Doctor – Should I get the COVID-19 vaccine? Infection and Immunization in Individuals with Neuromuscular Disorders

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ABSTRACT

The clinical course of neuromuscular disorders (NMDs) can be affected by infections, both in immunocompetent individuals, and in those with reduced immunocompetence due to immunosuppressive/immunomodulating therapies. Infections and immunizations may also trigger NMDs. There is a potential for reduced efficacy of immunizations in patients with reduced immunocompetence. The recent vaccination program for Coronavirus Disease- 2019 (COVID-19) raises several questions regarding the safety and efficacy of this vaccine in individuals with NMDs. In this Practice Statement, we address the role of vaccine-preventable infections in NMDs and the safety and efficacy of immunization in individuals with NMDs, with emphasis on vaccination against COVID-19.

Introduction:

The Coronavirus Disease-2019 (COVID-19) pandemic has raised several concerns about the care of individuals with neuromuscular disorders (NMDs). With the recent Emergency Use Approval (EUA) of two COVID-19 vaccines (PfizerBioNTech® and Moderna®)by the US Food and Drug Administration (FDA) [1,2] and more in the pipeline, questions arise regarding the safety and efficacy of these vaccines overall, and also in several special populations including individuals with NMDs. The course of NMDs varies depending on the underlying etiology and pathophysiology and can be affected by concomitant illnesses and infections. Weakness of respiratory or bulbar muscles result in aspiration risk due to dysphagia, impaired ability to take a deep breath, impaired cough reflex and ineffective airway clearance of secretions with resultant atelectasis and pneumonia.[3] Special concerns in some of these disorders include the use of immunosuppressive and immunomodulating (IS/IM) agents, which may increase susceptibility to infections and concurrently reduce the humoral response to immunizations. This Practice Statement addresses the following topics with emphasis on COVID-19: 1. Infection related disease

Running Title: COVID-19 Vaccine and Neuromuscular Disease

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exacerbations in patients with NMDs; 2. Infections associated with *de novo* NMDs; 3. Risk of infections related to IS/IM treatments of NMDs; 4. Immunization of patients with NMDs and 5. Association of immunization with *de novo* development of NMDs.

Immunization against a disease may be achieved by natural infection or by vaccination against a specific agent or agents. The aim of vaccination is to generate an immune response against a particular antigen and protect susceptible populations from communicable diseases. This may be accomplished by the administration of a living modified agent ("live vaccine", e.g., yellow fever vaccine), a suspension of killed organisms (e.g., pertussis vaccine), a protein expressed in a heterologous organism (e.g., hepatitis B vaccine), or an inactivated toxin (e.g., tetanus).[4] In this Practice Statement, we use the terms immunization and vaccination interchangeably to refer to immunity developed in response to vaccines.

A. Infections and Underlying NMDs

An increased risk mortality from influenza and increased rates of pneumococcal disease have been associated with NMDs.[5,6] In a large population-based cohort study, MG was associated with a 39% increased risk of serious infections, mainly respiratory, compared to 19.4% in the general population over a mean follow-up period of 5.4 years (multivariate analysis with an adjusted hazard ratio 1.39 (95% CI, 1.28–1.51).[7] Acute infections may, in turn, worsen respiratory function further, resulting in acute respiratory failure and the need for ventilatory assistance. Exacerbations of myasthenia gravis (MG) are commonly associated with infections.[8] In a recent study of 250 cases of myasthenic crisis requiring mechanical ventilation, the trigger for crisis was an infection in almost half of the patients.[9] In a retrospective cohort of patients below 21 years age hospitalized with community-acquired influenza, concomitant NMDs were associated with higher risk of respiratory failure.[10]

B. Infections associated with *de novo* NMDs

Infectious agents may directly cause NMDs (e.g. cytomegalovirus (CMV) polyradiculopathy) or may trigger a post-infectious immune reaction (e.g. Acute Inflammatory Demyelinating Polyneuropathy (AIDP) or Guillain Barre Syndrome, GBS). Acute anterior horn cell involvement or poliomyelitis/ acute flaccid paralysis is a feature of several viral infections including polio virus,[11] West-Nile virus[12] and enterovirus D68.[13] Human Immunodeficiency virus (HIV) infection is associated with several types of NMDs, either directly or due to opportunistic infections.[14] Distal symmetrical, axonal, predominantly sensory polyneuropathy is the most common type of neuropathy in individuals with HIV.[15] Mononeuritis multiplex due to vasculitis is a rare complication of HIV infection.[16] A progressive polyradiculopathy due to opportunistic infection with CMV is well known, but is also associated with lymphoma, tuberculosis, syphilis, and cryptococcus.[17] An amyotrophic lateral sclerosis (ALS) like syndrome has been described with HIV infection.[18] HIV associated polymyositis, nemaline myopathy, dermatomyositis, inclusion body myositis and necrotizing myopathy have been reported.[17] Reactivation of Varicella zoster virus (VZV) causes Herpes zoster or shingles, which is characterized by dermatomal vesicular eruption and pain affecting cranial or spinal nerves, and may be followed by post-herpetic neuralgia. Reactivation of VZV infection is also associated with myelitis, cranial neuropathies and rarely with segmental motor paresis resulting from VZV related radiculopathies, plexopathies or mononeuropathies.[19-21] Leprosy, caused by Mycobacterium leprae, is a common cause of neuropathy in developing countries.[22] Several bacteria, viruses, fungi and parasites can cause infectious myositis.[23]

Post-infectious *de novo* NMD is best exemplified by the association of AIDP/GBS with antecedent infections (Campylobacter jejuni, Influenza, CMV, Epstein-Barr virus, Mycoplasma pneumoniae, Hemophilus influenzae, hepatitis E, Zika virus), where molecular mimicry is the

proposed pathogenic mechanism.[24] One study found that 18% of GBS patients during an influenza outbreak had serological evidence of influenza. [25] There are recent reports of COVID-19 associated GBS (Section F). [26,27] Infections can also trigger multisystemic and peripheral nerve vasculitides, including cryoglobulinemia (hepatitis C) and polyarteritis nodosa (PAN; hepatitis B, HBV).[28,29] Most of these infections are not vaccine preventable except for influenza, H. influenzae and H. zoster, and, most recently, COVID-19.

C. Immunosuppression and risk of infections in individuals with NMDs

IS/IM agents are commonly used in the treatment of autoimmune neuromuscular disorders, and vaccinations have an important role in reducing the morbidity associated with vaccine-preventable infections in this population.[30] There is a common perception that IS agents increase the risk of infections, both typical and atypical. A retrospective review of 631 patients with MG, chronic inflammatory demyelinating polyneuropathy (CIDP) and dermatomyositis who were on IS/IM agents revealed an infection rate of 19% in all three diseases, with pneumonia being the most frequent. There was a significant independent association between infections and the use of plasmapheresis, mycophenolate mofetil and corticosteroids in multivariate analyses. Line infections due to plasmapheresis were not separately analyzed in this retrospective study.[31] Corticosteroids are associated with an increased risk of infections, including reactivation of latent tuberculosis.[32] B-cell depleting therapies such as rituximab can reactivate HBV infections. The risk of reactivation is estimated at >10% with rituximab or high-dose corticosteroid therapy (>20 mg prednisone/day for > 14 consecutive days).[33] The risk of HBV reactivation with azathioprine, methotrexate or low dose corticosteroids (less than 10 mg prednisone /day) is estimated at less than 1%.[33] Reactivation of VZV infections has also been reported with the use of rituximab.[34] Progressive multifocal leukoencephalopathy due to reactivation of JC virus infection is the most serious infectious complication of IS therapy, for which there is no effective vaccine or treatment currently.[35]Three cases of PML have been reported in MG, one rituximab related, with prior use of other IS agents, and the others related to azathioprine, corticosteroids and IVIg.[36] IS agents increase the risk of Pneumocystis jirovecii (previously carinii) pneumonia (PJP).[37] The risk of PJP is higher in patients receiving corticosteroids in combination with other IS agents. In a Cochrane review of prophylactic trimethoprim/ sulfamethoxazole (TMP/SMZ) in patients with leukemia, solid organ transplantation or autologous bone marrow transplant, there was an 85% reduction in the occurrence of PJP in patients receiving prophylaxis compared to no treatment or treatment with fluoroquinolones, which are inactive against PJP, (relative risk 0.15, 95% confidence interval 0.04 to 0.62; 10 trials, 1000 patients). Adverse events were not significantly different with TMP/SMZ and no severe adverse events were noted. Leucopenia was reported as more frequent in the TMP/SMZ group in one study but the difference was not significant.[38] Eculizumab is associated with a risk of serious meningococcal infections (meningitis, sepsis). It binds to complement protein C5 to block cleavage into C5a and C5b thus preventing the combination of C5b with complement proteins C6-C9, which form the membrane attack complex (MAC). The lack of MAC inhibits the ability of the immune system to respond effectively to acquired Neisseria infections, due to the lack of adequate serum bactericidal activity and impaired opsonization with reduced phagocytic destruction of the encapsulated organism.[39]

D: Effectiveness of Vaccinations in immunosuppressed individuals with NMDs:

Altered immunocompetence may reduce the effects of vaccination. However, there is limited information on the effectiveness of vaccines in individuals who are on IS/IM agents.[40, 41] Methotrexate reduces the humoral response to pneumococcal vaccine.[42] Rituximab depletes CD-19+ B cells, pre-plasma cell blasts and interferon-

γ–secreting T cells. Antibody responses may be impaired for at least 6 months after rituximab.[43] This drug appears to have the most profound effect on the immune response to vaccines including influenza vaccine and pneumococcal vaccines. The efficacy of other vaccines is also likely to be affected.[42] High dose immunosuppression (prednisone >20 mg daily for >14 consecutive days, azathioprine >3mg/kg/day, methotrexate >0.4 mg/kg/week) is more likely to affect response to vaccination than low doses.[44]

E. Risk of vaccinations for the development of *de novo* NMDs:

GBS has been described in case reports and case series following immunizations for influenza, polio, rabies, meningococcus, measles, mumps and tetanus toxoid.[45] The vaccination campaign for swine influenza (H1N1) in 1976 in was associated with an increased risk of GBS of 1 per 100,000 vaccinated individuals.[46] Subsequent studies have reported varying risks of GBS (none, lower or higher) associated with various influenza vaccines.[47-51] Vaccination does not appear to increase the risk of recurrent GBS.[52,53] At this time, the risk of GBS after influenza infection and the complications of influenza infection appear to outweigh the risk of influenza vaccine associated GBS.[50,54]In CIDP, antecedent infections and vaccinations have been reported in 12% and 1.5% respectively, within 6 weeks from onset.[55] Worsening of CIDP symptoms after tetanus vaccination has been reported in 8.7% of patients, but only 1 of 65 patients required treatment within 2 months from immunization.[56] There is no evidence of association of idiopathic inflammatory myopathies and vaccinations, and the H1N1 vaccination appears to be safe and effective in patients with inflammatory myopathies.[57,58] Overall, however, the risk of vaccination-triggered NMDs appears to be low, and should be evaluated in the context of the risk of NMDs being triggered or worsened by vaccine preventable infections.

F. COVID-19 infection, Vaccination and Neuromuscular Disorders

As of December 29, 2020, the COVID-19 pandemic has affected more than 79 million individuals worldwide with more than 1.7 million deaths.[59] COVID-19 is caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), a member of the virus family Coronaviridae, which contains four genera. Coronaviruses are single stranded, enveloped RNA viruses, named for their crown like appearance on electron microscopy. The SARS-CoV-2 sequence is similar to other human coronaviruses that are responsible for 15% of all cases of acute viral nasopharyngitis of the "common cold" and belongs to the betacoronavirus genus.[60] The SARS-CoV-2 has 4 structural proteins: The spike protein covers the surface of SARS-CoV-2 and binds to the host cell angiotensin-converting enzyme 2 receptor, mediating viral cell entry. It is targeted by host neutralizing antibodies.[61] Envelope proteins form viroporins, small hydrophobic proteins which are necessary for viral assembly/release and mediate pathogenicity and cytotoxicity.[62] The membrane protein is the most abundant structural protein, providing a scaffold in assembly of the virus.[63] The nucleocapsid protein binds to viral RNA to form a ribonucleoprotein which facilitates host cell entry and interaction with cellular processes.[64] Recently, new variants of SARS-CoV2 have been described in various parts of the world including UK, South Africa and Nigeria.[65] The variant identified in the UK is referred to as "SARS-CoV-2 VOC 202012/01" (the first variant of concern from 2020, December). This variant appears to have increased transmissability.[66]

The clinical picture of COVID-19 ranges from an asymptomatic illness to mildly symptomatic individuals with respiratory or gastrointestinal symptoms, to a severe illness with coagulopathy and systemic multiorgan failure.[67] Symptoms attributed to peripheral nervous system (PNS) involvement were reported in 19/214 (8.9%) hospitalized patients with COVID-19 in Wuhan,

China. Impaired smell and taste were the most frequent symptoms attributed to PNS involvement. Nerve pain and skeletal muscle injury were reported in 2.3% and 10.7% respectively, but skeletal muscle injury was not further characterized, since most diagnoses rested on subjective symptoms without complete examinations. Most patients with skeletal muscle injury had elevated creatine kinase (CK) levels (median 400 U/L; range 203-12216 U/L).[68]

COVID19 has been associated with parainfectious (during the acute infection) or postinfectious GBS and all common variants of GBS have been reported.[26, 67] The exact prevalence of COVID-19 associated GBS remains uncertain because of potential ascertainment bias and selective reporting but appears to be low.[26,27] It has been suggested that the spike protein of SARS-Co-V2 binds to sialic acid residues of gangliosides. This cross-reactivity to peripheral nerve gangliosides may trigger an immune reaction by molecular mimicry, resulting in GBS.[26,69-71] However, anti-ganglioside antibodies have been only infrequently detected in reported cases of COVID-19 associated GBS.[26] Other neuromuscular complications reported in COVID-19 patients include myalgias and elevated CK levels, myositis, critical illness myopathy, mononeuritis multiplex and entrapment neuropathies due to prolonged prone positioning. [72-79] It remains uncertain if these neuromuscular complications of COVID-19 are due to direct viral invasion, an inflammatory/cytokine response to the virus, or other factors. One patient with COVID-19 and generalized muscle weakness, proximal > distal, CK 29,800 IU/L was noted to have mild perivascular inflammation on muscle biopsy, abnormal sarcolemmal and sarcoplasmic expression of major histocompatibility complex class –1 (MHC-1) antigen, and abnormal myxovirus resistance protein (MxA) expression on the sarcolemma and sarcoplasm. MxA protein is expressed in response to viral infections and is induced by type I interferon. The authors suggest that the expression of this protein suggests a toxic effect of increased interferon-I expression (type I interferonopathy).[80]

The worldwide devastation wrought by the COVID-19 pandemic has stimulated a large number of clinical trials investigating different vaccines for COVID-19. The antigenic targets include inactivated whole virus, subunit formulations that utilize one or more viral components, nanoparticulate protein formulations using particulate antigens, and nucleic-acid vaccines which utilize genetic material (deoxyribonucleic acid, DNA or ribonucleic acid, RNA) to stimulate an immune response.[81] Messenger RNA (mRNA) based vaccines expressing the target antigen are delivered into the cell cytoplasm without incorporation to the human genome as in the case of DNA-based vaccines.[81-83] Vector vaccines use a modified virus (the vector) to deliver the genetic code for an antigen, such as the COVID-19 spike protein, into human cells. The infected cells then produce the antigen mimicking natural infection and prompting an immune response.[81]

As of December 10, 2020, studies of Phase 1-3 trials using nine different vaccines have been published. The Infectious Disease Society of America (IDSA) website provides updates on available studies.[84] The first vaccine to receive EUA by the US FDA for individuals 16 years and older was the Pfizer-BioNTech® COVID-19 vaccine (BNT162b2) on December 11, 2020. BNT162b2 is a lipid nanoparticle formulated nucleoside-modified mRNA vaccine that encodes a prefusion stabilized, membrane-anchored SARS-CoV-2 full-length spike protein. In a multinational, placebo-controlled, observer-blinded, pivotal efficacy trial, 43,448 persons 16 years of age or older were randomly assigned to BNT162b2 in a 1:1 ratio to two doses, 21 days apart, of either placebo or vaccine (30 µg per dose). It was found to confer 95% protection against COVID-19. Mild- moderate injection site pain was the most frequent local reaction, reported in 71% to 83% of older (>55 years) and younger participants (16-55 years) respectively

after the first dose compared to 9% and 14% of those receiving placebo. Fatigue and headache were the most frequent systemic side effect. Severe systemic effects were reported in >2% of participants. A median of at least 2 months of safety data was available for 37,706 participants, and the safety profile was reported as similar to that of other viral vaccines. Four related serious adverse events were reported: shoulder injury related to vaccine administration, right axillary lymphadenopathy, paroxysmal ventricular arrhythmia, and right leg paresthesia.[85] Post EUA, during clinical use, a few cases of anaphylaxis to the vaccine have been reported. The US Centers for Disease Control and Prevention (CDC) states "If you have ever had a severe allergic reaction to any ingredient in a COVID-19 vaccine, CDC recommends that you should not get that specific vaccine".[86]

The Moderna® mRNA vaccine mRNA-1273 received EUA by the US FDA on December 18, 2020 for individuals 18 years and older. A phase 3, observer blinded randomized controlled trial of 30,420 individuals randomly assigned in a 1:1 ratio to receive either vaccine or placebo reported symptomatic Covid-19 illness in 185 participants in the placebo group and 11 participants in the vaccine group. Vaccine efficacy was 94.1% (95% CI, 89.3 to 96.8%; P<0.001), with a median follow-up of 64 days post-dose 2. Thirty participants had severe COVID-19, all received placebo. Safety data with a median 7 week follow-up did not reveal specific safety concerns. The most common adverse reactions associated with mRNA-1273 were injection site pain (91.6%), fatigue (68.5%), headache (63.0%), muscle pain (59.6%), joint pain (44.8%), and chills (43.4%); severe adverse reactions occurred in 0.2% to 9.7% of participants. There were three reports of Bell's palsy in the vaccine group and one in the placebo group.[87] The effectiveness of both COVID-19 mRNA vaccines against the new variants of SARS-CoV2 continues to be investigated.[65,66]

As the COVID-19 vaccination program rolls out in the USA and other countries, the allocation of vaccines has been an issue with demand outpacing initial supply. The Advisory Committee on Immunization Practices (ACIP) recommendations for phased COVID-19 vaccine allocation have been adopted by the US CDC, and recommended as guidelines for state health departments. The overall principles informing allocation are: (a) decrease death and serious disease as much as possible, (b) preserve functioning of society, (c) reduce the extra burden the disease is having on people already facing disparities and (d) increase the chance for everyone to enjoy health and well-being. The ACIP guided their decision-making based on four ethical principles: (a) *maximize benefits and minimize harms*, (b) *mitigate health inequities*, (c) *promote justice* and (d) *promote transparency*. With these guiding principles, 3 initial phases of vaccine allocation have been recommended: Phase 1a: long term care facility residents and health care personnel; 1b: persons ≥ 75 years age and frontline essential workers; 1c: persons aged 65–74 years, persons aged 16–64 years with high-risk medical conditions, and essential workers not included in Phase 1b.[88,89]

G: Vaccination and infection prophylaxis in Individuals with NMDs

NMDs are diverse, affecting all age groups. From the perspective of infections and immunizations, two fairly distinct groups of NMDs emerge: those that are autoimmune and frequently treated with IS/IM agents, and those that are inherited/degenerative and treated mainly with supportive management. It is possible that the risk of infections in individuals with NMD receiving long-term IS/IM treatments may be greater than that in individuals with NMD who are not receiving these, although data to support this is sparse. Additionally, distinct questions regarding immunization arise in these two groups. Underlying cardiac and respiratory dysfunction places individuals with NMDs at greater risk of serious complications and increased mortality from infections such as influenza, regardless of treatment with IS/IM agents.[90] Additional considerations in individuals treated with NMD on IS/IM agents include vaccine-related worsening of the underlying

disorder, triggering of new autoimmune NMDs and sub-optimal vaccine efficacy. The following are general recommendations for immunization in patients with NMDs. All of these are subject to change and should be reviewed periodically. Table 1 provides a list of the common inactivated and live attenuated vaccines, and Table 2 describes specific vaccine recommendations in immunocompetent and immunocompromised hosts per the US CDC.

1. General Recommendations:

a. The rationale for vaccination, specific issues relevant to the individual, the benefits and risks of immunization and the limitations of available data should be discussed. Informed, shared decision- making is an important part of this process.

b. Age-appropriate immunization schedules recommended by authorities such as the US CDC or World Health Organization (WHO) should be followed in individuals with NMDs, with some modifications in those with reduced immunocompetence. [30,40,44]

c. In individuals with reduced immunocompetence, live vaccines may cause severe systemic infections and are contraindicated.[41] Individuals with reduced immunocompetence should be counseled that they should avoid the nasal spray (live) influenza vaccine and should receive the injectable inactivated vaccine.[41]

d. Because full immunity following vaccination may not be achieved in patients who are immunosuppressed, inactivated vaccines should be updated, if possible, 2 weeks prior to starting IS agents (4 weeks prior to starting IS agents for live vaccines). Patients vaccinated within a 14 day period before starting IS agents should be revaccinated at least 3 months after the treatment is discontinued.[91] Because of the attenuating effect of rituximab on multiple vaccines, it is recommended that all scheduled immunizations be completed 4 weeks before commencing rituximab and other B-cell depleting therapies, or at least 6 months after the treatment is completed. [91,92]

e. In patients receiving intravenous immunoglobulin (IVIg), response to varicella and measles/mumps/rubella and other may be attenuated because of the presence of passive antibodies interfering with replication of attenuated virus and subsequent immune response. It is recommended that the vaccines be given 14 days prior to the next dose of IVIg, and repeated 8 months after the treatment is completed.[41]

f. In immunosuppressed individuals, measuring serologic titers of antibodies post-vaccination may inform the need to revaccinate, but this is not a uniform practice. Ongoing treatment with IVIG may interfere with the accuracy of serologic testing.

g. If IS therapy is planned, screening for latent infections such as hepatitis B, hepatitis C, HIV and tuberculosis should be performed as per the manufacturer's prescribing information. It is suggested that screening for both Hepatitis B and Hepatitis C be performed before initiating rituximab in patients with rheumatoid arthritis.[93] Patients receiving corticosteroids (≥ 15 mg per day prednisone equivalent) or other IS agents in the setting of organ transplantation are deemed to be at high risk of reactivation of latent tuberculosis.[94] Although data specific to individuals with NMDs taking IS agents is not available, screening for these disorders may be appropriate in these individuals as well.

h. Infectious disease consultation should be sought to manage latent infections detected by screening prior to starting IS agents and to monitor for reactivation during IS treatment.

2: Recommendations for specific vaccines or drugs:

a. The ACIP recommends that persons who developed GBS within 6 weeks of receipt of an influenza vaccine generally should not receive influenza vaccine again unless they are at high

risk from influenza complications.[95] Patients should be counseled that the risk of influenza probably outweighs the risk of recurrent GBS if they are at risk of serious complications from influenza.

b. Two types of pneumococcal vaccines are available in the US: the pneumococcal 13-valent vaccine (PCV13) and pneumococcal 23-valent polysaccharide vaccine (PPSV23). Patients with NMDs and respiratory or cardiac involvement should receive one dose of PPSV23. If immunosuppressed, patients should receive 1 dose of PCV13, followed by 1 dose of PPSV23 8 weeks later and a second dose of PPSV23 5 years after the first dose (Table 2).[96]

c. The inactivated zoster vaccine (Shingrix®) is recommended (two doses, 2-6 months apart) in anticipation of IS therapy or for individuals on low dose IS therapy. At this time, it is not recommended for immunocompromised persons or those receiving high dose IS therapy.[97] The live inactivated zoster vaccine (Zostavax®) is no longer available in the US.

d. Individuals should receive the first doses of quadrivalent (meningitis ACWY) and group B meningococcal vaccination at least 2 weeks prior to starting therapy with complement inhibitors such as eculizumab.[98] As meningococcal vaccination may not fully prevent meningococcemia in patients treated with complement inhibitors, the CDC recommends consideration of antibiotic prophylaxis. Additionally, meningococcal vaccine boosters (both quadrivalent and serogroup B) are recommended for patients with continued risk of meningococcal infections (including ongoing treatment with complement inhibitors).[99]

e. There are no published guidelines for PJP prophylaxis in individuals with rheumatologic diseases or NMDs receiving IS agents. However, prophylaxis may be offered to patients receiving >20 mg of prednisone equivalent for over one month who are also on a second IS agent.[100]

3: COVID-19 vaccination in Individuals with NMDs

While NMDs have not been listed as a high-risk for COVID19, and are currently not considered in the planned allocation of an early phase of COVID19 vaccinations, ACIP and CDC recommendations are expected to expand as large enough quantities of vaccine become available.[88,89]

a. COVID-19 vaccination is recommended for persons 16-18 years and older with ACIP/CDC recommended allocation schedule based on perceived risk.[88,89]

b. The same brand of COVID-19 vaccine should be used for both initial and booster injections. They should not be administered within 14 days of other vaccines.[101]

c. All individuals with NMDs who are not taking IS agents should be encouraged to receive COVID-19 vaccines since the risk of COVID-19 infections likely outweighs the potential risks of the vaccine.

d. Individuals with NMDs who are taking IS/IM agents should be counseled that there is no data currently regarding the safety or efficacy of COVID-19 mRNA vaccines in this population, but the vaccine benefits of reducing COVID-19 infection likely outweigh the potential risks. Even reduced efficacy may confer benefits against COVID-19 infections.

e. Individuals with autoimmune NMDs should be counseled that no data are currently available on the safety and efficacy of mRNA COVID-19 vaccines in this population. An increased risk of developing autoimmune or inflammatory disorders was not observed in clinical trial participants who received an mRNA COVID-19 vaccine compared to placebo. There is no data regarding the risk of exacerbation of autoimmune NMDs by COVID-19 vaccine. Persons with autoimmune conditions who have no contraindications to vaccination may receive an mRNA COVID-19 vaccine.[102]

f. Persons with a history of GBS and autoimmune conditions may receive COVID19 mRNA vaccines unless they have other contraindications to vaccination.[101]

g. Individuals should be counseled that the vaccine does not carry the risk of inducing systemic COVID-19 infection, and that it does not alter their DNA.

h. Known adverse effects of the vaccine should be discussed and patients should be encouraged to participate in vaccine safety tracking programs such as V-safe® by the CDC.[102]

i. Based on current knowledge, it is believed that both COVID-19 mRNA vaccines in present use are unlikely to pose a risk to the pregnant person or fetus, but the potential risks are unknown. If pregnant people are a part of a group that is recommended to receive a COVID-19 vaccine, they should discuss the vaccination with their healthcare team to help them make an informed decision [103]

Abbreviations

ACIP	-	Advisory Committee on Immunization Practices
AIDP	-	acute inflammatory demyelinating polyradiculoneuropathy
ALS	-	amyotrophic lateral sclerosis
BCG	-	Bacillus Calmette and Guerin
CDC	-	Centers for Disease Control and Prevention
CIDP	-	chronic inflammatory demyelinating polyneuropathy
CK	-	creatine kinase
CMV	-	cytomegalovirus
COVID-19	-	Coronavirus Disease-2019
DNA	-	Deoxyribonucleic acid
EUA	-	Emergency Use Approval
FDA	-	Food and Drug Administration
GBS	-	Guillain Barre syndrome
HBV	-	hepatitis B virus
HIV	-	human immunodeficiency virus
IDSA	-	Infectious Diseases Society of America
IM	-	immunomodulatory
IVIG	-	intravenous immunoglobulin
IS	-	immunosuppressive
MG	-	myasthenia gravis
mRNA	-	messenger ribonucleic acid
NMD/s	-	neuromuscular disorder/s
PCP	-	pneuomocystis jirovecii pneumonia
PCV13	-	pneumococcal 13-valent vaccine
PNS	-	peripheral nervous system
PPSV23	-	pneumococcal 23-valent polysaccharide vaccine
RNA	-	Ribonucleic acid
SARS-CoV2	-	severe acute respiratory syndrome coronavirus 2
VZV	-	varicella zoster virus
WHO	-	World Health Organization

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Table 1. Inactive and live attenuated vaccines [104]

Inactivated Vaccines	***Live attenuated vaccines***
Inactivated influenza vaccine	Live influenza vaccine
Recombinant zoster vaccine *	Measles, mumps, rubella vaccine (MMR)
Pneumococcal vaccines (PCV13, PPSV23)	Varicella (chicken pox) vaccine (VAR)
Meningococcal vaccines	Measles, mumps, rubella, varicella vaccine
Hepatitis A and B	(MMRV)
Haemophilus influenzae	Oral typhoid vaccine
Inactivated polio vaccine †	Small pox (vaccinia) vaccine
Human papilloma virus vaccine	Yellow fever vaccine
Rabies vaccine	Rotavirus vaccine
Parenteral typhoid vaccine	Bacille Calmette Guerin (BCG)

* - live zoster vaccine (Zostavax) became unavailable in US since November 18, 2020; † – live oral polio vaccine (OPV) has not been used in US since 1999

Table 2. Recommended Adult immunization schedule for ages 19 and older, USA [105]

Vaccine	***Non-immunosuppressed***	***Immunosuppressed***
Influenza (IIV – inactivated, LAIV – live)	1 dose annually (IIV or LAIV)	1 dose annually (IIV only)
Tetanus, diphtheria, pertussis (Tdap or Td)	1 dose Tdap, then Td/Tdap booster every 10 years	Same
Measles, mumps and rubella (MMR)	If no immunity[†]: 1 dose	Contraindicated[‡]
Varicella (VAR)	If no immunity to varicella[§]: 1 dose	Contraindicated[‡]
Zoster recombinant (RZV)	*Age ≥ 50 years*: 2-dose series 2–6 months apart	Zoster vaccination not recommended
Human Papilloma virus vaccination (HPV)	2- or 3-dose series for adults through age *26 years*	Same
Pneumococcal vaccination (PCV13, PPSV23)	a.*Age ≥ 65 years*: 1 dose PPSV23 and shared clinical decision making for 1 dose PCV 13 b. If PPSV23 prior to age *65 years*, administer 1 dose PPSV23 at least 5 years after previous dose	1 dose PCV13 followed by 1 dose PPSV23 at least 8 weeks later, then another dose PPSV23 at least 5 years after previous PPSV23; at *age ≥ 65 years*, administer 1 dose PPSV23 at least 5 years after most recent PPSV23
Vaccine	***Non-immunosuppressed***	***Immunosuppressed***
Hepatitis A (Hep. A)	Individuals at risk: 2- or 3-dose series	Same
Hepatitis B (Hep. B)	Individuals at risk: 2- or 3-dose series	Same
Meningococcal vaccine (4-valent Men ACWY; Men B)	First-year college students who live in residential housing and military recruits: 1 dose Men ACWY Adolescents and young adults 16-23 years not at increased risk: consider 2-dose series of Men B	Complement inhibitors (eculizumab): a. Men ACWY: 2-dose series Men ACWY at least 8 weeks apart and booster every 5 years if risk remains b. Men B: 2- or 3-dose primary series; 1 dose Men B booster 1 year after primary series and revaccinate every 2–3 years if risk remains
Haemophilus influenza type B (HiB)	Individuals at risk	Same

* - additional considerations during pregnancy and other specific situations; [†] – born after 1957, never received MMR vaccination; [‡] – contraindicated with severe immunosuppression, may consider with low dose immunosuppression; [§] - born after 1980, never received varicella vaccination

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