



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Review Article

Psychopharmacology of COVID-19



Melanie Bilbul, M.D., C.M., F.R.C.P.(C), Patricia Paparone, M.D., Anna M. Kim, M.D.,
Shruti Mutalik, M.D., Carrie L. Ernst, M.D.

Background: *With the rapid, global spread of severe acute respiratory syndrome coronavirus 2, hospitals have become inundated with patients suffering from coronavirus disease 2019. Consultation-liaison psychiatrists are actively involved in managing these patients and should familiarize themselves with how the virus and its proposed treatments can affect psychotropic management. The only Food and Drug Administration–approved drug to treat COVID-19 is remdesivir, and other off-label medications used include chloroquine and hydroxychloroquine, tocilizumab, lopinavir/ritonavir, favipiravir, convalescent plasma therapy, azithromycin, vitamin C, corticosteroids, interferon, and colchicine.*

Objective: *To provide an overview of the major safety considerations relevant to clinicians who prescribe psychotropics to patients with COVID-19, both related to the illness and its proposed treatments. Methods:* *In this targeted review, we performed structured literature searches in PubMed to identify articles describing the impacts of COVID-19 on different organ systems, the*

neuropsychiatric adverse effects of treatments, and any potential drug interactions with psychotropics. The articles most relevant to this one were included. Results: *COVID-19 impacts multiple organ systems, including gastrointestinal, renal, cardiovascular, pulmonary, immunological, and hematological systems. This may lead to pharmacokinetic changes that impact psychotropic medications and increase sensitivity to psychotropic-related adverse effects. In addition, several proposed treatments for COVID-19 have neuropsychiatric effects and potential interactions with commonly used psychotropics. Conclusions:* *Clinicians should be aware of the need to adjust existing psychotropics or avoid using certain medications in some patients with COVID-19. They should also be familiar with neuropsychiatric effects of medications being used to treat this disease. Further research is needed to identify strategies to manage psychiatric issues in this population.*

(Psychosomatics 2020; 61:411–427)

Key words: COVID-19, psychotropic, psychopharmacology, side effects.

INTRODUCTION

With the rapid, global spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), hospitals have become inundated with patients suffering from COVID-19 infection. Remdesivir was recently approved by the US Food and Drug Administration (FDA) to treat severe COVID-19,¹ and many other medications are either being studied in clinical trials or being used off-label and/or for compassionate use.²

As the pandemic spreads, consultation-liaison psychiatrists are being called upon to help manage the

psychiatric conditions of individuals with COVID-19 and are encountering challenging clinical scenarios of multiple medical comorbidities and unfamiliar drugs. Psychiatrists should familiarize themselves

Received April 24, 2020; revised May 11, 2020; accepted May 12, 2020. From the Department of Psychiatry (M.B., P.P., A.M.K., S.M., C.L.E.), Icahn School of Medicine at Mount Sinai, New York, NY; Department of Medical Education (C.L.E.), Icahn School of Medicine at Mount Sinai, New York, NY. Send correspondence and reprint requests to Carrie L. Ernst, MD, One Gustave L. Levy Place, Box 1230, New York, NY 10029; e-mail: carrie.ernst@mssm.edu

© 2020 Academy of Consultation-Liaison Psychiatry. Published by Elsevier Inc. All rights reserved.

Psychopharmacology of COVID-19

with the mechanism of action of these treatments, neuropsychiatric side effects, and possible interactions with psychotropics. In addition, as COVID-19 affects multiple organ systems, psychiatrists will need to be aware of safety concerns inherent in prescribing psychotropics to these patients.

This article is divided into 2 main sections. The first provides an update on the organ systems that may be negatively impacted by COVID-19 and recommendations for safer use of psychotropics in these patients. The second section reviews potential neuropsychiatric side effects of the early approved and investigational treatments for COVID-19 as well as pharmacokinetic and pharmacodynamic drug interactions when used concurrently with psychotropics. COVID-19 therapies reviewed include remdesivir, chloroquine, hydroxychloroquine, azithromycin, tocilizumab, lopinavir/ritonavir, favipiravir, convalescent plasma therapy, corticosteroids, interferon (IFN), vitamin C, and colchicine.

Given the limited literature in this area, we undertook a nonsystematic narrative review that was focused on practical clinical concerns. We used a structured PubMed search using the following search terms in combination with the names of the medications mentioned previously: “COVID-19”, “coronavirus”, “Psychotropic medications”, “QT prolongation”, “Psychiatric side effects”, “Neuropsychiatric side effects”, “drug interactions”, and pertinent organ systems, for example, “hepatic”, “renal”, “hematological”, “pulmonary”, and “cardiac”. This was followed by a search of manufacturer’s package inserts for pertinent facts about specific medications, including drug interactions.

We selected the aforementioned medications as they were the ones most commonly being used in health care settings and clinical trials at the time of preparation of this article, although we are aware that this is a rapidly evolving field and thus this list is not meant to be comprehensive.

IMPACT OF COVID-19 ON PSYCHOTROPIC DRUG SAFETY

COVID-19 is believed to impact multiple organs, including the liver, kidneys, lungs, and heart, as well as the immune and hematological systems.³ Damage to these organs or systems may lead to pharmacokinetic changes that impact absorption, distribution,

metabolism, and/or excretion of psychotropic medications as well as increased sensitivity to certain psychotropic adverse effects. As such, clinicians should be aware of the potential need to make adjustments to existing psychotropic regimens or avoid using certain psychotropic agents if such safety concerns arise (Tables 1 and 2).

Hematological Effects

An early report noted the presence of lymphopenia (lymphocyte count less than $1.0 \times 10^9/L$) in 63% and leukopenia (white blood cell count less than $4 \times 10^9/L$) in 25% of patients with COVID-19.⁴ It has been proposed that lymphopenia is a feature of severe COVID-19 cases and may serve as a poor prognostic factor. Contributing factors likely include direct infection of lymphocytes and cytokine storm.⁵ It therefore seems prudent to use caution and consider avoiding medications that have the potential to further impact white blood cell production, particularly lymphocytes. By contrast, clinicians might determine that it is acceptable from a safety standpoint to continue psychotropics which have only been associated with agranulocytosis and neutropenia, assuming the patient does not have a secondary bacterial infection. Several psychotropics have been implicated in hematological adverse effects, including leukopenia, neutropenia, and agranulocytosis. The most commonly implicated psychotropics include carbamazepine and clozapine, but there is a class effect FDA warning on all first and secondary generation antipsychotics for the potential association with leukopenia, neutropenia, and agranulocytosis, as well as a number of published case reports. Carbamazepine is more likely to be associated with an early transient leukopenia but has also been associated with agranulocytosis and aplastic anemia.⁶

While the leukopenia and lymphopenia observed in patients with COVID-19 may be less of a concern for clozapine prescribers in the setting of a normal neutrophil count, clozapine deserves unique mention given several potential challenges associated with its use during the COVID-19 pandemic. These challenges have been recently reviewed along with recommendations for management in a consensus statement by Siskind and colleagues.⁷ Patients on clozapine may have difficulty accessing routine absolute neutrophil count monitoring, and the FDA has released guidance allowing health care providers to use medical judgment to delay

TABLE 1. Potential Psychotropic Safety Concerns in COVID-19 Organized by Drug Class

Drug class	Specific drugs	Problem	Solution
Antipsychotics	Clozapine	<p>Patients with difficulty accessing ANC monitoring May be associated with increased risk of pneumonia and its complications Levels can increase with acute infection leading to clozapine toxicity COVID-19 associated with leukopenia and lymphopenia; unclear impact on neutrophils; clozapine associated with neutropenia and agranulocytosis and more rarely lymphopenia or aplastic anemia COVID-19 associated with seizures; clozapine can lower seizure threshold</p>	<p>Reduce frequency of ANC monitoring at discretion of provider Education of patients and urgent clinical assessment including ANC for those with symptoms of infection Consider halving clozapine dose in patients with fever, pneumonia, and/or flu-like symptoms; temporarily discontinue clozapine if toxicity emerges Monitor complete blood count (CBC); if persistent white blood cell abnormalities, weigh risks versus benefits of continuing clozapine; when total white blood cell count is decreased but neutrophil count is normal, consider continuing clozapine Recognize potential for lowered seizure threshold; assure nontoxic clozapine level; consider holding clozapine, decreasing dose, or adding antiepileptic</p>
	Other antipsychotics	<p>COVID-19 associated with decreased white blood cell and lymphocyte counts; rare reports of antipsychotic-associated aplastic anemia or lymphopenia, especially with phenothiazines (chlorpromazine, fluphenazine, thioridazine) Coagulation abnormalities (PT and aPTT prolongation, thrombocytopenia) are observed in patients with COVID-19; rare reports of thrombocytopenia associated with multiple antipsychotics Concern for COVID-19 associated tachyarrhythmias and cardiac injury and potential for several medications being used to treat COVID-19 to cause QT prolongation; all antipsychotics with potential for QT prolongation Acute liver injury in patients with COVID-19; antipsychotics (especially chlorpromazine) with potential for drug-induced liver injury COVID-19 associated with seizures; all antipsychotics can lower seizure threshold</p>	<p>Monitor CBC; if persistent hematologic abnormalities (e.g., lymphopenia, neutropenia, thrombocytopenia) weigh risks versus benefits of continuing antipsychotic agent Baseline EKG for QTc; caution in patients with baseline prolonged QTc and/or other risk factors for drug-induced QT prolongation and TdP; daily EKG and electrolyte monitoring, reduce other risk factors, and cardiology consult in high-risk cases if opt to use antipsychotic; case-by-case risk-benefit discussion Monitor liver function tests and avoid chlorpromazine in patients with liver injury; risk versus benefit assessment for other antipsychotic use Consider avoiding antipsychotics (especially clozapine, quetiapine, olanzapine, and first-generation drugs) or adding antiepileptic drug (AED) in patients who have seizures</p>
Antiepileptics	Carbamazepine	<p>COVID-19 associated with leukopenia and lymphopenia; leukopenia and rare reports of aplastic anemia associated with carbamazepine use; Acute liver injury in patients with COVID-19; carbamazepine with potential for drug-induced liver injury</p>	<p>Monitor CBC; if persistent white blood cell abnormalities or aplastic anemia, use alternative AED Monitor liver function tests and avoid carbamazepine in patients with liver injury</p>
	Valproic acid	<p>Coagulation abnormalities (PT and aPTT prolongation, thrombocytopenia) observed in patients with COVID-19; valproic acid associated with thrombocytopenia Acute liver injury in patients with COVID-19; valproic acid with potential for drug-induced liver injury</p>	<p>Monitor platelet count; avoid valproic acid if thrombocytopenia Monitor liver function tests and avoid valproic acid in patients with liver injury</p>
	Gabapentin	<p>COVID-19 with potential for acute kidney injury; gabapentin clearance dependent on intact renal function</p>	<p>Adjust gabapentin dose based on renal function</p>

TABLE 1. (Continued)

Drug class	Specific drugs	Problem	Solution
Selective serotonin reuptake inhibitors (SSRIs) and serotonin norepinephrine reuptake inhibitors (SNRIs)	All	Coagulation abnormalities observed in patients with COVID-19 and many patients with COVID-19 receiving anticoagulation; SSRIs and SNRIs associated with impaired platelet aggregation and abnormal bleeding Concern for COVID-19-associated tachyarrhythmias and cardiac injury and potential for several medications being used to treat COVID-19 to cause QT prolongation; citalopram with potential for QT prolongation Acute liver injury in patients with COVID-19; duloxetine with a potential for drug-induced liver injury	Monitor coagulation factors and platelet count; weigh risks and benefits for individual patient but consider avoiding SSRIs and SNRIs in patients with recent bleeding or high risk for bleeding (e.g., thrombocytopenia, concurrent anticoagulation therapy, history of hemorrhage); can instead use nonserotonin reuptake inhibitor antidepressant such as bupropion Baseline EKG for QTc; caution in patients with baseline prolonged QTc and/or other risk factors for drug-induced QT prolongation and TdP; consider using SSRI other than citalopram in high-risk cases Monitor liver function tests, avoid duloxetine in patients with liver injury
Bupropion		COVID-19 associated with seizures; bupropion can lower seizure threshold	Avoid bupropion in patients with seizures or lowered seizure threshold
Lithium		COVID-19 with potential for acute kidney injury; lithium clearance dependent on intact renal function; lithium with nephrotoxic potential	Adjust lithium dose based on renal function; consider temporarily holding lithium until acute kidney injury resolves
Benzodiazepines	All	COVID-19 associated with delirium; benzodiazepines can exacerbate delirium COVID-19 associated with prominent respiratory symptoms; benzodiazepines can suppress respiratory drive Lopinavir/Ritonavir contraindicated with midazolam and triazolam (and can raise levels of some other benzodiazepines) due to CYP450 inhibition	Avoid or taper existing benzodiazepines in patients with delirium if possible Weigh risks versus benefits in using benzodiazepines in patients with prominent respiratory symptoms; a low dose may be able to be used safely in nondelirious patients Avoid midazolam and triazolam and consider using lorazepam, temazepam, or oxazepam in patients taking lopinavir/ritonavir

ANC = absolute neutrophil count; aPTT = activated partial thromboplastin time; COVID-19 = coronavirus disease 2019; EKG = electrocardiogram; PT = prothrombin time; TdP = torsades de pointes.

laboratory testing for drugs subject to Risk Evaluation and Mitigation Strategy.⁸ While there are no data yet available on COVID-19 in patients on clozapine, it has been suggested that clozapine is associated with a higher risk of pneumonia and its complications. Explanations include aspiration, sialorrhea, sedation, and poorly understood effects on the immune system.^{7,9} Patients should be educated on symptoms of pneumonia and urgently evaluated by a clinician if symptoms of infection emerge. Complicating the picture further, elevation of clozapine levels has been observed with multiple acute viral and bacterial infections. This may in part be related to effects of systemic infection and inflammation on CYP450 enzymes.¹⁰ Clinicians should closely monitor clozapine levels and consider reducing the dose by up to a half in patients with fever and other signs of infection.

Coagulation abnormalities such as prothrombin time and activated partial thromboplastin time

prolongation, thrombocytopenia, and disseminated intravascular coagulation are also frequently observed in patients with COVID-19. At the same time, many patients with COVID-19 experience increased thrombotic risk and may be prescribed prophylactic anticoagulants.⁵ These factors may impact the decision to prescribe psychotropics that have been associated with platelet dysfunction and increased bleeding risk (e.g., selective serotonin reuptake inhibitors [SSRIs] and valproic acid). Clinicians should be especially mindful of using these medications in patients who have other risk factors for bleeding, such as concomitant anticoagulation therapy and a history of significant bleeding event.

Cardiac Effects

There is limited available information regarding cardiovascular involvement in COVID-19 infection,

TABLE 2. Potential Psychotropic Safety Concerns in COVID-19 Organized by Organ System

Organ system affected by COVID-19	Systemic effects and symptoms	Potential psychotropic safety concerns
Hematologic	Lymphopenia Coagulopathy (increased PT, aPTT; decreased platelets)	Consider avoiding medications that can negatively impact white blood cell production Highest risk: carbamazepine, clozapine, olanzapine Moderate risk: all first and second generation antipsychotics (especially low-potency conventionals) Rare reports: TCAs, benzodiazepines (chlordiazepoxide), gabapentin, and valproate Consider avoiding medications that can increase bleeding risk (via thrombocytopenia or impaired platelet aggregation): valproic acid, SSRIs, SNRIs
Cardiac	Concern for tachyarrhythmias, heart failure, myopericarditis, acute cardiac injury Several medications being used for COVID-19 (azithromycin, hydroxychloroquine, chloroquine, lopinavir/ritonavir) reported to prolong QT interval	Caution with psychotropics known to prolong QTc and in patients with other underlying risk factors for QT prolongation Highest risk: antipsychotics, citalopram, tricyclic antidepressants
Hepatic	Risk of acute liver injury, especially in severe cases	In patients with hepatic injury or failure: Consider avoiding psychotropics that can also cause serious drug-induced liver injury: chlorpromazine, carbamazepine, valproate, duloxetine, and nefazodone. Refer to prescribing information to determine if dose adjustments are needed
Renal	Acute kidney injury has been observed, particularly in patients with COVID-19–associated acute respiratory distress syndrome (ARDS) and preexisting chronic kidney disease	Consider dose adjustment with some psychotropics (e.g., lithium, gabapentin, topiramate, pregabalin, paliperidone, and duloxetine) Consider avoiding potentially nephrotoxic drugs
Nervous system	Central nervous system: headache, dizziness, impaired consciousness, ataxia, stroke, delirium, seizures Peripheral nervous system: impaired taste/smell/vision, neuropathic pain	In patients with delirium, caution with deliriogenic medications: benzodiazepines, opioids, sedative-hypnotics, and those drugs with strong anticholinergic effects (tertiary amine tricyclic antidepressants, low-potency first-generation antipsychotics, some second-generation antipsychotics, benzotropine, and diphenhydramine) Caution with medications that can lower seizure threshold: antipsychotics and certain antidepressants (bupropion, tricyclics)
Pulmonary	Cough, shortness of breath, pneumonia and ARDS	In COVID-19 patients with anxiety or panic symptoms, weigh risks versus benefits in using benzodiazepines in patients with prominent respiratory symptoms, given potential to suppress respiratory drive

aPTT = activated partial thromboplastin time; COVID-19 = coronavirus disease 2019; PT = prothrombin time; QTc = corrected QT interval; SNRI = serotonin norepinephrine reuptake inhibitors; SSRI = selective serotonin reuptake inhibitor; TCA = tricyclic antidepressant.

although tachyarrhythmias and heart failure have been described with other SARS beta-coronavirus infections.¹¹ A recent report described acute myopericarditis in a patient with COVID-19,¹² and a meta-analysis found acute cardiac injury in at least 8% of patients with COVID-19.¹³ It has been suggested that COVID-19 most likely has an arrhythmogenic effect.¹⁴ Proposed mechanisms of myocardial injury include derangement of angiotensin-converting enzyme 2 signal pathways, cytokine storm, and myocarditis. In addition, several medications being used off-label in the

management of COVID-19 (azithromycin, hydroxychloroquine, chloroquine, and lopinavir/ritonavir) have been reported to prolong the QT interval. QT prolongation, particularly in those with underlying medical risk factors, has been linked to lethal ventricular arrhythmias, such as torsades de pointes.

A complete discussion of the cardiac side effects of psychotropics is beyond the scope of this article, except to note that it has been well described in the literature that a number of psychotropic medications can prolong the QT interval. Although the data are often difficult to

interpret because of confounding factors, antipsychotics, tricyclic antidepressants, and the SSRI citalopram appear to be the agents of most concern. It is difficult to stratify antipsychotic medications by QT prolongation risk. Of the typical antipsychotics, thioridazine causes the greatest QT prolongation, although intravenous haloperidol has also been implicated. The greatest risk among the atypicals appears to be related to ziprasidone and possibly iloperidone. Aripiprazole and possibly lurasidone have been associated with the lowest risk based on available data.¹⁵

Health care providers should be aware of the baseline corrected QT interval (QTc) and all concomitant medications, laboratory test results, medical comorbidities, and family history before prescribing psychotropics in patients with COVID-19. Caution should be used in patients with a baseline prolonged QTc and/or other risk factors for drug-induced QT prolongation and torsades de pointes: the use of QT-prolonging medications, cardiac comorbidities, age >65, female sex, family history of sudden cardiac death, hypokalemia/hypomagnesemia, and illicit substance use. If QT-prolonging medications are used in a patient with a QTc >500 ms or other significant risk factors, electrocardiograms should be monitored frequently (daily in high-risk cases), potassium and magnesium should be repleted, cardiology involvement should be considered, and every attempt made to reduce risk factors.¹⁵ In patients who test positive for COVID-19 but are already taking a psychotropic drug that has inherent potential for QTc prolongation, risk-benefit decisions must be made on a case-by-case basis regarding continuation versus switching to an alternative medication.

Hepatic Effects

Several studies have reported acute liver injury, particularly in severe COVID-19 cases.^{4,16,17} The etiology of the liver injury is not known, and hypotheses include viral infection, drug-induced liver injury, and systemic inflammation due to cytokine storm or hypoxia.¹⁶ Laboratory abnormalities observed include elevated aspartate aminotransferase, alanine aminotransferase, and bilirubin.¹⁷ Liver function tests should be monitored, and if abnormal, consideration should be given to avoiding psychotropics that can also cause hepatic injury or making dose adjustments if heavily dependent on hepatic

metabolism. As most psychotropics are lipid soluble and require hepatic metabolism before clearance, clinicians should review the package insert to determine if a dose adjustment is needed. In addition, many psychotropics (valproate, carbamazepine, tricyclic antidepressants, serotonin norepinephrine reuptake inhibitors, and second-generation antipsychotics) have been associated with mild hepatotoxicity that manifests with modest, transient increases in liver enzymes. Only a few are thought to have a high risk of causing serious drug-induced liver injury, including chlorpromazine, carbamazepine, valproate, duloxetine, and nefazodone.^{18,19} Such high-risk psychotropics should be preferentially avoided in patients with COVID-19-associated liver disease.

Renal Effects

Acute kidney injury has been observed, particularly in patients with COVID-19-associated acute respiratory distress syndrome and preexisting chronic kidney disease. Several causes have been proposed, including impaired gas exchange, hemodynamic alterations, sepsis, and an inflammatory/immune reaction involving release of circulating mediators that cause injury to kidney cells.²⁰ In such patients, avoiding potentially nephrotoxic drugs, such as lithium, may be required. In addition, psychiatrists should be aware of any renal impairment and make necessary dose adjustments as per the manufacturer's prescribing information. Psychotropics highly dependent on renal excretion include lithium, gabapentin, topiramate, pregabalin, and paliperidone. Many other psychotropics have caused renal excretion of active metabolites. Levels of these medications or their metabolites can increase in the setting of impaired renal clearance such that reduced dosing or avoiding the medication may be required. For example, administration of duloxetine is not recommended for patients with severe renal impairment (CrCL of <30 mL/min).¹⁸

Neurological Effects

Based on similarities between SARS-CoV2 and other coronaviruses, it is thought likely that SARS-CoV2 has a neuroinvasive potential,²¹ but there remain many unanswered questions about neurological manifestations of COVID-19. Initial observations note a variety of neurological syndromes in patients with COVID-19,

particularly the more severely affected ones. These include stroke, delirium, seizures, and an encephalitis-type presentation. A recent article from Wuhan²² reports neurologic symptoms in 36.4% of patients with COVID-19, falling into 3 categories: (1) central nervous system symptoms or diseases (headache, dizziness, impaired consciousness, ataxia, acute cerebrovascular disease, and seizure); (2) peripheral nervous system symptoms (impairment in taste, vision, and smell, neuropathic pain); and (3) skeletal muscular injury. It is not known whether these neurologic syndromes are a direct effect of the virus entering the central nervous system or an indirect response to the cytokine storm that patients are experiencing. A specific prevalence rate of delirium was not reported but is presumed to be very high and to contribute to poor adherence with care and other safety concerns. Certainly, for patients with severe COVID-19 infections, there are many other potential etiologies of delirium, including organ failure, hypoxia, sepsis, medication effects, and electrolyte/metabolic abnormalities. Observational studies have in fact reported high rates of benzodiazepine use for sedation in ventilator-dependent patients with COVID-19.²³ Environmental factors such as isolation from family members and difficulty mobilizing patients also contribute.²⁴

In patients with COVID-19 and delirium, clinicians should be mindful about prescribing benzodiazepines, opioids, and drugs with strong anticholinergic properties (tertiary amine tricyclic antidepressants, low-potency antipsychotics, benztropine, and diphenhydramine) as these medications have the potential to cause or exacerbate confusion, sedation, and/or falls. Clinicians should also be cautious about prescribing psychotropics that can lower the seizure threshold in patients with seizures or structural brain lesions. Such medications include most antipsychotics (especially clozapine, quetiapine, olanzapine, and first-generation antipsychotics)²⁵ and certain antidepressants (bupropion, tricyclics).²⁶

Pulmonary Effects

As the lung is considered the primary organ that is affected by COVID-19, most patients present with respiratory symptoms, such as cough and shortness of breath. Affected individuals may develop pneumonia and acute respiratory distress syndrome leading to high supplemental oxygen requirements and, in the most

severe cases, invasive ventilation.⁴ Psychiatric consultants may be asked to evaluate and manage patients with COVID-19 and anxiety or panic symptoms in addition to respiratory distress. While there may be circumstances in which the use of small doses of a benzodiazepine is appropriate, it is important to be aware of the potential of benzodiazepines to suppress respiratory drive, particularly at higher doses. Clinicians therefore need to consider risks versus benefits in using benzodiazepines in patients with prominent respiratory symptoms.

PSYCHIATRIC CONSIDERATIONS OF PROPOSED COVID-19 TREATMENTS

Many of the proposed COVID-19 treatments have the potential for neuropsychiatric side effects as well as drug-drug interactions. These are reviewed in the following section and summarized in [Table 3](#).

Remdesivir

Remdesivir is an antiviral medication that interacts with RNA polymerase and evades proofreading by viral exonuclease leading to a decrease in viral RNA.²⁷ On May 1, 2020, the US FDA issued an Emergency Use Authorization to use remdesivir for treatment of suspected or confirmed severe COVID-19 infection,¹ with severe defined as “patients with an oxygen saturation $\leq 94\%$ on room air or requiring supplemental oxygen, mechanical ventilation, or extracorporeal membrane oxygenation.” The Emergency Use Authorization was based on early promising data from a randomized double-blinded, placebo-controlled²⁸ and an open-label trial.²⁹ Remdesivir is administered by infusion, with a treatment course of 5 or 10 days, depending on severity of disease.

Neuropsychiatric Effects

No information is available regarding neuropsychiatric side effects, but administration has been associated with infusion-related reactions that can present with hypotension, diaphoresis, and shivering.¹ Such symptoms might be misconstrued as a panic attack.

Psychotropic Considerations

Remdesivir carries a risk of transaminase elevations,³⁰ specifically but not limited to alanine

TABLE 3. Psychiatric Side Effects and Drug Interactions with Proposed COVID-19 Treatments

Proposed COVID-19 treatment	Mechanism of action	Psychiatric side effects	Drug-drug interactions
Azithromycin	Used with hydroxychloroquine. Antibacterial (primarily) Antiviral and anti-inflammatory (potential)	Psychotic depression, catatonia, delirium, aggressive reaction, anxiety, dizziness, headache, vertigo, and somnolence	<ul style="list-style-type: none"> • Risk of QTc prolongation—caution with psychotropics known to prolong QTc • Risk of hepatotoxicity—caution with hepatotoxic drugs
Chloroquine and hydroxychloroquine	Anti-inflammatory Antiviral: interference with virus-receptor binding Immune-modulating effects	Psychosis, delirium, suicidality, personality changes, depression, nervousness, irritability, compulsive impulses, preoccupations, and aggressiveness	<ul style="list-style-type: none"> • Risk of QTc prolongation—caution with QT prolonging drugs. Do not use outside of the hospital setting or a clinical trial due to risk of heart rhythm problems (FDA) • Metabolized by CYP3A4—potential drug interactions with CYP3A4 inhibitors (e.g., fluvoxamine) and inducers (e.g., carbamazepine, oxcarbazepine, modafinil) • Risk of hepatotoxicity—caution with hepatotoxic drugs • Risk of seizures—caution with psychotropics that can lower the seizure threshold • Higher risk of neuropsychiatric side effects when combined with CYP3A4 inhibitors, low-dose glucocorticoids, alcohol intake, family history of psychiatric disease, female gender, low body weight, and supratherapeutic dosing • Long half-life (40 h)—adverse effects and drug-interactions may continue for days after the drug has been discontinued
Colchicine	Anti-inflammatory Immune modulator: targets IL-6 pathway, inhibition of NLRP3 inflammasome. May attenuate cytokine storm.	At toxic doses: delirium, seizures, muscle weakness, depressed reflexes	<ul style="list-style-type: none"> • Narrow therapeutic index—potential for toxicity • Caution in renal and hepatic failure • Caution with P-gp and CYP3A4 inhibitors (e.g., fluvoxamine) • CYP3A4 inducers may decrease levels
Convalescent plasma therapy	Antibody containing convalescent plasma from patients who have recovered from viral infections	No specific psychiatric effects (Note: allergic reactions can produce shortness of breath and palpitations that mimic panic attacks) Potential psychological effects for donors	<ul style="list-style-type: none"> • There are no specific interactions (Note: patients who develop transfusion reactions might receive steroids or diphenhydramine which can have negative synergistic effects with existing psychotropics.)
Corticosteroids	Immune modulators and anti-inflammatory: may lessen cytokine storm and hyperinflammation syndrome	Depression, mania, agitation, mood lability, anxiety, insomnia, catatonia, depersonalization, delirium, dementia, and psychosis	<ul style="list-style-type: none"> • Inconsistently reported to be weak CYP3A4 and CYP2C19 inducers • Phenytoin—increases hepatic metabolism of systemic corticosteroids • Caution with bupropion—lowers seizure threshold • Majority of neuropsychiatric side effects occur early in treatment course, usually within days, and dosing is the most significant risk factor (i.e., at prednisone equivalents of >40 mg/d)
Favipiravir	Antiviral: RNA-dependent RNA polymerase inhibitor	No information	<ul style="list-style-type: none"> • Possible QT prolongation

aminotransferase elevations up to 20 times the upper limit of normal.¹ This may impact the decision to use hepatically metabolized psychotropics, such as valproic acid.

Chloroquine and Hydroxychloroquine

Chloroquine, a synthetic form of quinine used for the treatment and prophylaxis of malaria, and

TABLE 3. (Continued)

Proposed COVID-19 treatment	Mechanism of action	Psychiatric side effects	Drug-drug interactions
Interferon	Immune modulator, antiproliferative, and hormone-like activities Antiviral	IFN alpha: boxed warning for “life-threatening or fatal neuropsychiatric disorders.” Specific effects include fatigue, mood disorders, suicidality, anxiety disorders, irritability, lability, apathy, sleep disturbance, and cognitive deficits IFN beta: fatigue, weight loss, myalgia, arthralgia	<ul style="list-style-type: none"> • No known pharmacokinetic interactions with psychotropics • Potential for bone marrow suppression—safety concerns with some psychotropics (e.g., carbamazepine, valproate, and clozapine) • May lower seizure threshold: caution with psychotropics that also lower seizure threshold
Lopinavir/Ritonavir	Antiviral Lopinavir: protease inhibitor Ritonavir: boosts plasma levels of lopinavir	Possible abnormal dreams, agitation, anxiety, confusion, and emotional lability All protease inhibitors associated with paresthesias, taste alterations, and neurotoxicity	<ul style="list-style-type: none"> • Extensively metabolized by cytochrome P450—risk of multiple possible interactions • May get increased concentrations of coadministered CYP3A4 or CYP2D6 substrates • May get decreased concentrations of CYP1A2 or CYP2B6 substrates • Contraindicated with pimozone, midazolam, and triazolam due to increased drug levels and potentiation of adverse effects • Lowers concentrations of some psychotropics (e.g., bupropion, methadone, lamotrigine, and olanzapine) • Other potential side effects that may impact psychotropic use: Stevens Johnson syndrome, diabetes mellitus, QTc prolongation, pancreatitis, neutropenia, hepatotoxicity, and chronic kidney disease
Remdesivir	Only FDA-approved medication for severe COVID-19 Interacts with RNA polymerase, leads to decrease in viral RNA	No information	<ul style="list-style-type: none"> • No information is available about pharmacokinetic drug-drug interactions • Risk of elevated aminotransferase levels (e.g. ALT up to 20× upper limit of normal)—caution with potentially hepatotoxic psychotropics
Tocilizumab	Immune modulator: recombinant humanized monoclonal antibody that acts as an IL-6 inhibitor; may lessen cytokine storm	Possible positive effects on depressive symptoms	<ul style="list-style-type: none"> • No major interactions reported
Vitamin C	Enhances immune response, antioxidant and reducing agent	No evidence for neuropsychiatric adverse effects; Of note, lower levels associated with depression, confusion, anger, delirium	<ul style="list-style-type: none"> • Coadministration with barbiturates may decrease the effects of vitamin C

ALT = alanine aminotransferase; COVID-19 = coronavirus disease 2019; FDA = Food and Drug Administration; IFN = interferon; IL = interleukin; P-gp = P-glycoprotein.

hydroxychloroquine, a derivative compound used in the treatment of inflammatory disorders such as rheumatic arthritis and systemic lupus erythematosus, are being considered as a possible treatment for COVID-19 infection. Interest in these medications is in part because of their potential for interference with

virus-receptor binding and immune-modulating effects.³¹ The most promising study is a small open-label trial from France,³² although a recent large observational study showed that the risk of intubation or death was not significantly higher or lower among patients who received the drug than among

Psychopharmacology of COVID-19

those who did not.³³ The authors suggest that their findings do not support continued use of the drug in patients with COVID-19 outside of clinical trials.

Neuropsychiatric Effects

Neuropsychiatric side effects of chloroquine and hydroxychloroquine include psychosis, delirium, agitation, suicidality, personality changes, depression, and sleep disturbances.^{34,35} Risk factors for hydroxychloroquine-induced neuropsychiatric effects may be concurrent use of CYP3A4 inhibitors or low-dose glucocorticoids, alcohol intake, family history of psychiatric disease, female gender, low body weight, and supratherapeutic dosing.³⁶

A number of mechanisms have been postulated for the pathogenesis of hydroxychloroquine-induced neuropsychiatric effects, such as cholinergic imbalance due to acetylcholinesterase inhibition, inhibition of the serotonin transporter protein, and *N*-methyl-D-aspartate and gamma aminobutyric acid antagonism.³⁴

Psychotropic Considerations

Hydroxychloroquine and chloroquine can cause heart conduction disorders, including QT interval prolongation, bundle branch block, atrioventricular block, and torsades de pointes.³⁷ On April 24, 2020, the FDA issued a safety announcement against the use of hydroxychloroquine or chloroquine for COVID-19 outside of the hospital setting or a clinical trial because of risk of heart rhythm problems.³⁸ Caution should be used when combining them with QT-prolonging psychotropics. These agents can also be hepatotoxic³⁹ and epileptogenic,⁴⁰ so caution should be exercised in patients with hepatic disease, or in conjunction with psychotropics that may be hepatotoxic or may lower the seizure threshold.

Both chloroquine and hydroxychloroquine are metabolized by CYP3A4,⁴¹ so CYP3A4 inhibitors (e.g., fluvoxamine) could raise plasma levels and increase the potential for adverse effects. By contrast, CYP3A4 inducers, such as carbamazepine, oxcarbazepine, and modafinil, could decrease levels of chloroquine or hydroxychloroquine, potentially rendering them less effective. Given hydroxychloroquine's long half-life (40 h), the potential for continued adverse effects and drug interactions may continue for days after the drug has been discontinued.³⁵

Tocilizumab

Tocilizumab is a recombinant humanized monoclonal antibody that acts as an interleukin-6 receptor inhibitor⁴² and is FDA approved to treat several types of arthritis.⁴³ Tocilizumab is being trialed in patients with severe COVID-19 and elevated interleukin-6 because interleukin-6 appears to be involved in cytokine storms that have been observed in critically ill patients with COVID-19.⁴⁴

Neuropsychiatric Effects

Data from rheumatic arthritis patients suggest that tocilizumab may have some positive effects on depressive symptoms in rheumatoid arthritis^{45,46}; however, unpublished data from a small study surprisingly suggest that patients who received tocilizumab after allogeneic hematopoietic cell transplantation experienced worse symptoms of depression, anxiety, pain, and sleep.⁴⁷

Psychotropic Considerations

No major interactions have been reported.

Favipiravir

Favipiravir is an antiviral thought to act as an RNA-dependent RNA polymerase inhibitor.⁴⁸ It was approved in China in February 2020 for treatment of influenza,⁴⁸ and there are current trials evaluating its efficacy on SARS-Cov-2. It is not currently approved for use in the United States.

Neuropsychiatric Effects

No published information is available.

Psychotropic Considerations

There is no published information available. One published case report suggested a mild QT prolongation in a patient with Ebola virus who received favipiravir.⁴⁹

Lopinavir/Ritonavir (Kaletra)

Lopinavir/Ritonavir is an antiviral medication used to treat HIV-1 infection.⁵⁰ The 2 medications work synergistically: Lopinavir is a protease inhibitor, and ritonavir helps to boost plasma levels of lopinavir by

inhibiting its metabolism.⁵⁰ Unfortunately, a recently published randomized, controlled, open-label trial found no additional benefit with lopinavir-ritonavir treatment in hospitalized patients with SARS-CoV-2 as compared with standard care.⁵¹

Neuropsychiatric Effects

The manufacturer's prescribing information lists possible psychiatric side effects, including abnormal dreams, agitation, anxiety, confusion, and emotional lability although there is limited information in published case reports or trials regarding the incidence of such effects.⁵⁰ Protease inhibitors as a class have been associated with neurological adverse events, such as paresthesias, taste alterations, and neurotoxicity.⁵²

Psychotropic Considerations

Protease inhibitors are extensively metabolized by the cytochrome P450 system and have been shown to interact with many drugs, including psychotropics.⁵³ The use of ritonavir may lead to increased concentrations of coadministered drugs that are CYP3A4 or CYP2D6 substrates or decreased concentrations of CYP1A2 or CYP2B6 substrates, many of which are psychotropics.

The use of lopinavir/ritonavir is contraindicated with medications that include pimozide, midazolam, and triazolam because of increased drug levels and potentiation of adverse effects. The use of benzodiazepines not dependent on CYP metabolism (lorazepam, temazepam, or oxazepam) is recommended. Owing to CYP450 enzyme or glucuronidation-inducing effects, ritonavir-boosted protease inhibitors also have been shown to lower concentrations of some psychotropics (e.g., bupropion, methadone, lamotrigine, and olanzapine), thus leading to increased dose requirements for these medications.⁵³

As most psychotropics are substrates for CYP isoenzymes, there are many additional theoretical interactions, but the clinical significance varies by agent. Clinicians should assess each potential interaction individually by reviewing available literature and manufacturer's prescribing information.

Other potential nonpsychiatric side effects that may have implications for psychiatrists include Stevens Johnson syndrome, diabetes mellitus, QTc prolongation, pancreatitis, neutropenia, hepatotoxicity, and chronic kidney disease.⁵⁰

Convalescent Plasma Therapy

Antibody containing convalescent plasma from recovered patients has been used with some success as a last resort to treat severe viral respiratory infections such as SARS-CoV, Middle Eastern respiratory syndrome-CoV, and Ebola, although large clinical trials are absent.⁵⁴ Trials are currently underway to study the effectiveness of convalescent plasma therapy in the treatment of individuals with severe respiratory failure associated with COVID-19.

Neuropsychiatric Effects

When used for the treatment of other severe acute viral respiratory infections, convalescent plasma therapy was not associated with serious adverse events,⁵⁵ although in general, plasma transfusions can cause a range of adverse events from mild fever and allergic reactions to life-threatening bronchospasm/anaphylaxis, transfusion-related acute lung injury, and transfusion-associated circulatory overload.⁵⁶

Specific neuropsychiatric effects have not been reported, although allergic reactions, cardiovascular complications, and bronchospasm can produce symptoms such as shortness of breath and palpitations that mimic panic attacks.

A potential psychological adverse effect of convalescent plasma therapy relates to ethical concerns about coercion, confidentiality, and privacy of the prospective donors that were initially raised during the Ebola outbreak⁵⁷ and led to a World Health Organization document providing guidance on the ethical use of convalescent plasma.⁵⁸

Psychotropic Considerations

There are no specific interactions between psychotropics and plasma transfusions, but patients who develop transfusion reactions might receive steroids or diphenhydramine which can have negative synergistic effects with existing psychotropics.

Azithromycin

Azithromycin is an antibacterial agent which may have antiviral and anti-inflammatory activities.³² It is under investigational use for treatment of COVID-19 when given in conjunction with chloroquine or hydroxychloroquine. In one small French study ($n = 20$), azithromycin added to hydroxychloroquine was

Psychopharmacology of COVID-19

significantly more efficient for virus elimination than hydroxychloroquine alone.³²

Neuropsychiatric Effects

Side effects that have been reported include psychotic depression, catatonia, delirium, aggressive reaction, anxiety, dizziness, headache, vertigo, and somnolence.^{59,60}

Psychotropic Considerations

Azithromycin has not been implicated in pharmacokinetic interactions with psychotropics but has been associated with QTc prolongation and life-threatening torsades de pointes arrhythmias. It has also been associated with hepatotoxicity.⁶¹

Vitamin C

High-dose intravenous vitamin C (ascorbic acid), an antioxidant and reducing agent, has been investigated in the treatment of sepsis because of its enhancement of the immune response.⁶² In the intensive care setting, vitamin C administration has been correlated with preventing progressive organ dysfunction and reducing mortality in sepsis and acute respiratory distress syndrome⁶³ and is being investigated in critically ill patients with COVID-19.

Neuropsychiatric Effects

There are no known adverse neuropsychiatric consequences of high-dose intravenous vitamin C administration, but some studies have associated lower levels of vitamin C with depression, confusion, and anger.⁶⁴ Vitamin C deficiency has also been identified as a possible risk factor for delirium.⁶⁵

Psychotropic Considerations

Coadministration with barbiturates may decrease the effects of vitamin C.⁶²

Corticosteroids

Corticosteroids are involved in immune function, inflammation, and carbohydrate metabolism and are used in the treatment of endocrinopathies, autoimmune disorders, and asthma/allergies.⁶⁶ In previous pandemics, such as SARS and Middle Eastern respiratory syndrome, corticosteroids were not recommended

because of the concern that they may exacerbate lung injury.⁶⁷ Given evidence suggesting that severe COVID-19 may be associated with a cytokine storm and hyperinflammation syndrome,⁶⁷ corticosteroids may have a role in treatment.

Neuropsychiatric Effects

The neuropsychiatric side effects of corticosteroids have been well described in the literature and include depression, mania, agitation, mood lability, anxiety, insomnia, catatonia, depersonalization, delirium, and psychosis.⁶⁶ Most neuropsychiatric side effects occur early in the treatment course, usually within days, and dosing is the most significant risk factor (i.e., at prednisone equivalents of >40 mg/d).⁶⁶

Psychotropic Considerations

Corticosteroids have been inconsistently reported to be weak CYP3A4 and CYP2C19 inducers,⁶⁸ which could lead to decreased effects of CYP3A4 or CYP2C19 substrate psychotropics.⁶⁹ In addition, phenytoin has been shown to increase hepatic metabolism of systemic corticosteroids.⁷⁰

Interferon

IFNs are glycoproteins that have immunomodulatory, antiproliferative, and hormone-like activities.⁷¹ IFN alpha and beta have anti-SARS-CoV-1 activity *in vitro*, and IFN beta reduces the replication of Middle Eastern respiratory syndrome-coronavirus *in vitro*.^{72,73} Based on this information, IFN has been considered as a potential treatment for COVID-19, including in combination with ribavirin, a guanosine analogue with a broad-spectrum antiviral potency.⁷⁴

Neuropsychiatric Effects

IFN alpha has a boxed warning for “life-threatening or fatal neuropsychiatric disorders.”⁷⁵ Specific effects include fatigue, mood disorders, suicidality, anxiety disorders, irritability, lability, apathy, sleep disturbance, and cognitive deficits.⁷⁶ Side effects of IFN beta can include fatigue, weight loss, myalgia, and arthralgia,⁷⁷ but not generally depression. Given the potential for significant psychiatric side effects of IFN alpha, it is important for clinicians to screen for baseline psychiatric history and monitor closely for emergence of any symptoms.

Psychotropic Considerations

There are no known pharmacokinetic interactions with psychotropics, but clinicians should be mindful of the potential for bone marrow suppression which may raise safety concerns with concurrent use of psychotropics, such as carbamazepine, valproate, and clozapine. In addition, seizures in conjunction with bupropion use have been reported.⁷⁸

Colchicine

Colchicine is a plant-derived alkaloid with anti-inflammatory properties that is used for a variety of rheumatological and cardiac conditions.⁷⁹ It is hypothesized that colchicine could treat COVID-19 through targeting the overactive interleukin-6 pathway.⁸⁰

Neuropsychiatric Effects

Colchicine does not typically produce any neuropsychiatric effects, but at toxic doses, it can cause delirium, seizures, and muscle weakness.⁸¹

Psychotropic Considerations

Colchicine has a narrow therapeutic index, and attention must be paid to potential drug interactions that might increase toxicity. Colchicine is metabolized by CYP3A4 and excreted via the P-glycoprotein transport system as well as cleared by the kidneys through glomerular filtration. Dose adjustment is recommended with concurrent use of CYP3A4 or P-glycoprotein inhibitors as well as in patients with hepatic or renal impairment.⁸² CYP3A4 inducers can lead to increased metabolism and theoretically decreased effectiveness of colchicine.

DISCUSSION

COVID-19 and its treatments can impact many organ systems and contribute to a host of drug interactions and neuropsychiatric effects. This can have safety implications for use of psychotropics, which are highly metabolized by the hepatic cytochrome p450 system and carry their own potential for drug-interactions and end-organ adverse effects.

While there are no absolute contraindications to the use of psychotropics in patients with COVID-19, psychiatrists must be mindful of potential adverse

effects and conduct a thoughtful risk-benefit analysis as part of their clinical decision-making process. For example, chloroquine, hydroxychloroquine, and azithromycin have the potential for QT prolongation, which can be problematic in patients with tenuous cardiac status. Generally, psychiatrists might avoid antipsychotic medications in the setting of a prolonged QT interval. However, in our experience, hyperactive delirium in patients with COVID-19 is highly prevalent, manifests with severe agitation that can be difficult to treat, and leads to dangerous behaviors such as removing oxygen or assaulting staff. While there is limited evidence to support the use of any interventions in the management of agitation in COVID-19-associated delirium, most consultation-liaison psychiatrists consider antipsychotics such as haloperidol the gold standard for managing agitation in delirious patients. In these situations, the consultation-liaison psychiatrist should assist the medical team in reasoning through the cardiac risks of using an antipsychotic balanced against effective management of the agitation. The use of an antipsychotic with cardiology involvement and frequent electrocardiogram monitoring or telemetry may be deemed acceptable. Alternatives such as alpha-2 agonists (dexmedetomidine and clonidine) or antiepileptics (valproic acid) should be considered if the individual patient's cardiac risk is determined to be high and/or if the antipsychotic is clinically ineffective. Melatonin has been proposed for addressing consciousness and sleep-wake cycle disturbances in delirious patients with COVID-19, especially given its potential for antioxidative, anti-inflammatory, and immune-enhancing effects.⁸³ With the exception of patients who chronically use alcohol or benzodiazepines and may be at risk for withdrawal, benzodiazepines should be avoided if possible and considered only as a last resort for highly agitated delirious patients for whom other treatments are unavailable or ineffective. Early delirium screening and nonpharmacological strategies to prevent or treat delirium such as frequent orientation and early mobilization should be used if practically feasible.²⁴

As another example, we have observed many nondelirious patients with COVID-19 and significant anxiety in the setting of respiratory distress. In some cases, the anxiety leads to requests to leave against medical advice or refusal to remain isolated. For these patients, psychiatrists should consider whether the benefit of a low-dose benzodiazepine outweighs the

potential risk of respiratory depression. The use of benzodiazepines may be reasonable in patients with adequate oxygen saturation and in the absence of confusion or a depressed sensorium. Depending on the individual patient's circumstances and symptoms, alternative medications such as gabapentin, buspirone, hydroxyzine, a low-dose atypical antipsychotic, or a SSRI may be appropriate. Nonpharmacological/psychosocial interventions (e.g., behaviorally oriented therapies) should also be used.

Other important tasks for the psychiatrist treating a patient with COVID-19 include review of all medications, monitoring for neuropsychiatric side effects of medications such as hydroxychloroquine or corticosteroids, and differentiating between primary psychiatric symptoms versus those that are secondary to COVID-19 or other medications.

Interestingly, several psychotropics, including haloperidol and valproic acid, were recently named on a list of FDA-approved medications with potential for *in vitro* action against SARS-CoV-2.⁸⁴ Fluvoxamine is also under investigation for its potential to reduce the

inflammatory response during sepsis by inhibiting cytokine production,⁸⁵ and melatonin for its anti-oxidative and anti-inflammatory properties.⁸⁶ If more data become available, psychiatrists might consider preferentially using these agents if clinically appropriate.

In summary, psychiatrists must be aware of the likelihood of encountering patients with COVID-19 infection and must remain cognizant of the neuropsychiatric effects and drug-drug interactions of COVID-19 treatments as well as the end-organ effects of COVID-19.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure: C.L.E. receives royalty payments from American Psychiatric Publishing, Inc. The other authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

References

1. Fact Sheet for Healthcare Providers - Emergency Use Authorization (EUA) of Remdesivir (GS-5734TM) [Internet]. U.S. Food and Drug Administration (FDA). 2020. Available from: <https://www.fda.gov/media/137566/download>. [Accessed 24 May 2020]
2. Kalil AC: Treating COVID-19—off-label drug use, compassionate use, and randomized clinical trials during pandemics. *JAMA* 2020. <https://doi.org/10.1001/jama.2020.4742>
3. Wang T, Du Z, Zhu F, et al: Comorbidities and multi-organ injuries in the treatment of COVID-19. *Lancet* 2020; 395:e52
4. Huang C, Wang Y, Li X, et al: Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020; 395:497–506
5. Terpos E, Ntanasis-Stathopoulos I, Elalamy I, et al: Hematological findings and complications of COVID-19. *Am J Hematol* 2020; 95:834–847
6. Oyesanmi O, Kunkel EJS, Monti DA, Field HL: Hematologic side effects of psychotropics. *Psychosomatics* 1999; 40:414–421
7. Siskind D, Honer WG, Clark S, et al: Consensus statement on the use of clozapine during the COVID-19 pandemic. *J Psychiatry Neurosci* 2020; 45:200061
8. Policy for Certain REMS Requirements During the COVID19 Public Health Emergency [Internet]. FDA. Available from: <https://www.fda.gov/media/136317/download>. [Accessed 24 May 2020]
9. de Leon J, Sanz EJ, Norén GN, De las Cuevas C: Pneumonia may be more frequent and have more fatal outcomes with clozapine than with other second-generation antipsychotics. *World Psychiatry* 2020; 19:120
10. Clark SR, Warren NS, Kim G, et al: Elevated clozapine levels associated with infection: a systematic review. *Schizophr Res* 2018; 192:50–56
11. Yu C-M, Wong RS-M, Wu EB, et al: Cardiovascular complications of severe acute respiratory syndrome. *Postgrad Med J* 2006; 82:140–144
12. Inciardi RM, Lupi L, Zaccone G, et al: Cardiac involvement in a patient with coronavirus disease 2019 (COVID-19). *JAMA Cardiol* 2020. <https://doi.org/10.1001/jamacardio.2020.1096>
13. Li B, Yang J, Zhao F, et al: Prevalence and impact of cardiovascular metabolic diseases on COVID-19 in China. *Clin Res Cardiol* 2020; 109:531–538
14. Wu C-I, Postema PG, Arbelo E, et al: SARS-CoV-2, COVID-19 and inherited arrhythmia syndromes. *Hear Rhythm* 2020. <https://doi.org/10.1016/j.hrthm.2020.03.024>
15. Beach SR, Celano CM, Sugrue AM, et al: QT prolongation, torsades de Pointes, and psychotropic medications: a 5-year update. *Psychosomatics* 2018; 59:105–122
16. Lee I-C, Huo T-I, Huang Y-H: Gastrointestinal and liver manifestations in patients with COVID-19. *J Chin Med Assoc* 2020; 83:521–523
17. Xie H, Zhao J, Lian N, Lin S, Xie Q, Zhuo H: Clinical characteristics of non-ICU hospitalized patients with

- coronavirus disease 2019 and liver injury: a retrospective study. *Liver Int* 2020; 40:1321–1326
18. Goldberg J, Ernst C: Managing the side effects of psychotropic medications, 2nd ed. Washington DC: American Psychiatric Association Publishing; 2019
 19. Telles-Correia D, Barbosa A, Cortez-Pinto H, Campos C, Rocha NBF, Machado S: Psychotropic drugs and liver disease: a critical review of pharmacokinetics and liver toxicity. *World J Gastrointest Pharmacol Ther* 2017; 8:26–38
 20. Fanelli V, Fiorentino M, Cantaluppi V, et al: Acute kidney injury in SARS-CoV-2 infected patients. *Crit Care* 2020; 24:155
 21. Li Y-C, Bai W-Z, Hashikawa T: The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. *J Med Virol* 2020; 92:552–555
 22. Mao L, Jin H, Wang M, et al: Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. *JAMA Neurol* 2020:e201127
 23. Helms J, Kremer S, Merdji H, et al: Neurologic features in severe SARS-CoV-2 infection. *N Engl J Med* 2020; 382:2268–2270
 24. Kotfis K, Roberson SW, Wilson JE, Dabrowski W, Pun BT, Ely EW: COVID-19: ICU delirium management during SARS-CoV-2 pandemic. *Crit Care* 2020; 24:1–9
 25. Wu C-S, Wang S-C, Yeh I-J, Liu S-K: Comparative risk of seizure with use of first- and second-generation antipsychotics in patients with schizophrenia and mood disorders. *J Clin Psychiatry* 2016; 77:e573–e579
 26. Johannessen Landmark C, Henning O, Johannessen SI: Proconvulsant effects of antidepressants — what is the current evidence? *Epilepsy Behav* 2016; 61:287–291
 27. Al-Tawfiq JA, Al-Homoud AH, Memish ZA: Remdesivir as a possible therapeutic option for the COVID-19. *Trav Med Infect Dis* 2020; 34:101615
 28. A Multicenter, Adaptive, Randomized Blinded Controlled Trial of the Safety and Efficacy of Investigational Therapeutics for the Treatment of COVID-19 in Hospitalized Adults Adaptive COVID-19 Treatment Trial (ACTT) [Internet]. 2020. Available from: <https://ichgcp.net/de/clinical-trials-registry/NCT04280705>. [Accessed 20 May 2020]
 29. Study to Evaluate the Safety and Antiviral Activity of Remdesivir (GS-5734TM) in Participants With Severe Coronavirus Disease (COVID-19) [Internet]. 2020. Available from: <https://clinicaltrials.gov/ct2/show/NCT04292899>. [Accessed 24 May 2020].
 30. COVID-19 Investigation Team. Clinical and virologic characteristics of the first 12 patients with coronavirus disease 2019 (COVID-19) in the United States. *Nat Med* 2020. <https://doi.org/10.1038/s41591-020-0877-5>
 31. Sahraei Z, Shabani M, Shokouhi S, Saffaei A: Aminoquinolines against coronavirus disease 2019 (COVID-19): chloroquine or hydroxychloroquine. *Int J Antimicrob Agents* 2020; 55
 32. Gautret P, Lagier J-C, Parola P, et al: Hydroxychloroquine and azithromycin as a treatment of COVID-19: results of an open-label non-randomized clinical trial. *Int J Antimicrob Agents* 2020:105949
 33. Geleris J, Sun Y, Platt J, et al: Observational study of hydroxychloroquine in hospitalized patients with Covid-19. *N Engl J Med* 2020. <https://doi.org/10.1056/NEJMoa2012410>
 34. Good MI, Shader RI: Behavioral toxicity and equivocal suicide associated with chloroquine and its derivatives. *Am J Psychiatry* 1977; 134:798–801
 35. Manufacturer's Package Insert, Hydroxychloroquine [Internet]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2017/009768s037s045s0471bl.pdf. [Accessed 20 May 2020]
 36. Mascolo A, Berrino PM, Gareri P, et al: Neuropsychiatric clinical manifestations in elderly patients treated with hydroxychloroquine: a review article. *Inflammopharmacology* 2018; 26:1141–1149
 37. McGhie TK, Harvey P, Su J, Anderson N, Tomlinson G, Touma Z: Electrocardiogram abnormalities related to anti-malarials in systemic lupus erythematosus. *Clin Exp Rheumatol* 2018; 36:545–551
 38. FDA cautions against use of hydroxychloroquine or chloroquine for COVID-19 outside of the hospital setting or a clinical trial due to risk of heart rhythm problems [Internet]. FDA. 2020. Available from: <https://www.fda.gov/media/137250/download>. [Accessed 24 May 2020]
 39. Makin AJ, Wendon J, Fitt S, Portmann BC, Williams R: Fulminant hepatic failure secondary to hydroxychloroquine. *Gut* 1994; 35:569–570
 40. Krzeminski P, Lesiak A, Narbutt J: Seizures as a rare adverse effect of chloroquine therapy in systemic lupus erythematosus patients: a case report and literature survey. *Postepy Dermatol Alergol* 2018; 35:429–430
 41. Browning DJ. In: Browning DJ, (ed) Pharmacology of chloroquine and hydroxychloroquine BT - hydroxychloroquine and chloroquine retinopathy. New York, NY: Springer New York; 2014. p. 35–63. Available from: https://doi.org/10.1007/978-1-4939-0597-3_2. [Accessed 24 May 2020]
 42. Sheppard M, Laskou F, Stapleton PP, Hadavi S, Dasgupta B: Tocilizumab (actemra). *Hum Vaccin Immunother* 2017; 13:1972–1988
 43. Manufacturer's Package Insert, Actemra (tocilizumab) [Internet]. Available from: <https://www.actemrahcp.com/>. [Accessed 20 May 2020]
 44. Luo P, Liu Y, Qiu L, Liu X, Liu D, Li J: Tocilizumab treatment in COVID-19: a single center experience. *J Med Virol* 2020; 92:814–818
 45. Singh JA, Beg S, Lopez-Olivo MA: Tocilizumab for rheumatoid arthritis: a Cochrane systematic review. *J Rheumatol* 2011; 38:10–20
 46. Harrold LR, John A, Reed GW, et al: Impact of tocilizumab monotherapy on clinical and patient-reported quality-of-life outcomes in patients with rheumatoid arthritis. *Rheumatol Ther* 2017; 4:405–417
 47. Knight JM, Costanzo ES, Singh S, et al: Inflammation and the brain: tocilizumab may redefine our understanding of depression and related symptoms in the medically ill. Orlando, FL: ACLP; 2018

48. Dong L, Hu S, Gao J: Discovering drugs to treat coronavirus disease 2019 (COVID-19). *Drug Discov Ther* 2020; 14:58–60
49. Chinello P, Petrosillo N, Pittalis S, et al: QTc interval prolongation during favipiravir therapy in an Ebola virus-infected patient. *PLoS Negl Trop Dis* 2017; 11:e0006034
50. Kaletra (lopinavir and ritonavir): Manufacturer's Prescribing Information [Internet]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/021251s052_021906s0461bl.pdf. [Accessed 23 April 2020]
51. 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; 382:1787–1799
52. Abers MS, Shandera WX, Kass JS: Neurological and psychiatric adverse effects of antiretroviral drugs. *CNS Drugs* 2014; 28:131–145
53. Goodlet KJ, Zmarlicka MT, Peckham AM: Drug–drug interactions and clinical considerations with co-administration of antiretrovirals and psychotropic drugs. *CNS Spectr* 2019; 24:287–312
54. Chen L, Xiong J, Bao L, Shi Y: Convalescent plasma as a potential therapy for COVID-19. *Lancet Infect Dis* 2020; 20:398–400
55. Cunningham AC, Goh HP, Koh D: Treatment of COVID-19: old tricks for new challenges. *Crit Care* 2020; 24:91
56. Pandey S, Vyas GN: Adverse effects of plasma transfusion. *Transfus* 2012; 52:65S–79S
57. Van Griensven J, De Weigheleire A, Delamou A, et al: The use of Ebola convalescent plasma to treat Ebola virus disease in resource-constrained settings: a perspective from the field. *Clin Infect Dis* 2016; 62:69–74
58. World Health Organization (2015). Ethics of using convalescent whole blood and convalescent plasma during the Ebola epidemic: interim guidance for ethics review committees, researchers, national health authorities and blood transfusion services. World Health Organization 2015. Available from: <https://apps.who.int/iris/handle/10665/161912>
59. ZITHROMAX® (azithromycin tablets) and (azithromycin for oral suspension) [Internet]. FDA. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2013/050710s039,050711s036,050784s0231bl.pdf. [Accessed 22 April 2020]
60. Ginsberg DL: Azithromycin-induced psychotic depression and catatonia. *Prim Psychiatry* 2006; 13:22–26
61. Leitner JM, Graninger W, Thalhammer F: Hepatotoxicity of antibacterials: pathomechanisms and clinical data. *Infection* 2010; 38:3–11
62. Linster CL, Van Schaftingen E: Vitamin C. *FEBS J* 2007; 274:1–22
63. Truitt JD, Hite RD, Morris PE, et al: Effect of vitamin C infusion on organ failure and biomarkers of inflammation and vascular injury in patients with sepsis and severe acute respiratory failure: the CITRIS-ALI randomized clinical trial. *JAMA* 2019; 322:1261–1270
64. Pullar JM, Carr AC, Bozonet SM, Vissers M: High vitamin C status is associated with elevated mood in male tertiary students. *Antioxidants* 2018; 7:91
65. Torbergsen AC, Watne LO, Frihagen F, Wyller TB, Brugaard A, Mowe M: Vitamin deficiency as a risk factor for delirium. *Eur Geriatr Med* 2015; 6:314–318
66. Dubovsky AN, Arvikar S, Stern TA, Axelrod L: The neuropsychiatric complications of glucocorticoid use: steroid psychosis revisited. *Psychosomatics* 2012; 53:103–115
67. Mehta P, McAuley DF, Brown M, Sanchez E, Tattersall RS, Manson JJ: COVID-19: consider cytokine storm syndromes and immunosuppression. *Lancet* 2020; 395:1033–1034
68. Flockhart DA, Oesterheld JR: Cytochrome P450-mediated drug interactions. *Child Adolesc Psychiatr Clin N Am* 2000; 9:43–76
69. Villikka K, Varis T, Backman J, Neuvonen P, Kivistö K: Effect of methylprednisolone on CYP3A4-mediated drug metabolism in vivo. *Eur J Clin Pharmacol* 2001; 57:457–460
70. McLelland J, Jack W: Phenytoin/dexamethasone interaction: a clinical problem. *Lancet* 1978; 311:1096–1097
71. Jacobs L, Johnson KP: A brief history of the use of interferons as treatment of multiple sclerosis. *Arch Neurol* 1994; 51:1245–1252
72. Hensley LE, Fritz EA, Jahrling PB, Karp C, Huggins JW, Geisbert TW: Interferon-β 1a and SARS coronavirus replication. *Emerg Infect Dis* 2004; 10:317
73. Ströher U, DiCaro A, Li Y, et al: Severe acute respiratory syndrome-related coronavirus is inhibited by interferon-α. *J Infect Dis* 2004; 189:1164–1167
74. Lu C-C, Chen M-Y, Chang Y-L: Potential therapeutic agents against COVID-19: what we know so far. *J Chin Med Assoc* 2020; 83:534–536
75. PEGASYS (peginterferon alfa-2a) injection - Highlights of Prescribing Information [Internet]. FDA. 2020. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2017/103964s52701bl.pdf. [Accessed 20 April 2020].
76. Davoodi L, Masoum B, Moosazadeh M, Jafarpour H, Haghshenas MR, Mousavi T: Psychiatric side effects of pegylated interferon-α and ribavirin therapy in Iranian patients with chronic hepatitis C: a meta-analysis. *Exp Ther Med* 2018; 16:971–978
77. Reder AT, Feng X: How type I interferons work in multiple sclerosis and other diseases: some unexpected mechanisms. *J Interferon Cytokine Res* 2014; 34:589–599
78. Ahmed F, Jacobson IM, Herrera JL, et al: Seizures during pegylated interferon and ribavirin therapy for chronic Hepatitis C: observations from the WIN-R trial. *J Clin Gastroenterol* 2011; 45:286–292
79. Slobodnick A, Shah B, Krasnokutsky S, Pillinger MH: Update on colchicine, 2017. *Rheumatology (Oxford)* 2017; 57(suppl_1):i4–i11
80. Tardif J-C, Bassevitch Z: Colchicine Coronavirus SARS-CoV2 Trial (COLCORONA) (COVID-19) [Internet]. Available from: <https://clinicaltrials.gov/ct2/show/NCT04322682>. [Accessed 24 May 2020]
81. Finkelstein Y, Aks SE, Hutson JR, et al: Colchicine poisoning: the dark side of an ancient drug. *Clin Toxicol* 2010; 48:407–414

82. Nuki G: Colchicine: its mechanism of action and efficacy in crystal-induced inflammation. *Curr Rheumatol Rep* 2008; 10:218
83. Zambrelli E, Canevini M, Gambini O, D'Agostino A: Delirium and sleep disturbances in COVID-19: a possible role for melatonin in hospitalized patients? *Sleep Med* 2020; 70:111
84. Gordon DE, Jang GM, Bouhaddou M, et al: A SARS-CoV-2-Human Protein-Protein Interaction Map Reveals Drug Targets and Potential Drug-Repurposing. *bioRxiv* [Internet]. 2020. Available from: <http://biorxiv.org/content/early/2020/03/27/2020.03.22.002386.abstract>. [Accessed 24 May 2020].
85. Rosen DA, Seki SM, Fernández-Castañeda A, et al: Modulation of the sigma-1 receptor-IRE1 pathway is beneficial in preclinical models of inflammation and sepsis. *Sci Transl Med* 2019; 11:eaa5266
86. Zhang R, Wang X, Ni L, et al: COVID-19: melatonin as a potential adjuvant treatment. *Life Sci* 2020; 250: 117583