COVID-19 and Vaccination in the Setting of Neurologic Disease: An Emerging Issue in Neurology

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Abstract
The COVID-19 pandemic caused by the SARS-CoV-2 virus has left many unanswered questions for patients with neurological disorders and the providers caring for them. Elderly and immunocompromised patients are at increased risk for severe symptoms due to COVID-19, and the virus may increase symptoms of underlying neurological illness, particularly for those with significant bulbar and respiratory weakness or other neurologic disability. Emerging SARS-CoV-2 vaccines offer substantial protection from symptomatic infection, but both patients and providers may have concerns regarding theoretical risks of vaccination, including vaccine safety and efficacy in the context of immunotherapy and the potential for precipitating or exacerbating neurological symptoms. In this statement on behalf of the Quality Committee of the AAN we review the current literature, focusing on COVID-19 infection in adults with neurological disease, in order to elucidate risks and benefits of vaccination in these individuals. Based on existing evidence, neurologists should recommend COVID-19 vaccination to their patients. For those patients being treated with immunotherapies, attention should be paid to timing of vaccination with respect to treatment and the potential for an attenuated immune response.

Introduction
The Coronavirus-19 (COVID-19) pandemic caused by the novel SARS-CoV-2 has resulted in over 3 million deaths worldwide;¹ and nearly 600,000 in the United States alone. High rates of infection and subsequent long-term sequelae have raised significant concerns, particularly for those with underlying medical illnesses who may be more severely affected. This includes not only those treated with immunosuppressive therapies for their neurological disorders (e.g.,
myasthenia gravis or multiple sclerosis) but also those with significant functional disability from their disease and elderly patients with a history of cerebrovascular disease and dementia. As neurological disorders are common, the impact of SARS-CoV-2 on patients with neurological illnesses poses a significant public health risk. Consideration of this population is critical when considering the risks and benefits of vaccination.

The approval of three vaccines (PfizerBioNTech®, Moderna®, and Johnson and Johnson®) by the U.S. Food and Drug Administration (FDA) for emergency use results in the potential to significantly reduce the incidence of symptomatic disease in these vulnerable populations. However, the rapidity of approval, and history of prior vaccination regimens resulting in neurological and other complications, creates concern surrounding widespread vaccination. This is particularly so in groups with pre-existing neurological conditions. In this statement, written on behalf of the Quality Committee and approved by the Board of Directors of the American Academy of Neurology, we review the risk of COVID-19 in adults with neurological disorders. We also review the potential risks associated with vaccination using data from the existing COVID-19 vaccination trials and known history of responses to vaccines for other diseases. We also provide guidance on the optimal timing of vaccination for those on immunotherapies and recommendations for groups with specific neurological disorders. We hope that this additional information will allow medical providers to better guide their patient populations toward safe and effective prevention strategies, lowering the overall rate of COVID-19 transmission, decreasing disease severity, and optimizing neurological health. This manuscript reflects the impressions of the authors based on data currently available.

The Impact of COVID-19 on Patients with Neurological Disorders

With its wide range of disease severity ranging from asymptomatic carriers to severe respiratory compromise and death, SARS-CoV-2 has impacted more than 110 million individuals worldwide. The potential for neurologic complications is concerning, particularly to those who already suffer from neurological disorders. Neurological complications have been reported in 30 to 60%
of COVID-19 patients and typically fall into three broad categories: those that are caused acutely by the virus’ systemic effects on the body itself, those that result from direct invasion of the nervous system, and those with long-term sequelae after an individual has recovered from the acute illness. While there is no clear evidence at this time that those with pre-existing neurological illness are at higher risk of infection or neurologic complications, the question of whether individuals with neuromuscular or bulbar weakness may be more vulnerable to either infection or neurologic sequelae will require careful study.

Prevalence data on acute neurological effects of COVID-19 are limited. In a paper published in JAMA Neurology detailing 214 COVID-19 positive patients hospitalized in Wuhan, China, headache and dizziness were the most commonly reported neurological complaints and seen early after symptom onset. These early symptoms contrast with the encephalopathy seen days to weeks into the hospital course of patients with severe disease. Encephalitis has been reported, mainly in a series of case reports, though imaging and CSF profiles have been nonspecifically abnormal or nonrevealing.

Evidence is largely lacking for direct CNS invasion of SARS-CoV-2 as a primary cause of neurologic sequelae. Several studies have detected low viral loads in brain tissue using quantitative real-time polymerase chain reaction (qRT-PCR), but the clinical significance of these findings is uncertain. For instance, a recent autopsy study of 41 consecutive patients who died from SARS-CoV-2 infection found low to very low viral RNA levels in some of the brains by qRT-PCR, but viral proteins were not detected, and the level of detectable RNA did not correlate with histopathological alterations. Other studies have not been able to detect viral RNA or protein in the brain. Based on rodent studies with other coronaviruses, researchers have speculated that the virus might be able to enter the central nervous system via retrograde dissemination. Thus far, evidence for SARS-CoV-2 doing so is lacking. The virus does infect the sustencular cells of the nasal mucosa, causing inflammation that causes loss of smell and headache. Similar systemic inflammatory effects of the virus might cause altered mental
status in patients either directly or through an inflammatory cascade leading to cardiac or respiratory compromise with hypoxia or thrombosis.\textsuperscript{7,10,19} CNS effects have also been hypothesized to be caused by damage to vascular endothelium or blood-brain barrier breakdown.\textsuperscript{19} There have been case reports suggesting increased risk of large vessel occlusion and ischemic stroke associated with infection in the young.\textsuperscript{20} It is also possible that the virus triggers underlying neurologic disease through immunomodulation as there have been case reports of acute inflammatory demyelinating polyneuropathy (AIDP), acute myoclonus, acute cerebellitis with ataxia, encephalitis, and status epilepticus occurring as para- or post-infectious phenomena.\textsuperscript{9,21-24}

Long-term sequelae have been reported following previous viral epidemics; however, clear evidence linking specific complications to prior viral infection remains somewhat controversial and do not appear related to a single mechanism of action. The 1918 H1N1 pandemic’s association with post encephalitic parkinsonism (PEP) and Zika virus induced congenital Zika syndrome are prominent examples. PEP is associated with encephalitis lethargica (von Economo’s encephalitis). Though encephalitis lethargica has been associated with the H1N1 epidemic, this association has been challenged.\textsuperscript{25} Moreover, the idea that PEP had a one-to-one relationship with encephalitis lethargica has also come into question.\textsuperscript{26} Unlike the putative post-infectious autoimmune etiology of PEP, Zika syndrome is in large part the direct result of acute infectious injury to developing brain.\textsuperscript{27} Any report of long-term neurological sequelae of COVID will require careful epidemiological and mechanistic analysis to demonstrate the validity of the association. That said, reports of long-term neurological sequelae post-recovery from COVID-19 have begun to accrue, and thus far include dysautonomia, chronic fatigue and cognitive impairment.\textsuperscript{28} More time is needed to fully characterize these issues and estimate their incidence. Global registries will be crucial for determining whether COVID-19 infection, like other viral infections, will be associated with increased incidence of psychiatric disease, dementia, thrombosis, or demyelination later in life. True causality can be difficult to establish, so associations with neurological syndromes are typically labeled as “probable” or “possible”.\textsuperscript{8}
No definitive pathophysiologic mechanism has yet been established for acute or chronic neurologic symptoms following COVID-19.

Some literature supports the indirect impact of viral infections on those with neurological disorders. Along with potentially triggering disease, there is an increased risk of mortality in patients with pre-existing neuromuscular illness who contracted influenza or pneumococcal pneumonia due to worsening respiratory status. Exacerbations of symptoms are commonly associated with infections, with infection accounting for almost half of patients presenting with myasthenia gravis flares. Viral infections are a common cause of pseudo-relapse (transient worsening of existing symptoms) in people with multiple sclerosis, and increased disability has been identified as a risk factor for severe COVID-19 in multiple sclerosis patients. Viral illnesses can be a predisposing factor for delirium in patients with dementia or mild cognitive impairment, leading to poor prognosis. In addition, those on immunomodulating therapy are at risk for more severe, recurrent and persistent infection. In patients with multiple sclerosis, anti-CD20 therapies have been linked with a more severe course of COVID-19.

In conjunction with its impact on patient health, COVID-19 has had profound effects on our healthcare system. The pandemic has been linked to decreased hospitalizations for those with ischemic stroke and other neurologic illnesses, resulting in poor access to care and the potential future increased burden of undiagnosed and untreated ischemic disease. Vaccination against SARS-CoV-2 infection may inspire confidence and allow the anxious to seek the care required to prevent increased morbidity and mortality.

**COVID-19 Vaccines Currently Approved for Use in the United States**

*Mechanisms of Action*

To lower overall viral transmission through herd immunity and decrease disease severity, particularly in vulnerable populations, three vaccines using distinct approaches have been approved by the FDA for emergency use. None of these vaccines utilize inactivated or live-
attenuated SARS-CoV-2 virus, nor do they use recombinant protein technology (the three most commonly used technologies for vaccine development in the past). Two of these (Pfizer and Moderna) utilize a novel messenger RNA (mRNA) approach, in which mRNA encoding a subunit of the SARS-CoV-2 spike protein is encapsulated within lipid nanoparticles to increase stability and augment uptake by antigen presenting cells. After uptake, the mRNA is translated into antigenic spike protein, inducing cell-based and humoral immune responses. This technology has advantages with regard to vaccine production and potentially immunogenicity and has been shown to be effective in animal models and clinical trials against a wide variety of infectious agents. Under emergency use authorization, it is now being used to vaccinate against SARS-CoV-2. The Johnson and Johnson vaccine, in contrast, utilizes a replication-deficient adenovirus vector to deliver DNA encoding the SARS-CoV-2 spike protein into host cells, which is then transcribed/translated into antigenic protein. Adenoviruses are common cold-causing viruses. In the context of the Johnson and Johnson vaccine, the adenovirus has been genetically engineered to prevent replication, meaning it cannot produce an active adenovirus infection. A similar platform has been used in a prior Ebola virus vaccine approved for use in the European Union. Importantly, because none of the currently approved vaccines utilize live-attenuated SARS-CoV-2 virus, none have the potential to cause SARS-CoV-2 infection.

Safety and Efficacy

Messenger RNA based vaccine approaches provide a novel, highly potent mechanism toward building immunity. In a multinational randomized placebo-controlled trial of greater than 40,000 people, the Pfizer vaccine was found to be 95% effective against development of symptomatic disease in recipients compared to controls. In their initial report to the FDA, fatigue and headache were the most frequent side effects of vaccination and initial severe systemic symptoms occurred in only about 2% of participants. Longer term severe events were rare, occurring in only 4 participants, and included shoulder injury, lymphadenopathy, ventricular arrhythmia, and paresthesias. Similar results were seen with the Moderna vaccine.
To date, the most recent safety data is the preliminary analysis of a multicenter Phase 3 trial of greater than 30,000 volunteers assigned to mRNA-1273 SARS-CoV-2 vaccine (Moderna) versus placebo. The trial showed high efficacy (94.1%) and a low rate of complications in individuals at high risk for infection and mortality due to COVID-19 who received active vaccine. While neurological illness was not an inclusion criterion, other high-risk comorbidities such as heart failure, pulmonary hypertension, diabetes, and HIV resulted in a diverse population with multiple comorbidities that would be expected to encompass some patients with neurological disease. The most frequent complications included injection site reactions, headache, and fatigue. Severe adverse events attributable to vaccine or placebo were uncommon, and similar between the vaccine and placebo groups (0.5 versus 0.2%).

The Johnson and Johnson vaccine phase 3 trial differed from the Moderna and Pfizer trials in its pre-specified outcomes, timing, and setting. It found a 66% reduction in moderate-to-severe COVID-19 infection in its treatment arm, with 85% reduction in severe disease and no hospitalizations or COVID-19-related deaths compared to controls. Recently, blood clots occurring 7-14 days after administration have been reported, primarily in young women on oral contraceptive medications, though whether this is higher than the baseline rate of thrombosis in this group and whether the mechanism can be reliably linked to vaccine administration is still under investigation. In these events vaccination was typically followed by cerebral venous sinus thrombosis (CVST), which was associated with thrombocytopenia and antibodies to platelet activating factor-4. In April 2021, the FDA instituted a 10-day pause in the use of the Johnson and Johnson vaccine for further evaluation of these events, which constituted 6 cases out of approximately 7.98 million doses given. Following review, the recommendation and emergency use authorization for this vaccine were reaffirmed for individuals aged 18 years and older, with a warning regarding rare clotting events primarily among women aged 18 - 49 years. Of note, similar rare clotting events that appear to share a pathophysiologic mechanism have
been reported with the Oxford/AstraZeneca vaccine approved outside the United States, with an estimated incidence of 1 in 40,000. 43 This vaccine uses a similar adenovirus-based mechanism.

Though neurological side effects were not more commonly observed following active vaccine over the extended follow-up period for any of the vaccines, a number of neurological complications of these vaccines are now being reported in the most comprehensive registry, the Vaccine Adverse Events Reporting System (VAERS) database. These include strokes, cranial neuropathies including Bell’s palsy, tinnitus and trigeminal neuralgia, peripheral neuropathies, dysautonomia, acute disseminated encephalomyelitis, transverse myelitis and AIDP. 44 Case reports are also starting to emerge in the published literature 45,46 and the popular press. Most recently, the possibility of increased risk of AIDP in the weeks following vaccination was formally added to the label for the Johnson and Johnson vaccine. These complications are rare when compared to the large number of vaccinated individuals; however, it is too early to know the true incidence and risk factors for these complications. They are thought to be immune mediated and early recognition and treatment with immunomodulatory therapies might be warranted. Unfortunately, there are little to no data regarding the safety or efficacy of the COVID-19 vaccines in patients with pre-existing neurological conditions and/or patients receiving immunomodulatory therapies. Based on COVID-19 vaccine data from the general population and extrapolations from other vaccines studied in patients with neurological disease, statements from the American Academy of Neuromuscular and Electrodiagnostic Medicine and the National Multiple Sclerosis Society support vaccination. 47,48 As discussed further below, a single study has now reported no increased risk of complications in multiple sclerosis patients receiving the Pfizer COVID-19 vaccine. 49

Additional Considerations from Prior Vaccine Experience

With regard to vaccination in patients with neurologic disease, several concerns arise. First, what is the risk a particular vaccine might precipitate or worsen neurologic disease? Although this concern applies to all neurologic patients, it may be most relevant to those with pre-existing
inflammatory/autoimmune neurologic conditions. Second, given that patients with neurological diseases are increasingly treated with therapies that either modulate or suppress the immune system, concerns arise regarding a) the risk that a vaccine might produce active infection; and b) whether vaccine efficacy might be reduced in the context of these therapies.

As discussed above, none of the currently approved COVID-19 vaccines utilize live-attenuated SARS-CoV-2 virus and thus none have the potential to produce SARS-CoV-2 infection. The Johnson and Johnson vaccine (along with vaccines using similar technology available outside the United States) utilizes an adenovirus vector to deliver nucleic acids encoding the SARS-CoV-2 spike protein but the adenovirus has been genetically engineered to prevent replication. It cannot produce adenovirus infection even in immunocompromised individuals. Beyond this concern, much of our knowledge about the safety and efficacy of vaccination in neurologic patients comes from the results of previous vaccine studies and our understanding of the mechanisms of action of commonly used immunotherapies. It must be noted, of course, that the currently available COVID-19 vaccines utilize largely novel technologies, complicating precise extrapolations from prior experience.

**Neurological Complications Associated with Prior Vaccines**

Prior studies have shed light on the likelihood of neurological complications following vaccination. These data can be difficult to interpret and are often seen as controversial, suffering from potential reporting bias and lack of clear causality, but illustrate theoretical concerns for both patients and physicians and must be acknowledged. The VAERS Database has reported adverse events affecting both the central and peripheral nervous systems, though clear causal relationships remain difficult to establish. AIDP is the most common neurologic syndrome and has been described in case reports following vaccination for influenza, polio, rabies, meningococcus, measles, mumps, and tetanus. Vaccination for H1N1 in 1976 was associated with an increased risk of AIDP of 1 additional case per 100,000 of vaccinated individuals. These cases occurred between one and six weeks following immunization. On
the basis of this the vaccine was discontinued in January 1977. However, one must also consider the baseline rate of Guillain Barre and the seasonal variability when interpreting this data. The 2009 H1N1 epidemic showed that individuals were actually more likely to experience AIDP after viral infection than after administration of the vaccine, and subsequent influenza vaccines have been considered safe with an excess risk of about 0.1 case per 100,000 vaccinations. Case reports of AIDP have been reported with a number of vaccines such as hepatitis A, Japanese encephalitis, smallpox, yellow fever and meningococcus. Current guidelines by the advisory committee on immunization practices of the CDC, lists AIDP within six weeks of previous influenza as a “precaution” for immunization against influenza. This means that while the risks may be elevated, individual risks versus benefits should be considered before recommending immunization. Vaccination has been associated with the development of chronic inflammatory demyelinating polyneuropathy (CIDP) in 1.5% of CIDP patients within 6 weeks of administration and worsening symptoms were also reported after tetanus vaccination in 8.7% of patients. Fortunately, the overall rate of complication is rare, and consideration of vaccination type is also important when considering risk.

In addition to peripheral nervous system effects, central nervous system involvement has been reported most often in the form of acute disseminated encephalomyelitis (ADEM). In the early 1990s seizures and encephalitis were loosely linked to the Diphtheria-Tetanus-Pertussis vaccine, though later studies reported no increased seizure frequency over baseline. ADEM has been reported in the form of case reports with the antirabies vaccine, as well as vaccinations to yellow fever, Japanese encephalitis, measles, influenza, smallpox, anthrax, and others. The strongest association of ADEM has been with the Semple rabies vaccine likely because it was made in cells derived from the nervous system. With regard to multiple sclerosis, theoretical concerns about vaccines precipitating relapses have existed for decades, although published studies have failed to identify any correlation between vaccination and either initial or subsequent clinical attacks. In contrast, several vaccines have been possibly linked to a lower risk of subsequent MS diagnosis. Thus far, a single study of adult
MS patients receiving the Pfizer COVID-19 vaccine (555 having received the first dose and 435 having received the second dose) demonstrated no safety concerns and no increased risk of relapse. 49

Vaccine Efficacy in Patients Receiving Immunotherapies

Studies of COVID-19 vaccine efficacy in patients receiving immunotherapies are currently limited. A recently published real-world study of the Pfizer COVID-19 vaccine found that two doses of the vaccine reduced SARS-CoV-2 infection by 71% in immunosuppressed patients compared to a 90% reduction among the non-immunosuppressed. e11 However, the specific therapies used and the definition of immunosuppression were not reported. A small study of patients with rheumatic and musculoskeletal diseases found a blunted antibody response to two doses of SARS-CoV-2 mRNA vaccine in those treated with glucocorticoids (82% seroconversion), mycophenolate (73% seroconversion), or rituximab (26% seroconversion). e12

Despite limited data specific to COVID-19 vaccination, prior studies have been helpful in elucidating the impact of immunomodulatory and immunosuppressive therapies on vaccine response. In general, immunomodulatory therapies have less impact on vaccine response than immunosuppressive or cell-depleting therapies. For patients with multiple sclerosis, there appears to be preserved immunity post-vaccination for those taking interferons. e6,e8 Dimethyl fumarate was similarly found to have no effect on vaccine response, although only in a single study. e13 Glatiramer acetate, teriflunomide, and natalizumab have demonstrated mixed results, with mildly attenuated immune responses in some but not all studies. e14-e20 Based on mechanism of action and the at most modest impact on vaccine response in prior studies, the above therapies are not expected to substantially decrease the efficacy of COVID-19 vaccines. In contrast, fingolimod, anti-CD20 therapies, and alemtuzumab have been shown to significantly impair vaccine responses in prior studies. e21-e23 A recent study in 23 patients showed that patients treated with cladribine had normal immune responses to the vaccine. e24 For these therapies, timing considerations must be taken into account for vaccination, as outlined in

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recently released guidelines from the National Multiple Sclerosis Society (Table 1). However, it is important to note that partial immunity might still be achieved even with those therapies that blunt measured vaccine responses. Furthermore, many studies of vaccine response have evaluated only humoral (antibody-mediated) immunity, without consideration of cell-mediated T lymphocyte responses.

In addition to the above multiple sclerosis therapies, other immunotherapies are commonly used in patients with inflammatory/autoimmune neurologic disease. Methotrexate acts by inhibiting lymphocyte activation and results in a decreased response to pneumococcal vaccine. Similarly, azathio- prine, mycophenolate mofetil, and systemic corticosteroids generally have been associated with decreased immunologic response to vaccines. The anti-IL6 monoclonal antibody tocilizumab has thus far not been shown to attenuate humoral responses to vaccination, at least after short durations of therapy. However, the possibility of decreased vaccine response must still be considered. The impact of eculizumab on vaccine response has not been extensively studied. When possible, it is generally prudent to complete vaccinations 2 - 4 weeks prior to initiating the above therapies, but treatment with these therapies does not preclude vaccination except for live-attenuated vaccines.

**Population Specific Considerations**

Clearly, there is evidence that SARS-CoV-2 infection poses risk to patients with neurological disease. Fortunately, vaccination presents an opportunity to decrease transmission and reduce severity of infection within vulnerable populations. However, along with the optimal timing of vaccination, there are additional considerations for many groups prompting national societies to offer statements in support of vaccine administration.

**Neuromuscular and Neuroinflammatory Disorders**

The weakness and disability associated with neuromuscular and neuroinflammatory disorders can result in increased symptomatology with viral infection, though there is no clear evidence
that infection is associated with increased risk of flare or disease progression. These patient populations are most likely to be treated with immunotherapies, which are discussed above in the context of SARS-CoV-2 infection and vaccination. Despite a paucity of data specifically evaluating the currently available COVID-19 vaccines in these groups, vaccination is expected to be safe. Both the American Academy of Neuromuscular and Electrodiagnostic Medicine and the National Multiple Sclerosis Society are in favor of vaccination for patients with neuromuscular disease and multiple sclerosis, regardless of immunosuppressive status. Although consensus guidelines from these groups discuss optimal timing of vaccination in relation to treatment with certain immunotherapies, it is important to note that vaccination should not necessarily be delayed if immediately available, as in some cases the risk of delaying even partial immunity may outweigh the benefit of waiting to achieve optimal vaccine response.  

For those patients treated with immunotherapies known or suspected to decrease vaccine response, patients should be counseled to remain vigilant about infection mitigation efforts even after vaccination due to the possibility of absent or diminished immunity. Unfortunately, evidence-based guidance does not exist regarding COVID-19 risk and appropriate ongoing safety measures for vaccinated patients on immunocompromising therapies. These issues are becoming increasingly relevant and challenging as a greater share of the population becomes vaccinated, leading to lifting of state- and locally-mandated safety measures and recommendations regarding the return to normal activities for the fully vaccinated. Some providers may choose to measure post-vaccination antibody levels against the SARS-CoV-2 spike protein to assess vaccine response and aid in counseling these patients, although the clinical significance of such testing with regard to COVID-19 risk remains uncertain. Further studies are needed regarding how best to evaluate post-vaccination immunity in this patient population and whether additional measures (such as booster vaccines) may be useful.

**Dementia, Cerebrovascular Disease, and the Elderly**
The possibility of side effects from vaccination is a significant concern in the elderly population, given it includes many individuals with potential vulnerability due to cognitive impairment or cerebrovascular disease. However, the risk of viral infection is also highest in this demographic and the Alzheimer’s Association is recommending vaccination for elderly individuals and their caregivers. More research is required to determine whether individuals with neurodegenerative cognitive disease are at risk for accelerated decline after COVID-19.

Vaccine administration for the majority of patients with stroke and cardiovascular disease is also supported by the American Heart Association, as infection with COVID-19 can exacerbate neurological sequelae of prior strokes. There are rare case reports of increased risk of stroke in young individuals with COVID-19 without traditional vascular risk factors, as well as reports of clotting in individuals with severe COVID-19. There is as yet no evidence to suggest that those with traditional risk factors are at an increased risk of stroke. As of this writing, 75% of the elderly population of the United States have received at least one vaccine dose and 55% are fully vaccinated. Careful surveillance will be required to determine whether there are age-related vaccination risks, but in the absence of clear data indicating increased risk the clear impetus is to vaccinate that portion of the population that has constituted 80% of US deaths due to COVID to date.

**Epilepsy**

Though seizures are not a common presentation of COVID-19, infection can increase seizure frequency in those at increased risk and the Epilepsy Foundation recommends the vaccine for eligible patients as there does not appear to be worsening of epileptic seizures following vaccine administration. To date there has been no evidence of increased risk of seizures following vaccination in those with a history of epilepsy.

**Pregnant Women and Children**

Recently, the first mRNA vaccine was approved for administration in children over the age of 12 years of age; however, this review focuses on the ramifications of COVID-19 and evidence
regarding safety of vaccination in the adult population, as the risk-benefit ratio is likely different between the two groups. Data is also sparse, though emerging regarding the vaccines use in pregnant women.\textsuperscript{e37} Though “no obvious safety signals” were seen, we await further evidence of its safety and efficacy.

\textit{Underrepresented Populations}

Underrepresented populations, including the Black, Latinx, and indigenous communities, also merit special consideration due to disproportionate risk of morbidity and mortality related to SARS-CoV-2 infection\textsuperscript{e38-e41} and disparities in access to available vaccines,\textsuperscript{e42-e44} although no data exist specifically regarding the interaction between COVID-19 and pre-existing neurologic illness in these groups. An additional challenge is vaccine hesitancy related to relative mistrust of the medical community, which stems from a variety of historical events and experiences.\textsuperscript{e45,e46} Of course, it is important to note that vaccine hesitancy is not restricted to underrepresented populations and transcends age, sex, race, and socioeconomic class, although the historical experiences producing hesitancy is often unique to these groups. Given the challenges facing underrepresented and underserved groups, strategies to increase vaccine access and advocacy within these communities remain critical.

\textit{Conclusions}

Given the widespread impact of the COVID-19 pandemic on adults with neurological disease, the risks and benefits of vaccination must be considered for each patient. Though limited, the currently available data report low rates of neurologic complications post-vaccination, particularly when weighed against the severity of morbidity and mortality resulting from the infection in populations of people with neurological illness. Special consideration relative to the timing of vaccination should be given to groups currently treated with immunotherapies. Patients treated with immunotherapies known or suspected to attenuate vaccine response must be counseled about the ongoing potential for SARS-CoV-2 infection, an issue of increasing relevance as state and local safety mandates are lifted. As neurology providers, it is our duty to
seek evidence-based guidance for our patients and to tailor education for all patient demographics. Due to the rapid development of the pandemic and COVID-19 vaccination, the current evidence base is limited in regard to patients with neurological disease. However, barring the rare circumstance of an absolute contraindication to available vaccine formulations, it is the American Academy of Neurology’s formal position that eligible patients should be offered the COVID-19 vaccine.\textsuperscript{647}
Table 1. Recommendations for Timing of Vaccine Administration for Patients on Common Immunotherapies

<table>
<thead>
<tr>
<th>Medications / Disease Modifying Therapies</th>
<th>Timing of Vaccine Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avonex (interferon beta-1a), Betaseron (interferon beta-1b), Copaxone (glatiramer acetate), Extavia (interferon beta-1b), Plegridy (peginterferon beta-1a), Rebif (interferon beta-1a), Aubagio (teriflunomide), Bafiertam (monomethyl fumarate), dimethyl fumarate, Tysabri (natalizumab), Vumerity (diroximel fumarate)</td>
<td>If starting: Do not delay starting treatment while waiting for the vaccine. If already taking: No adjustments needed. Continue as prescribed.</td>
</tr>
<tr>
<td>Gilenya (fingolimod), Mayzent (siponimod), Zeposia (ozanimod)</td>
<td>If starting: Time dosing so that the 2nd vaccine injection is administered 4 weeks or more before starting medication. If already taking: No adjustments needed. Continue as prescribed. Vaccine response may be attenuated.</td>
</tr>
<tr>
<td>Lemtrada (alemtuzumab), Mavenclad (cladribine)</td>
<td>If starting: Time dosing so that the 2nd vaccine injection is administered 4 weeks or more before starting medication. If already taking: Consider delaying 1st vaccine injection 12 weeks or more after the last Lemtrada or Mavenclad dose (optimal timing 24 weeks or more). If possible,</td>
</tr>
<tr>
<td>Medications / Disease Modifying Therapies</td>
<td>Timing of Vaccine Administration</td>
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<tr>
<td><strong>Lemtrada or Mavenclad</strong> 4 weeks or more following the 2(^{nd}) vaccine injection. Vaccine response may be attenuated.</td>
<td></td>
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</table>
| Ocrevus (ocrelizumab), Rituxan (rituximab) | **If starting:** Time dosing so that the 2\(^{nd}\) vaccine injection is administered 4 weeks or more before starting medication.  
**If already taking:** Consider delaying 1\(^{st}\) vaccine injection 12 weeks after the last treatment dose. If possible, resume treatment 4 weeks or more following the 2\(^{nd}\) vaccine injection. Vaccine response may be attenuated. |
| Kesimpta (ofatumumab) | **If starting:** Time dosing so that the 2\(^{nd}\) vaccine injection is administered 4 weeks or more before starting medication.  
**If already taking:** Consider delaying 1\(^{st}\) vaccine injection 4 weeks or more after the last Kesimpta injection. If possible, resume Kesimpta 4 weeks or more following the 2\(^{nd}\) vaccine injection. Vaccine response may be attenuated. |
| High-Dose Steroids | Consider getting the vaccine 3-5 days after the last dose of steroids. |

*Other Immunotherapies Commonly Used to Treat Neurologic Disease*
<table>
<thead>
<tr>
<th>Medication</th>
<th>If starting: Time dosing so that the 2nd vaccine injection is administered 2 - 4 weeks or more before starting medication. If already taking: No adjustments needed. Continue as prescribed. Vaccine response may be attenuated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methotrexate, Imuran (azathioprine), CellCept (mycophenolate mofetil), Actemra (tocilizumab), Enspryng (satralizumab), Soliris (eculizumab), systemic corticosteroids</td>
<td></td>
</tr>
<tr>
<td>Uplizna (inebilizumab)</td>
<td>If starting: Time dosing so that the 2nd vaccine injection is administered 2 - 4 weeks or more before starting medication. If already taking: Consider delaying 1st vaccine injection 12 weeks after the last treatment dose. If possible, resume treatment 4 weeks or more following the 2nd vaccine injection. Vaccine response may be attenuated.</td>
</tr>
</tbody>
</table>

*Based on Recommendations from the National Multiple Sclerosis Society.*

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