, São Caetano do Sul, Brazil (D'Andrea Saba Arruda); Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil (de Albuquerque); Evandro Chagas National Institute of Infectious Diseases, Oswaldo Cruz Foundation, Rio de Janeiro, Brazil (de Sousa); Federal University of Rio de Janeiro, Rio de Janeiro, Brazil (de Sousa); Hospital Villa Lobos, São Paulo, Brazil (Giusti); Hospital São Rafael, Salvador, Brazil (Noya-Rabelo, Hamilton); Escola Bahiana de Medicina e Saúde Pública, Salvador, Brazil (Noya-Rabelo); Hospital SinoBrasileiro, Osasco, Brazil (Dionísio, Furquim); Hospital São Luiz Morumbi, São Paulo, Brazil (De Luca, dos Santos Sousa); Hospital Caxias D'Or, Duque de Caxias, Brazil (Bandeira); Hospital Copa D'Or, Rio de Janeiro, Brazil (Zukowski); Hospital Quinta D'Or, Rio de Janeiro, Brazil (de Oliveira); Hospital Santa Luzia, Brasília, Brazil (Ribeiro); Hospital Assunção, São Bernardo do Campo, Brazil (de Moraes); Hospital Barra D'Or, Rio de Janeiro, Brazil (Petritz); Hospital Niterói D'Or, Niterói, Brazil (Pimentel); Hospital Copa Star, Rio de Janeiro, Brazil (Miranda, de Souza); Hospital Oeste D'Or, Rio de Janeiro, Brazil (de Jesus Abufaiad); Harvard Medical School, Harvard University, Boston, Massachusetts (Gibson).

**Author Contributions:** Dr Lopes had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Concept and design:** Lopes, Macedo, de Barros E Silva, Moll-Bernardes, Mazza, Feldman, D'Andrea Saba Arruda, de Albuquerque, de Sousa, Dionísio,

Granger, Alexander, de Souza.

**Acquisition, analysis, or interpretation of data:** Lopes, Macedo, de Barros E Silva, Moll-Bernardes, dos Santos, Feldman, D'Andrea Saba Arruda, Camiletti, de Paula, Giusti, Domiciano, Noya-Rabelo, Hamilton, Loures, Dionísio, Furquim, De Luca, dos Santos Sousa, Bandeira, Zukowski, de Oliveira, Ribeiro, de Moraes, Petritz, Pimentel, Miranda, de Jesus Abufaiad, Gibson, Alexander.

**Drafting of the manuscript:** Lopes, Macedo, de Barros E Silva, Moll-Bernardes, Feldman, D'Andrea Saba Arruda, de Albuquerque, Camiletti, de Sousa, Dionísio, Zukowski, de Moraes, Miranda.

**Critical revision of the manuscript for important intellectual content:** Lopes, Macedo, de Barros E Silva, Moll-Bernardes, dos Santos, Mazza, Feldman, D'Andrea Saba Arruda, de Sousa, de Paula, Giusti, Domiciano, Noya-Rabelo, Hamilton, Loures, Dionísio, Furquim, De Luca, dos Santos Sousa, Bandeira, de Oliveira, Ribeiro, Petritz, Pimentel, de Jesus Abufaiad, Gibson, Granger, Alexander, de Souza.

**Statistical analysis:** Macedo, dos Santos, D'Andrea Saba Arruda, de Paula.

**Obtained funding:** Lopes, Moll-Bernardes.

**Administrative, technical, or material support:** Lopes, Macedo, Moll-Bernardes, Mazza, Feldman, D'Andrea Saba Arruda, de Albuquerque, Camiletti, de Sousa, de Paula, Giusti, Domiciano, Noya-Rabelo, Loures, Dionísio, Furquim, De Luca, Bandeira, de Oliveira, de Moraes, de Jesus Abufaiad, de Souza.

**Supervision:** Lopes, Macedo, de Barros E Silva, Moll-Bernardes, Feldman, D'Andrea Saba Arruda, de Albuquerque, Camiletti, de Sousa, Giusti, Noya-Rabelo, Dionísio, Petritz, Pimentel, Miranda, de Jesus Abufaiad.

**Conflict of Interest Disclosures:** Dr Lopes reported receiving grant support from Bristol-Myers Squibb, GlaxoSmithKline, Medtronic, Sanofi, and Pfizer; and receiving consulting fees from Bayer, Boehringer Ingelheim, Bristol-Myers Squibb, Daiichi-Sankyo, GlaxoSmithKline, Medtronic, Merck, Pfizer, Sanofi, and Portola. Dr Macedo reported receiving consulting fees from Pfizer, Bayer, AstraZeneca, Novartis, Daiichi-Sankyo, Zodiac, Roche, and Janssen. Dr de Barros E Silva reported receiving grants from Pfizer, Bayer, and Roche Diagnostics; and receiving consulting fees from Pfizer, Bayer, and Roche Diagnostics. Dr Feldman reported receiving consulting fees from Pfizer, Bayer, Daiichi-Sankyo,

Boehringer, and Servier. Dr D'Andrea Saba Arruda reported receiving consulting fees from Bayer, Pfizer, Servier, AstraZeneca, and Daiichi Sankyo. Dr de Albuquerque reported receiving consulting fees from Boehringer Ingelheim, AstraZeneca, Bayer, and Servier. Dr de Oliveira reported receiving consulting fees from Bayer, Pfizer, and Daiichi Sankyo. Dr Gibson reported receiving consulting fees and grants from Johnson & Johnson, Janssen, and Bayer. Dr Granger reported receiving grant support from AstraZeneca, the US Food and Drug Administration, the National Institutes of Health, GlaxoSmithKline, Medtronic, Novartis, Apple, Boehringer Ingelheim, Bristol-Myers Squibb/Pfizer, and Janssen; receiving consulting fees from AstraZeneca, Espero, GlaxoSmithKline, Medtronic, Novartis, Boehringer Ingelheim, Boston Scientific, Bristol-Myers Squibb/Pfizer, Daiichi Sankyo, Merck, Roche, Eli Lilly, and Janssen; and that all relationships with industry are listed at [dcri.org/about-us/conflict-of-interest/](http://dcri.org/about-us/conflict-of-interest/). Dr Alexander reported receiving grant support from Boehringer Ingelheim, Bayer, Bristol-Myers Squibb, CryoLife, CSL Behring, GlaxoSmithKline, Ferring, the US Food and Drug Administration, the National Institutes of Health, and XaTek; and receiving consulting fees from AbbVie, Bayer, Bristol-Myers Squibb, GlaxoSmithKline, CryoLife, CSL Behring, Novo Nordisk, Pfizer, Portola, Quantum Genomics, the US Department of Veterans Affairs, XaTek, Inositec, and Zafgen. Dr de Souza reported receiving grant support from Boehringer Ingelheim; and receiving consulting fees from Pfizer, Bayer, Daiichi-Sankyo, and Boehringer Ingelheim. No other disclosures were reported.

**The BRACE CORONA Principal Investigators:** The BRACE CORONA Principal Investigators are listed in [Supplement 2](#).

**Data Sharing Statement:** See [Supplement 4](#).

**Additional Information:** The trial was designed and led by an academic executive committee whose members were responsible for the trial's conduct. Only authors contributed to the writing of the article. The executive committee members are listed in [Supplement 2](#).

## REFERENCES

- Gheblawi M, Wang K, Viveiros A, et al. Angiotensin-converting enzyme 2. *Circ Res*. 2020;126(10):1456-1474.
- Soler MJ, Barrios C, Oliva R, et al. Pharmacologic modulation of ACE2 expression. *Curr Hypertens Rep*. 2008;10(5):410-414.
- Varagic J, Ahmad S, Nagata S, et al. ACE2: angiotensin II/angiotensin-(1-7) balance in cardiac and renal injury. *Curr Hypertens Rep*. 2014;16(3):420.
- Chung MK, Karnik S, Saef J, et al. SARS-CoV-2 and ACE2. *EBioMedicine*. 2020;58:102907.
- Patel AB, Verma A. COVID-19 and angiotensin-converting enzyme inhibitors and angiotensin receptor blockers. *JAMA*. 2020;323(18):1769-1770.
- Jarcho JA, Ingelfinger JR, Hamel MB, et al. Inhibitors of the renin-angiotensin-aldosterone system and Covid-19. *N Engl J Med*. 2020;382(25):2462-2464.
- Fanaroff AC, Califf RM, Harrington RA, et al. Randomized trials versus common sense and clinical observation. *J Am Coll Cardiol*. 2020;76(5):580-589.
- Ellenberg SS, Keusch GT, Babiker AG, et al. Rigorous clinical trial design in public health emergencies is essential. *Clin Infect Dis*. 2018;66(9):1467-1469.
- Fanaroff AC, Califf RM, Lopes RD. New approaches to conducting randomized controlled trials. *J Am Coll Cardiol*. 2020;75(5):556-559.
- Lopes RD, Macedo AVS, de Barros E Silva PGM, et al. Continuing versus suspending angiotensin-converting enzyme inhibitors and angiotensin receptor blockers. *Am Heart J*. 2020;226:49-59.
- Fanaroff AC, Cyr D, Neely ML, et al. Days alive and out of hospital. *Circ Cardiovasc Qual Outcomes*. 2018;11(12):e004755.
- Cavalcanti AB, Zampieri FG, Rosa RG, et al. Hydroxychloroquine with or without azithromycin in mild-to-moderate Covid-19. *N Engl J Med*. 2020;383(21):2041-2052.
- Beigel JH, Tomashek KM, Dodd LE, et al. Remdesivir for the treatment of Covid-19. *N Engl J Med*. 2020;383(19):1813-1826.
- Rigby RA, Stasinopoulos DM. Generalized additive models for location, scale and shape. *J R Stat Soc Ser C Appl Stat*. 2005;54(3):507-554. doi:10.1111/j.1467-9876.2005.00510.x
- R: A Language and Environment for Statistical Computing v. 3.5.1. R Foundation for Statistical Computing; 2019.
- Vaduganathan M, Vardeny O, Michel T, et al. Renin-angiotensin-aldosterone system inhibitors in patients with Covid-19. *N Engl J Med*. 2020;382(17):1653-1659.
- Imai Y, Kuba K, Rao S, et al. Angiotensin-converting enzyme 2 protects from severe acute lung failure. *Nature*. 2005;436(7047):112-116.
- Reynolds HR, Adhikari S, Pulgarin C, et al. Renin-angiotensin-aldosterone system inhibitors and risk of Covid-19. *N Engl J Med*. 2020;382(25):2441-2448.
- Mancia G, Rea F, Ludergnani M, et al. Renin-angiotensin-aldosterone system blockers and the risk of Covid-19. *N Engl J Med*. 2020;382(25):2431-2440.
- Meng J, Xiao G, Zhang J, et al. Renin-angiotensin system inhibitors improve the clinical outcomes of COVID-19 patients with hypertension. *Emerg Microbes Infect*. 2020;9(1):757-760.
- Zhang P, Zhu L, Cai J, et al. Association of inpatient use of angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers with mortality among patients with hypertension hospitalized with COVID-19. *Circ Res*. 2020;126(12):1671-1681. Published correction appears in *Circ Res*. 2020;127(6):e147.
- Li J, Wang X, Chen J, et al. Association of renin-angiotensin system inhibitors with severity or risk of death in patients with hypertension hospitalized for coronavirus disease 2019 (COVID-19) infection in Wuhan, China. *JAMA Cardiol*. 2020;5(7):825-830.
- Bravi F, Flacco ME, Carradori T, et al. Predictors of severe or lethal COVID-19, including angiotensin converting enzyme inhibitors and angiotensin II receptor blockers, in a sample of infected Italian citizens. *PLoS One*. 2020;15(6):e0235248.
- Huang Z, Cao J, Yao Y, et al. The effect of RAS blockers on the clinical characteristics of COVID-19 patients with hypertension. *Ann Transl Med*. 2020;8(7):430.
- Khera R, Clark C, Lu Y, et al. Association of angiotensin-converting enzyme inhibitors and angiotensin receptor blockers with the risk of hospitalization and death in hypertensive patients with coronavirus disease-19. *medRxiv*. 2020:2020.05.17.20104943. doi:10.1101/2020.05.17.20104943.
- de Abajo FJ, Rodríguez-Martín S, Lerma V, et al. Use of renin-angiotensin-aldosterone system inhibitors and risk of COVID-19 requiring admission to hospital. *Lancet*. 2020;395(10238):1705-1714.
- Mehta N, Kalra A, Nowacki AS, et al. Association of use of angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers with testing positive for coronavirus disease 2019 (COVID-19). *JAMA Cardiol*. 2020;5(9):1020-1026.
- Pan W, Zhang J, Wang M, et al. Clinical features of COVID-19 in patients with essential hypertension and the impacts of renin-angiotensin-aldosterone system inhibitors on the prognosis of COVID-19 patients. *Hypertension*. 2020;76(3):732-741.
- Guo T, Fan Y, Chen M, et al. Cardiovascular implications of fatal outcomes of patients with coronavirus disease 2019 (COVID-19). *JAMA Cardiol*. 2020;5(7):811-818.
- Elijovich F, Laffer CL. What kind of evidence is needed to dictate practice regarding inhibitors of the renin-angiotensin system in COVID-19? *Hypertension*. 2020;76(3):665-669.
- Bean DM, Kraljevic Z, Searle T, et al. Angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers are not associated with severe COVID-19 infection in a multi-site UK acute hospital trust. *Eur J Heart Fail*. 2020;22(6):967-974.
- European Society of Cardiology Council on Hypertension. Position statement on ACE-inhibitors and angiotensin receptor blockers. Published March 13, 2020. Accessed October 27, 2020. [https://www.escardio.org/Councils/Council-on-Hypertension-\(CHT\)/News/position-statement-of-the-esc-council-on-hypertension-on-ace-inhibitors-and-ang](https://www.escardio.org/Councils/Council-on-Hypertension-(CHT)/News/position-statement-of-the-esc-council-on-hypertension-on-ace-inhibitors-and-ang)
- Bozkurt B, Kovacs R, Harrington B. Joint HFSA/ACC/AHA statement addresses concerns. *J Card Fail*. 2020;26(5):370.
- Fonarow GC, Abraham WT, Albert NM, et al. Influence of beta-blocker continuation or withdrawal on outcomes in patients hospitalized with heart failure. *J Am Coll Cardiol*. 2008;52(3):190-199.
- Drager LF, Pio-Abreu A, Lopes RD, et al. Is hypertension a real risk factor for poor prognosis in the COVID-19 pandemic? *Curr Hypertens Rep*. 2020;22(6):43.
- Sattar N, McInnes IB, McMurray JJV. Obesity is a risk factor for severe COVID-19 infection. *Circulation*. 2020;142(1):4-6.
- Cao B, Wang Y, Wen D, et al. A trial of lopinavir-ritonavir in adults hospitalized with severe Covid-19. *N Engl J Med*. 2020;382(19):1787-1799.
- Furtado RHM, Berwanger O, Fonseca HA, et al. Azithromycin in addition to standard of care versus standard of care alone in the treatment of patients admitted to the hospital with severe COVID-19 in Brazil (COALITION II). *Lancet*. 2020;396(10256):959-967.
- Hung IF, Lung KC, Tso EY, et al. Triple combination of interferon beta-1b, lopinavir-ritonavir, and ribavirin in the treatment of patients admitted to hospital with COVID-19. *Lancet*. 2020;395(10238):1695-1704.
- Ah Y-M, Lee J-Y, Choi Y-J, et al. Persistence with antihypertensive medications in uncomplicated treatment-naïve patients. *J Korean Med Sci*. 2015;30(12):1800-1806.

**BRIEF REPORT**

# Comparable COVID-19 outcomes with current use of GLP-1 receptor agonists, DPP-4 inhibitors or SGLT-2 inhibitors among patients with diabetes who tested positive for SARS-CoV-2

Simone Bastrup Israelsen MD<sup>1,2</sup>  | Anton Pottegård DMSc<sup>3</sup>  |  
 Håkon Sandholdt MSc<sup>1</sup> | Sten Madsbad DMSc<sup>2,4</sup> | Reimar Wernich Thomsen PhD<sup>5</sup> |  
 Thomas Benfield DMSc<sup>1,2</sup>

<sup>1</sup>Center of Research and Disruption of Infectious Diseases, Department of Infectious Diseases, Copenhagen University Hospital, Hvidovre, Denmark

<sup>2</sup>Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark

<sup>3</sup>Clinical Pharmacology and Pharmacy, Department of Public Health, University of Southern Denmark, Odense, Denmark

<sup>4</sup>Department of Endocrinology, Copenhagen University Hospital, Hvidovre, Denmark

<sup>5</sup>Department of Clinical Epidemiology, Aarhus University Hospital, Aarhus, Denmark

**Correspondence**

Simone Bastrup Israelsen, MD, Center of Research and Disruption of Infectious Diseases, Department of Infectious Diseases, Copenhagen University Hospital, Amager and Hvidovre, Kettegaard Alle 30, DK-2650 Hvidovre, Denmark.  
 Email: simone.elisabeth.bastrup.israelsen.02@regionh.dk

**Abstract**

Incretin-based therapies, glucagon-like peptide-1 receptor agonists (GLP-1 RAs) and dipeptidyl peptidase-4 inhibitors (DPP-4i), have been hypothesized to exert beneficial effects on COVID-19 outcomes due to anti-inflammatory properties. In this population-based cohort study, we retrieved data from nationwide registries on all individuals diagnosed with severe acute respiratory syndrome coronavirus 2 infection up to 1 November 2020. For individuals with diabetes, we examined the impact of use of GLP-1 RAs (n = 370) and DPP-4i (n = 284) compared with sodium-glucose cotransporter-2 inhibitors (SGLT-2i) (n = 342) on risk of hospital admission and severe outcomes. Relative risks (RRs) were calculated after applying propensity score weighted methods to control for confounding. Current users of GLP-1 RAs had an adjusted RR of 0.89 (95% confidence interval 0.34-2.33), while users of DPP-4i had an adjusted RR of 2.42 (95% confidence interval 0.99-5.89) for 30-day mortality compared with SGLT-2i use. Further, use of GLP-1 RAs or DPP-4i compared with SGLT-2i was not associated with decreased risk of hospital admission. Thus, use of incretin-based therapies in individuals with diabetes and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was not associated with improved clinical outcomes.

**KEYWORDS**

antidiabetic drug, DPP-4 inhibitor, GLP-1 analogue, population study, SGLT-2 inhibitor

**1 | INTRODUCTION**

Diabetes is associated with up to two-fold increased risk of mortality for individuals with coronavirus disease 2019 (COVID-19).<sup>1,2</sup> Recent recommendations advise discontinuation of metformin and sodium-glucose cotransporter-2 inhibitors (SGLT-2i) in severe cases due to a risk of lactic acidosis or ketoacidosis and dehydration.<sup>3</sup> Meanwhile, glucagon-like peptide-1 receptor agonists (GLP-1 RAs) and dipeptidyl peptidase-4 inhibitors (DPP-4i) are hypothesized to have a beneficial anti-inflammatory effect on COVID-19 mediated by cytokine inhibition.<sup>4</sup> Sitagliptin, the first approved agent of DPP-4i, has been associated with reduced mortality in

patients with COVID-19 and with type 2 diabetes when administered at hospital admission.<sup>5</sup> However, most previous studies were restricted to hospitals and selected populations, and population-based evidence of an impact of current use of novel glucose-lowering drugs (GLDs) on COVID-19 outcomes is limited.

**2 | METHODS**

Data were retrieved from nationwide registries throughout Denmark on all individuals diagnosed with severe acute respiratory syndrome

coronavirus 2 infection (SARS-CoV-2; using the reverse transcriptase-polymerase chain reaction test) up to 1 November 2020.<sup>6</sup>

The current use of GLP-1 RA, DPP-4i or SGLT-2i was defined as redeemed prescriptions within 90 days before testing positive for SARS-CoV-2. The primary outcome was death within 30 days after a positive SARS-CoV-2 test, while secondary outcomes included hospital admission, intensive care unit (ICU) admission and mechanical ventilation. Patients were followed from the date of positive test for SARS-CoV-2 until death, migration or end of follow-up (30 days). We compared rates of outcomes in users of GLP-1 RA or DPP-4i with those among users of SGLT-2i. Individuals receiving combinations of these drugs and individuals with less than 1 year of available data were excluded from the analyses.

SGLT-2is were chosen as active comparators as they are generally used for similar medical indications, that is, second- or third-line GLD. Furthermore, GLP-1 RA and SGLT-2i users in Denmark have previously been shown to be comparable regarding age, duration of diabetes and GLD therapy, prevalence of diabetic complications and comorbidities.<sup>7</sup> Both drug groups can induce a weight loss, although this is more pronounced for GLP-1 RA. Finally, DPP-4i users are expected to be slightly older and experience more comorbidities compared with GLP-1 RA and SGLT-2i users.<sup>8</sup>

An individual propensity score of drug exposure was computed by using logistic regression based on age, sex, markers of diabetes severity, comorbidities and use of cardiovascular medication (Table 1). Propensity scores were used to calculate stabilized inverse probability of treatment weights, which were applied to account for differences in patient characteristics between treatment groups, that is, to control for confounding.

Descriptive statistics are reported as median with interquartile range for continuous variables or number with percentages for categorical variables. Baseline characteristics are presented for the unweighted and weighted patient cohort for both comparisons (GLP-1 RA vs. SGLT-2i and DPP-4i vs. SGLT-2i). The differences in risk factors between treatment groups were quantified by standardized mean differences. Relative risks were calculated by log binomial regression and presented as both crude (unweighted) and adjusted (weighted) estimates with 95% confidence intervals (CI).

### 3 | RESULTS

In total, 49 332 cases with SARS-CoV-2 infection were identified between 27 February and 1 November 2020. Of these, 1970 were current users of any GLDs, including 370 GLP-1 RA, 284 DPP-4i and 342 SGLT-2i users. Patients receiving both GLP-1 RA and SGLT-2i ( $n = 96$ ) or both DPP-4i and SGLT-2i ( $n = 68$ ) were excluded from the analyses. Individuals with <1 year of baseline data ( $n = 886$ ) due to recent migration were excluded as well.

DPP-4i use was associated with older age (median 67 compared with 59 years for GLP-1 RA and SGLT-2i use) and higher Charlson's Comorbidity Index (CCI) scores (CCI  $\geq 3$ : 9% vs. 6% and 5% in users of GLP-1 RA and SGLT-2i, respectively) (Table 1). In the GLP-1 RA and

DPP-4i versus SGLT-2i analyses, 2.11% and 2.33% of the weights were >3, with 5-95% percentiles at 0.47-1.89 and 0.54-1.91, respectively. No weights were >10 after stabilization.

In weighted analyses, GLP-1 RA users had similar 30-day mortality to SGLT-2i users (3.3% vs. 3.7%) that both were lower than for DPP-4i users (8.6%) corresponding to an adjusted and weighted relative risk (RR) of 0.89 (95% CI 0.34-2.33) for GLP-1 RA and an adjusted and weighted RR of 2.42 (95% CI 0.99-5.89) for DPP-4i compared with SGLT-2i users, respectively (Table 2). Risks of hospital admission, ICU admission and mechanical ventilation were overall similar in GLP-1 RA and DPP-4i users compared with SGLT-2i users (Table 2). Risks of hospital admission and mechanical ventilation were increased across all treatment groups with adjusted RRs between 1.22 and 2.22, while adjusted RR for ICU admission was close to 1.0 for GLP-1 RA users and 1.30 for DPP-4i users (Table 2). However, all these estimates had low statistical precision (Table 2).

### 4 | DISCUSSION

Use of GLP-1 RA or DPP-4i was not associated with improved outcomes compared with SGLT-2i use in individuals infected with SARS-CoV-2. However, DPP-4i users had a more than a two-fold increased 30-day mortality compared with SGLT-2i users, although this result had low statistical precision. These findings do not support a preventive or attenuation effect of current use of DPP-4i or GLP-1 RA in patients with diabetes and SARS-CoV-2 infection including those admitted with COVID-19.<sup>4</sup> Indeed, they contradict the recent findings by Solerte et al.<sup>5</sup> concluding that treatment with sitagliptin at hospital admission is associated with reduced mortality in COVID-19 patients with diabetes. However, several aspects may limit the comparability of the studies. Our study differs in that less than 30% of individuals were hospitalized and in the timing of treatment, that is, individuals included in our study were users of DPP-4i before being infected with SARS-CoV-2. Owing to the retrospective design of both studies, the results are not definitive and require confirmation in a randomized controlled trial. Although we adjusted for diabetes severity markers, comorbidities and cardiovascular comedications, our results could still have been influenced by residual confounding from unmeasured or unknown factors driven by more comorbidities and less obesity in DPP-4i compared with SGLT-2i users. Finally, the generalizability of our study results may depend on the availability of novel GLD combination therapies and high-quality diabetes care in health care systems that may be overwhelmed by workload due to steep infection curves.

Overall, our findings that incretin-based therapies (GLP-1 RA and DPP-4i) in individuals with diabetes and COVID-19 were not associated with improved outcomes are consistent with previous reports on use of GLD before a diagnosis of SARS-CoV-2 infection.<sup>9,10</sup> The CORONADO study included 1317 patients with diabetes and did not find an association between type of GLD use and mechanical ventilation or death.<sup>9</sup> Dalan et al.<sup>11</sup> found an increased risk of ICU admission among 27 patients with diabetes and concomitant use of DPP-4i, within a cohort of 717 patients hospitalized with SARS-CoV-2

**TABLE 1** Patient characteristics before and after inverse probability of treatment weighting

	GLP-1 RA (n = 370)	SGLT-2i (n = 246)	SMD	wGLP-1 RA (n = 373)	wSGLT-2i (n = 243)	wSMD	DPP-4i (n = 284)	SGLT-2i (n = 274)	SMD	wDPP-4i (n = 291)	wSGLT-2i (n = 266)	wSMD
Age, median (IQR)	59 (51-70)	59 (52-68)	0.02	60 (52-69)	59 (52-68)	0.00	67 (57-76)	58 (52-68)	0.57	63 (53-74)	62 (53-71)	0.08
Sex (male)	196 (53.0)	152 (61.8)	0.18	209 (55.9)	138 (56.8)	0.02	173 (60.9)	165 (60.2)	0.01	172 (59.0)	160 (60.2)	0.03
Other diabetes treatment												
Metformin	218 (58.9)	190 (77.2)	0.40	249 (66.8)	163 (67.2)	0.01	215 (75.7)	212 (77.4)	0.04	219 (75.2)	208 (78.0)	0.07
Insulin	141 (38.1)	43 (17.5)	0.47	113 (30.4)	72 (29.5)	0.02	40 (14.1)	77 (28.1)	0.35	64 (22.0)	58 (21.7)	0.01
Sulfonylureas	11 (3.0)	17 (6.9)	0.18	20 (5.3)	11 (4.6)	0.03	27 (9.5)	15 (5.5)	0.15	19 (6.6)	17 (6.2)	0.02
Diabetes markers												
Duration, median (IQR), years <sup>a</sup>	10 (5-15)	8 (4-13)	0.16	10 (5-15)	10 (5-15)	0.02	10 (6-14)	10 (5-14)	0.10	10 (6-15)	10 (6-15)	0.02
Microvascular complications <sup>b</sup>	112 (30.3)	41 (16.7)	0.33	95 (25.4)	59 (24.2)	0.03	65 (22.9)	60 (21.9)	0.02	69 (23.6)	60 (22.4)	0.03
Macrovascular complications <sup>b</sup>	97 (26.2)	62 (25.2)	0.02	98 (26.2)	64 (26.4)	0.01	92 (32.4)	76 (27.7)	0.10	92 (31.5)	80 (29.9)	0.04
Charlson's Comorbidity Index												
0	278 (75.1)	199 (80.9)	0.14	288 (77.2)	193 (79.3)	0.05	203 (71.5)	220 (80.3)	0.21	222 (76.5)	203 (76.1)	0.01
1-2	69 (18.6)	36 (14.6)	0.11	60 (16.1)	39 (16.1)	0.00	56 (19.7)	41 (15.0)	0.13	51 (17.5)	45 (17.0)	0.01
≥3	23 (6.2)	11 (4.5)	0.08	25 (6.6)	11 (4.7)	0.11	25 (8.8)	13 (4.7)	0.16	18 (6.1)	18 (6.9)	0.04
Diagnoses <sup>b</sup>												
Myocardial infarction	7 (1.9)	11 (4.5)	0.15	12 (3.3)	7 (3.1)	0.01	15 (5.3)	11 (4.0)	0.06	15 (5.2)	15 (5.8)	0.02
Heart failure	24 (6.5)	11 (4.5)	0.09	20 (5.3)	13 (5.2)	0.01	18 (6.3)	16 (5.8)	0.02	14 (4.8)	15 (5.6)	0.04
Obesity	108 (29.2)	38 (15.4)	0.33	88 (23.5)	55 (22.4)	0.03	35 (12.3)	62 (22.6)	0.27	51 (17.7)	47 (17.7)	0.00
Medication <sup>c</sup>												
Antihypertensives	208 (56.2)	122 (49.6)	0.13	194 (51.9)	133 (54.8)	0.06	175 (61.6)	145 (52.9)	0.18	166 (57.0)	150 (56.3)	0.01
Statins	185 (50.0)	124 (50.4)	0.01	186 (49.7)	123 (50.5)	0.02	151 (53.2)	149 (54.4)	0.02	150 (51.7)	141 (52.9)	0.02
Antiplatelets	117 (31.6)	59 (24.0)	0.17	102 (27.3)	65 (26.6)	0.02	94 (33.1)	79 (28.8)	0.09	79 (27.3)	76 (28.7)	0.03

Abbreviations: DPP-4i, dipeptidyl peptidase-4 inhibitor; GLP-1 RA, glucagon-like peptide-1 receptor agonist; IQR, interquartile ranges; SGLT-2i, sodium-glucose cotransporter-2 inhibitor; SMD, standardized mean differences; w, weighted.

<sup>a</sup>Years since first redeemed glucose-lowering drug prescription (registered since 2005).

<sup>b</sup>Complications or diagnoses within 10 years before inclusion.

<sup>c</sup>Use within 90 days before inclusion.

**TABLE 2** Outcomes of SARS-CoV-2 infection in users of GLP-1 RA and DPP-4i compared with users of SGLT-2i before and after inverse probability of treatment weighting

Outcome	GLP-1 RA		SGLT-2i		GLP-1 RA vs. SGLT-2i		DPP-4i		SGLT-2i		DPP-4i vs. SGLT-2i	
	Events	Risk (%)	Events	Risk (%)	Relative risk	Events	Risk (%)	Events	Risk (%)	Events	Risk (%)	Relative risk
Crude estimates												
30-day death	14/370	3.8 (1.8-5.7)	9/246	3.7 (1.3-6.0)	1.03 (0.45-2.35)	30/284	10.6 (7.0-14.1)	7/274	2.6 (0.7-4.4)	4.13 (1.85-9.26)		
ICU admission	12/370	3.2 (1.4-5.1)	9/246	3.7 (1.3-6.0)	0.89 (0.38-2.07)	16/282	5.7 (3.0-8.4)	9/274	3.3 (1.2-5.4)	1.73 (0.78-3.85)		
Mechanical ventilation	10/370	2.7 (1.0-4.4)	7/246	2.8 (0.8-4.9)	0.95 (0.37-2.46)	15/284	5.3 (2.7-7.9)	6/274	2.2 (0.5-3.9)	2.41 (0.95-6.13)		
Hospital admission	94/362	26.0 (21.4-30.5)	54/243	22.2 (17.0-27.5)	1.17 (0.87-1.57)	85/276	30.8 (25.3-36.3)	55/273	20.1 (15.4-24.9)	1.53 (1.14-2.05)		
Adjusted estimates <sup>a</sup>												
30-day death	12/373	3.3 (1.4-5.2)	9/243	3.7 (0.8-6.5)	0.89 (0.34-2.33)	25/291	8.6 (4.9-12.3)	9/266	3.6 (0.8-6.4)	2.42 (0.99-5.89)		
ICU admission	10/373	2.7 (1.2-4.3)	8/243	3.2 (0.8-5.5)	0.87 (0.34-2.21)	12/290	4.1 (2.1-6.2)	8/266	3.2 (0.9-5.5)	1.30 (0.54-3.12)		
Mechanical ventilation	13/373	3.5 (0.3-6.8)	5/243	2.1 (0.3-3.9)	1.65 (0.47-5.76)	14/291	4.8 (1.9-7.7)	6/266	2.2 (0.3-4.1)	2.22 (0.77-6.46)		
Hospital admission	102/367	27.9 (21.7-34.1)	54/241	22.4 (16.0-28.8)	1.25 (0.87-1.79)	74/285	26.1 (20.0-32.2)	57/265	21.5 (16.0-27.0)	1.22 (0.86-1.72)		

Abbreviations: DPP-4i, dipeptidyl peptidase-4 inhibitor; GLP-1 RA, glucagon-like peptide-1 receptor agonist; ICU, intensive care unit; SGLT-2i, sodium-glucose cotransporter-2 inhibitor.

<sup>a</sup>Adjusted estimates obtained in an inverse probability of treatment weighted pseudo-population using stabilized weights. Factors included in the propensity score informing the weights were age, sex, duration of glucose-lowering drug (GLD) treatment, concomitant use of other GLDs (metformin, insulin, sulfonylureas), diabetic complications, medical obesity, myocardial infarction, chronic heart failure, chronic obstructive pulmonary disease, Charlson's Comorbidity Index without diabetes mellitus (0, 1-2, ≥3), and cardiovascular medications (antihypertensives, statins, antiplatelets).

infection, but did not include data on mortality. Other studies have reported a worse prognosis of insulin-treated versus non-insulin-treated patients with diabetes and COVID-19, but it is unclear whether this reflects insulin effects per se or the presence of more advanced or poorly controlled diabetes with additional comorbidity that is associated with both insulin use and more severe COVID-19.<sup>1,10</sup>

## 5 | CONCLUSION

In conclusion, neither current use of GLP-1 RA nor DPP-4i was associated with improved outcomes of individuals with diabetes infected with SARS-CoV-2 when compared with SGLT-2i use. Use of DPP-4i before infection with SARS-CoV-2 might even have a harmful effect, in contrast to the current anti-inflammation hypotheses and the possible association of sitagliptin treatment at hospital admission with reduced mortality. However, our study results should be interpreted cautiously due to the limited sample size.

## ACKNOWLEDGMENTS

No funding was obtained for this study.

## CONFLICT OF INTEREST

T.B. reports grants from Pfizer, Novo Nordisk Foundation, Simonsen Foundation, Lundbeck Foundation and Kai Hansen Foundation, grants and personal fees from GSK, Pfizer and Gilead, and personal fees from Boehringer Ingelheim and MSD, with no relation to the work reported in this paper. A.P. reports grants from Alcon, Almirall, Astellas, Astra-Zeneca, Boehringer-Ingelheim, Novo Nordisk, Servier and LEO Pharma, with no relation to the work reported in this paper. R.W.T. reports that the Department of Clinical Epidemiology is involved in studies with funding from various companies as research grants to and administered by Aarhus University. None of these studies have relation to the present study. S.M. reports grants and personal fees from Novo Nordisk A/S and Boehringer-Ingelheim, and personal fees from MSD and Sanofi, with no relation to the work reported in this paper. S.B.I. and H.S. report no conflicts of interest.

## PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1111/dom.14329>.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the Danish Health Data Authority. Restrictions apply to the availability of these data, which were used under license for this study

## ORCID

Simone Bastrup Israelsen  <https://orcid.org/0000-0002-0653-1289>

Anton Pottegård  <https://orcid.org/0000-0001-9314-5679>



## REFERENCES

1. Reilev M, Kristensen KB, Pottegård A, et al. Characteristics and predictors of hospitalization and death in the first 11 122 cases with a positive RT-PCR test for SARS-CoV-2 in Denmark: a nationwide cohort. *Int J Epidemiol.* 2020;49:1468-1481. <https://doi.org/10.1093/ije/dyaa140>.
2. Williamson EJ, Walker AJ, Bhaskaran K, et al. OpenSAFELY: factors associated with COVID-19 death in 17 million patients. *Nature.* 2020;584:430-436. <https://doi.org/10.1038/s41586-020-2521-4>.
3. Bornstein SR, Rubino F, Khunti K, et al. Practical recommendations for the management of diabetes in patients with COVID-19. *Lancet Diabetes Endocrinol.* 2020;8(6):546-550. [https://doi.org/10.1016/S2213-8587\(20\)30152-2](https://doi.org/10.1016/S2213-8587(20)30152-2).
4. Mirabelli M, Chiefari E, Puccio L, Foti DP, Brunetti A. Potential benefits and harms of novel antidiabetic drugs during COVID-19 crisis. *Int J Environ Res Public Health.* 2020;17(10):3664. <https://doi.org/10.3390/ijerph17103664>.
5. Solerte SB, D'Addio F, Trevisan R, et al. Sitagliptin treatment at the time of hospitalization was associated with reduced mortality in patients with type 2 diabetes and COVID-19: a multicenter, case-control, retrospective, observational study. *Diabetes Care.* 2020;43:2999-3006. <https://doi.org/10.2337/dc20-1521>.
6. Pottegård A, Kristensen KB, Reilev M, et al. Existing data sources in clinical epidemiology: the Danish COVID-19 cohort. *Clin Epidemiol.* 2020;12:875-881. <https://doi.org/10.2147/CLEP.S257519>.
7. Knudsen JS, Baggesen LM, Lajer M, et al. Changes in SGLT2i and GLP-1RA real-world initiator profiles following cardiovascular outcome trials: a Danish nationwide population-based study. *PLoS One.* 2020;15(3):e0229621. <https://doi.org/10.1371/journal.pone.0229621>.
8. Pottegård A, Lund LC, Henriksen DP, et al. Use of dipeptidyl peptidase-4 inhibitors and risk of splanchnic vein thrombosis: a Danish nationwide new-user active comparator cohort study. *Diabetes Obes Metab.* 2020;23:648-652. <https://doi.org/10.1111/dom.14253>.
9. Cariou B, Hadjadj S, Wargny M, et al. Phenotypic characteristics and prognosis of inpatients with COVID-19 and diabetes: the CORONADO study. *Diabetologia.* 2020;63(8):1500-1515. <https://doi.org/10.1007/s00125-020-05180-x>.
10. Chen Y, Yang D, Cheng B, et al. Clinical characteristics and outcomes of patients with diabetes and COVID-19 in association with glucose-lowering medication. *Diabetes Care.* 2020;43(7):1399-1407. <https://doi.org/10.2337/dc20-0660>.
11. Dalan R, Ang LW, Tan WYT, et al. The association of hypertension and diabetes pharmacotherapy with COVID-19 severity and immune signatures: an observational study. *Eur Heart J Cardiovasc Pharmacother.* 2020. <https://doi.org/10.1093/ehjcvp/pvaa098>.

**How to cite this article:** Israelsen SB, Pottegård A, Sandholdt H, Madsbad S, Thomsen RW, Benfield T. Comparable COVID-19 outcomes with current use of GLP-1 receptor agonists, DPP-4 inhibitors or SGLT-2 inhibitors among patients with diabetes who tested positive for SARS-CoV-2. *Diabetes Obes Metab.* 2021;1-5. <https://doi.org/10.1111/dom.14329>