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SHORT COMMENTARY

Acute transverse myelitis following SARS-CoV-2 vaccination: a case report and review of literature

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Abstract

Objective To report a unique case and literature review of post COVID-19 vaccination associated transverse myelitis and with abnormal MRI findings.

Background Coronavirus disease have been reported to be associated with several neurological manifestations such as stroke, Guillain-Barré syndrome, meningoencephalitis amongst others. There are only a few reported cases of transverse myelitis with the novel coronavirus (n-CoV-2). Here, we identify a post COVID-19 vaccination patient diagnosed with acute transverse myelitis.

Method A retrospective chart review of a patient diagnosed with post SARS-CoV-2 vaccination acute transverse myelitis, and a review of literature of all the reported cases of other post vaccination and transverse myelitis, from December 1st, 2010 till July 15th, 2021, was performed.

Conclusion To our knowledge, this is the one of early reported case of transverse myelitis and with post SARS-CoV-2 vaccination, who responded well to plasmapheresis. Further studies would be recommended to identify the underlying correlation between COVID-19 vaccination and transverse myelitis.

Keywords COVID-19 · SARS-CoV-2 · Transverse myelitis · MRI spine · Post vaccination myelitis

Abbreviations

SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
RT-PCR	Reverse transcription polymerase chain
ATM	Acute transverse myelitis
CSF	Cerebrospinal fluid
CNS	Central nervous system
AEFI	Adverse event following immunization
VAERS	Vaccine adverse event reporting system
MHRA	Medicines and healthcare products regulatory agency
NMO	Neuromyelitis optica
PLEX	Plasmapheresis
IVMP	Intravenous methylprednisone
MRC	Medical research council

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Introduction

As the coronavirus (COVID-19) vaccines are being distributed around the world, we are witnessing the rise of Adverse Event following Immunization (AEFI). The Vaccine Adverse Event Reporting System (VAERS) of Centers for Disease Control (CDC) has reported AEFI related to Pfizer-BioNtech, Moderna and Johnson and Johnson's COVID-19 vaccines, among which there are reported neurological complications ranging from facial palsy to stroke [1]. The predominant post-vaccination side effects are the nonspecific systemic symptoms, among which the neurological symptoms include dizziness, headache, pain, muscle spasms, myalgia and paresthesia. On some rare occasions, tremor, dysphonia, diplopia, tinnitus, seizures and reactivation of herpes zoster have been reported [2]. Other serious neurological manifestation such as stroke, Guillain-Barré syndrome, Bell's palsy, transverse myelitis and acute

disseminated encephalomyelitis were also reported in the VAERS database and Medicines and Healthcare products Regulatory Agency (MHRA) from UK, COVID-19 database [1, 3–5].

According to the analysis of the database by CDC in the first month of vaccination, there appear to be very little to no safety concerns along with respect to the causal link between these side effects and vaccination [6]. However, due to the passive surveillance, the VAERS database is subjected to reporting bias and may contain some errors. Considering the large-scale vaccination campaign and less prevalence of neurological conditions in the population, the post-vaccination neurological morbidity may be due to chance alone.

Transverse myelitis (TM) is a very uncommon condition, and rarer is the vaccine-associated TM. However, some studies have reported its occurrence following administration of other vaccines, including diphtheria, tetanus toxoids and pertussis vaccine [7], measles, mumps, and rubella (MMR) virus vaccine [8, 9], oral poliovirus vaccine [10], Japanese encephalitis virus vaccine [11], hepatitis B vaccine [12–14], yellow fever vaccine [15, 16], typhoid vaccine [17], rabies vaccine [18], and seasonal influenza virus vaccine [19–25]. In addition, only oral polio vaccine was found to have a pathogenic causal relationship while other vaccines showed a temporal relationship to TM due to a common denominator such as an adjuvant [26].

We report a case of transverse myelitis after COVID-19 vaccination. To better identify and differentiate temporal and causal associations, AEFI should be reported with a low threshold of vigilance. As our understanding grows on fronts of disease as well as the vaccine, we will be able to better prevent and cure such dreaded outcomes.

Case report

A 67-year-old patient with a significant medical history of coronary artery disease, chronic kidney disease, neuropathy and a previous colon rupture with colostomy received her first dose of the Moderna COVID-19 vaccine on May 11th, 2021. On day one post-inoculation, she experienced bilateral upper and lower extremity weakness right more than left. 5 days later, the patient presented to the Emergency Department (ED) with complaints of symptoms described above. She described her symptoms as if she were "melting in the floor like a puddle". She also mentioned tingling in right lower extremity and difficulty in ambulating requiring assistance for walking. She denied any vision changes, difficulty in swallowing or speech, shortness of breath, chest pain, and loss of smell or taste sensation.

Initial workup revealed decreased hemoglobin 8.5 g/dL (12.0–15.5 g/dL), hematocrit 27% (normal 36–48%), platelet count 1,30,000 platelets/uL (150,000–450,000 platelets/uL), Calcium 8.4 mg/dL (8.6–10.3 mg/dL, total protein 5.8 g/dL (6–8.3 g/dL), albumin 3.2 g/dL (3.4–5.4 g/dL). Creatinine was elevated to 1.32 mg/dL (0.7–1.2 mg/dL) and D-dimer elevated to 1.28 (range < 0.5).

On arrival, she was lethargic, oriented, afebrile and vitals were stable. Physical examination demonstrated cranial nerves were intact, however, motor strength showed Medical Research Council (MRC) grade of 3/5 throughout right lower extremity and 4/5 in right upper extremity, rest of motor strength was 5/5 on MRC scale. Upper motor neuron signs were present in bilateral lower extremities with Grade 3 + reflex, positive bilateral Babinski reflex and marked loss of vibration up to the ankle. Proprioception and light touch sensation were intact.

The patient underwent a brain CT, which was unremarkable. Brain MRI revealed scattered patchy foci nonspecific for white matter signal change suggestive of chronic microvascular changes no acute infarction; MRI of the cervical spine revealed hyperintense lesions in the upper cervical spine and cord edema extending from C1-C3 with patchy post-contrast enhancement (Fig. 1). MRI T- spine showed no intramedullary cord signal changes. Other investigations to determine the causes were done.

Cerebrospinal fluid (CSF) study revealed cell count 2, glucose 77 mg/dl, serum glucose 125 mg/dl, CSF protein 56 mg/dl, oligoclonal bands 2 in CSF and 2 in serum, with 0 isolated bands, IgG index 0.48. CSF labs yielded negative results for gram stain, culture, Cryptococcus, HSV, and VDRL, CSF-RT PCR negative for SARS-CoV-2. CSF paraneoplastic panel, autoimmune panel, flow cytometry, cytopathology were within normal limits. Patient's basic metabolic panel (BMP), lipid panel, LFTs, CK, HbA1C were within normal limits. Serum perinuclear staining antineutrophil cytoplasmic antibody (P-ANCA), ANA, myeloperoxidase antibodies, cytoplasmic-ANCA and proteinase 3 were also negative. TPO Ab and thyroglobulin Ab test were within the normal limit. Hepatitis B, RPR and HIV testing were negative. Serum MOG antibodies (Ab), HTLV I/II Ab, MTB PCR were all negative. CSF and serum NMO Anti-AQP4 AB were negative. Overall, findings were compatible with inflammatory central nervous system disorder and the presentation was thought to be from post-vaccination myelitis.

The patient was treated with IV solumedrol (IVMP) 1 g daily for 3 days. Patient showed no improvement with IV solumedrol, so Plasmapheresis (PLEX) therapy were initiated on 5/20/2021 for a 5-day period. On day 5 post-admission, the patient regained some use of her right hand, along with improved upper extremity weakness and underwent physical therapy was discharged to rehabilitation facility.

The patient began to show improvement in edema and right upper extremity weakness to the point where she was able to perform fine-motor movement. At outside Hospital, she continued to show improvements with her

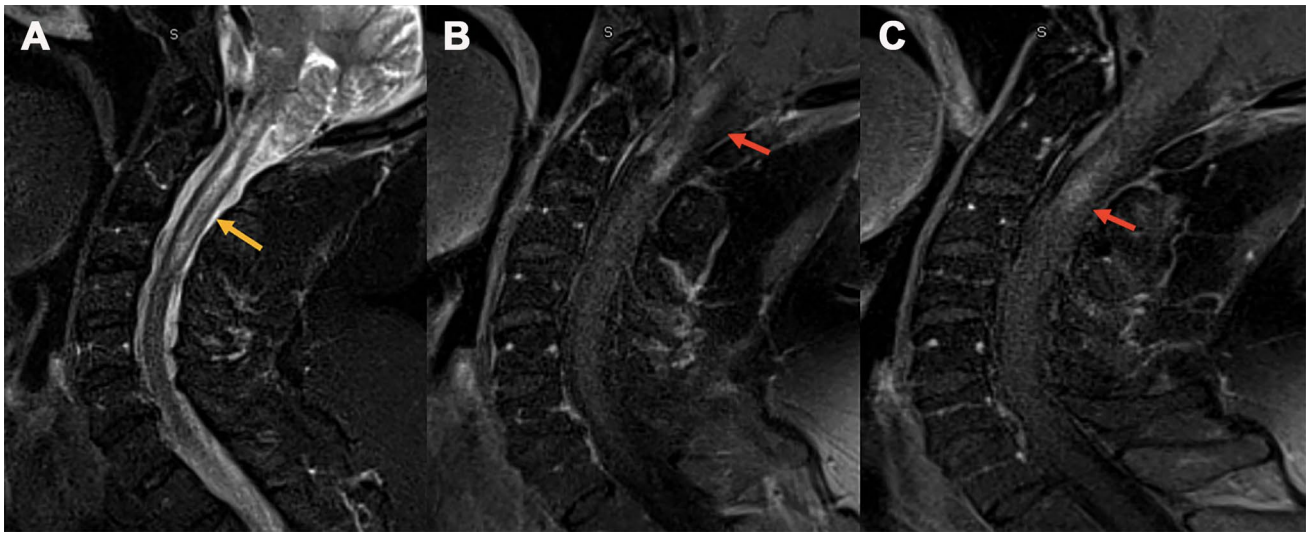

Fig. 1 MRI sagittal STIR weighted image of cervical spine (**a**), sagittal cervical spine; sagittal T1 post contrast (**b** and **c**) reveals ill-defined long segment signal alteration with mild cord expansion (yellow arrow) (**a**) and abnormal enhancement on post-contrast study (**b** and **c**) (red arrow) extending from C1–C3 level

paresthesia and weakness. On follow-up in outpatient clinic on 07/15/2021, patient was able to ambulate without walker, motor strength was 4/5 throughout the right lower extremity, rest on the MRC motor scale was 5/5. Reflexes were 2/4, all cranial nerves were intact and marked loss of vibration was present up to the ankle. To gauge the recovery, repeat MRI scan was done and was consistent with improvement with no abnormal enhancement and improvement of prior seen abnormal hyperintensities on repeat MRI Cervical spine (Fig. 2). Further studies like motor and sensory evoked potentials were not done since the motor and sensory recovery was evident in outpatient examinations.

Discussion

Transverse myelitis has been attributed to infectious, parainfectious, systemic autoimmune diseases, paraneoplastic, and ischemic diseases. Acute infectious transverse myelitis is usually caused by herpes simplex virus type 2, varicella-zoster virus (VZV), Epstein-Barr virus (EBV) or cytomegalovirus (CMV), flaviviruses and enteroviruses [27–31].

As the various infections mentioned above can trigger an immune response in our body, similarly, administration of vaccine can also induce the same response. When our immune system cannot distinguish between foreign antigens and host antigens, then it triggers autoimmunity which leads

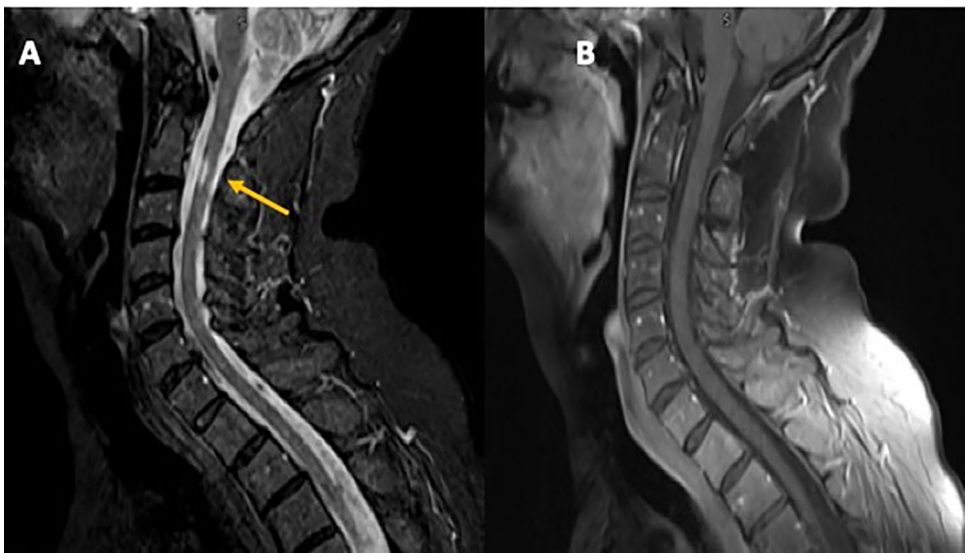

Fig. 2 Repeat MRI of the cervical was performed on 2 months follow-up visit, which showed complete interval resolution of previously identified abnormal enhancement (**b**) with residual focal hyperintensity at C2 (yellow arrow) (**a**) in the cervical spine as shown in Fig. 2

to the destruction of host cells. It is most commonly associated with environmental factors such as infectious antigens. Therefore, vaccine such as live attenuated or recombinant, can also induce autoimmunity leading to transverse myelitis [32, 33]. The following mechanisms induce autoimmunity in a person:

- The most common mechanism is molecular mimicry between infectious antigens and self-antigens [34].
- The acceleration of an ongoing autoimmune process by local activation of antigen-presenting cells and over processing of antigens induced by foreign antigens [35].
- Polyclonal activation of B lymphocytes or bystander activation which enhances cytokine production and further induce the expansion of autoreactive T-cells [36, 37].

Acute transverse myelitis basically presents with a varied signs and symptoms of sensory, motor and autonomic dysfunction. Pathological changes in the spinal cord tract are seen on spinal imaging, as a result of focal inflammation. As this disorder can lead to debilitating effects and permanent disability, it is imperative to recognize it early and distinguish it from other neurological entities. The diagnosis of transverse myelitis involves characteristic clinical presentation of bilateral signs and symptoms with a clearly defined sensory level, in addition to evidence on neuroimaging, CSF and serologic studies [38, 39]. The inclusion criteria of transverse myelitis include the non-specific hyperintense lesion of the spinal cord and isolated grey matter involvement which makes the differential of demyelinating diseases less likely as MS affects short segments usually and concerns white matter [40, 41].

Our case was diagnosed with transverse myelitis and fulfill the diagnostic criteria based on Transverse Myelitis Consortium Working Group [38]. Due to the absence of multiple sclerosis-like lesion in brain and oligoclonal bands in CSF along with extensive spinal cord lesion, the diagnosis of multiple sclerosis was unlikely. The imaging studies were also negative for acute disseminated encephalomyelitis and vascular lesions. Even though LETM is correlated with neuromyelitis optica, due to the absence of optic neuritis and neuromyelitis optica-IgG antibodies in serum, the diagnostic criteria are not met. Infectious cause is also ruled out due to negative serology tests along with negative CSF bacterial, viral and fungal culture results. Laboratory evidences of vasculitis and connective tissue disease were also absent. As most of the possible causes were eliminated, the above-mentioned featured were attributed to post vaccination TM following SARS-CoV-2 vaccination.

The case shows close temporal association to COVID-19 vaccination with symptoms presenting and worsening within a week of first dose of Moderna Vaccine. The patient did not show any signs of COVID-19 infection before this presentation, neither were COVID-19 antibodies detected in the serum. The acute attack of transverse myelitis appeared within a week of COVID-19 vaccination, and deterioration occurred on the 12th day. This is consistent with previously reported post covid vaccine-related TM [42, 43]. National board in UK has received reports like 22 cases of myelitis following the Pfizer-BioNtech Vaccine and 72 cases after AstraZeneca [3–5]. Whereas the VAERS CDC database reported so far total of 9 cases of transverse myelitis [1]. The marked deterioration and recovery may be cause by the immune dysregulation triggered by the vaccination. Immune dysregulation may have triggered acute transverse myelitis which may be secondary to vaccination. Neurological manifestations of both the PNS and CNS like GBS, ADEM, and ATM have been reported as vaccine induce immune-mediated events.

In our brief literature review, we reviewed cases of post-vaccination cases of transverse myelitis (Refer to Table 1). Among the 20 cases reviewed, 19 met diagnostic criteria for acute transverse myelitis according to Transverse Myelitis Consortium Working Group [38] except a case of post hepatis B vaccine myelitis reported by Trevisani F et.al [13]. The most common reported vaccine-related myelitis was due to influenza vaccine (H1N1) (7 out of 20 cases) [19–25] followed by myelitis due to hepatitis B vaccine (3 of the 20 cases) [12–14]. Other causes of vaccine-related transverse myelitis included COVID-19 (SARS-CoV-2) vaccine [42], Japanese B encephalitis [11], Measles, Mumps and Rubella (MMR), inactivated Rabies vaccine [18], Diphtheria, tetanus and acellular pertussis (DTaP) vaccine [7], typhoid Vi capsular polysaccharide vaccine [17], oral Polio vaccine (OPV) [10], Yellow fever [15, 16].

The predominant patient population affected were males (13 M, 7 F) with an average age of 45.3 years old with age range 7 months to 70 years. Common clinical presentations included paresthesia and sensory deficits of the lower limbs, urinary retention, paraplegia and hyperactive reflexes. MRI of this patient population revealed non-enhancing longitudinal hyperintensities and extending from the cervical spine to the thoracic spine [19–24] rest had short segment intramedullary spinal cord lesion, case by Joyce K et.al and Trevisani had normal MRI imaging [8, 13]. Predominant cerebral spinal fluid (CSF) analyses revealed normal white blood cells (WBC) and relatively normal glucose and elevated protein levels. Oligoclonal bands, NMO and MOG were either absent or not reported. Patients improved with IVMP and/or PLEX therapy. All of the 20 confirmed cases showed at least partial symptomatic improvement. Four cases had only partial improvement, while 16 had near complete resolution of symptoms. Based on the literature, IVMP ± IVIG may improve the clinical course in post-vaccination acute transverse myelitis (Refer Table 1).

Table 1 Review of published cases of post-vaccination transverse myelitis

Author/country	Age/gender	Type of vaccine	Time duration from vaccination to symptom onset	Clinical presentation	Lab work, CSF, serological and immunologic markers	MRI findings	Managements	Outcomes	Based on *proposed diagnostic criteria of acute transverse myelitis fulfill or not full diagnostic criteria
Akkad W et. al/ USA	27/F	Nasal novel influenza (H1N1) vaccine	< 1 week	Back pain and lower extremity weakness. Paresthesia of legs, urinary retention and inability to stand	CSF: WBC- 517 / mm^3, Protein- 223 mg/dl, Glucose- 41 mg/dl No oligoclonal bands, NMO NA, MOG NA	MRI spine- intramedullary hyperintensity extending from the cervical medullary junction throughout the length of the thoracic cord, no enhancement MRI brain—normal	IVMP, PLEX	Improved	Fulfilled
Bakshi R. et. al./ USA	36/ F	Influenza (H1N1) vaccine	4 weeks	Leg weakness and numbness below chest with associated urinary retention	CSF: WBC- 84, Protein – 96 mg/dl, Glucose- normal Elevated myelin basic protein. NMO NA, MOG NA	MRI cervical and thoracic spine- diffuse hyperintensity from C1-C3 to the visualized upper thoracic levels along with with no enhancement MRI brain – normal	IVMP	Improved	Fulfilled
Pagenkopf C. et. al. /Germany	45/M	COVID-19 (SARS-CoV-2) vaccine	> 1 week	Chills, headache, thoracic back pain and generalized weakness. Acute flaccid tetra paresis	CSF: WBC- 481/ mm^3 Protein- 140 mg/dl Glucose- 43 mg/dl No oligoclonal bands NMO NA, MOG NA	MRI spine- T2 hyperintense signal of the spinal cord from C3 to T2 without gadolinium enhancement MRI Brain- normal	IVMP	Improved	Fulfilled

Table 1 (continued)

Author/country	Age/gender	Type of vaccine	Time duration from vaccination to symptom onset	Clinical presentation	Lab work, CSF, serological and immunologic markers	MRI findings	Managements	Outcomes	Based on *proposed diagnostic criteria of acute transverse myelitis fulfill or not full diagnostic criteria
Matsui M. et. al. (Japan)	4/F	Japanese B encephalitis (JBE) vaccine	2 weeks	Pain in knees and lumbar spine. Lower limb weakness, progressive flaccid paraplegia and areflexia	CSF: WBC- 950/mm3Protein- 62 mg/dl, Glucose- 45 mg/dl No oligoclonal band. NMO NA, MOG NA	MRI spine high signal intensity on T2-weighted imaging between T6-T7 and L2 MRI brain- normal	IVIG IVMP	Partially improved	Fulfilled
Joyce K et. al. (UK)	20/M	MMR vaccine	2 weeks	Urinary retention and ascending paresthesia. Flaccid paraplegia	CSF: WBC- 370/mm3 Protein- 180 mg/dl, Glucose- 54 mg/dl NMO NA, MOG NA	MRI brain and spinal cord- normal	IV steroid	Partially Improved	Fulfilled
Fonseca L. et. al. (Brazil)	3/M	Hepatitis B vaccination (HBV)	< 1 week	Urinary retention and lower limb weakness	CSF: WBC- 2/mm^3, Protein- 25 mg/dl, Glucose- 82 mg/dl NMO NA, MOG NA	MRI spine hyperintense signal from C4 to T3	IVMP IVIG	Improved	Fulfilled
Trevisani F. et. al. (Italy)	11/F	Hepatitis B vaccine (HBV)	3 weeks	Back pain, leg weakness and urinary retention. Flaccid paraplegia	CSF: WBC- NA Protein- increased Glucose- NA NMO NA, MOG NA	MRI brain and spinal cord- normal	NA	Improved	Not Fulfilled
Song H. et. al. (South Korea)	31/M	Hepatitis B vaccine (HBV)	2 weeks	Paresthesia in upper and lower extremities	CSF: within normal limits, absent oligoclonal bands and myelin basic protein. NA NMO NA, MOG NA	MRI cervicothoracic spine- T2 high signal at C4 to C5 cord level with isolated enhancement in posterior column between C4 and C5 cords Brain MRI- normal	IVMP	Improved	Fulfilled

Table 1 (continued)

Author/country	Age/gender	Type of vaccine	Time duration from vaccination to symptom onset	Clinical presentation	Lab work, CSF, serological and immunologic markers	MRI findings	Managements	Outcomes	Based on *proposed diagnostic criteria of acute transverse myelitis fulfill or not full diagnostic criteria
Larner A et. al. (UK)	42/M	Nasal novel influenza (H1N1) vaccine	> 1 week	Difficulty walking and right-sided weakness	CSF: Normal limit, no oligoclonal bands NA NMO NA, MOG NA	MRI spine showed hyperintensity of the cervical portion of the spinal cord with hazy ill- defined enhancement of the upper cervical cord following gadolinium	IVMP	Improved	Fulfilled
Bir L et. al. (Turkey)	25/M	Inactivated Rabies Vaccine (Rabipur)	8 weeks	Back pain with lower limb weakness and urinary/bowel retention	CSF: WBC- 110/mm3, Protein- 114 mg/dl, Glucose- 70 mg/dl. No oligoclonal bands NA NMO NA, MOG NA	MRI spine- hyperintense lesion and expansion at the level of conus medullaris MRI brain – normal	IVMP Azathioprine	Improved	Fulfilled
Nakamura N. et. al. (Japan)	70/M	Influenza Vaccination (HA type, 22–7-B)	< 1 week	Upper limb paraplegia, paresis and hyperactive patellar reflexes. Absent sensation below T5. Back ache and dysuria	CSF- within normal limit NMO NA, MOG NA	MRI spine – High T2 signal intensity in C6-T3 vertebral level MRI brain – lacunar infarction	IVMP PLEX IVIG	Improved	Fulfilled
Riel-Romero R et. al. (USA)	7 Month/M	Diphtheria, tetanus, acellular pertussis (DTaP)	> 2 weeks	Urinary dribbling and priapism. Lower extremity weakness and flaccid paraplegia	CSF: WBC- 7 l/mm3, Protein- 30 mg/dl, Glucose- 63 mg/dl, no oligoclonal bands NMO NA, MOG NA	MRI of the spinal cord showed diffuse T2 signal within the spinal cord from the level of C3–T6 with a faint and patchy enhancement MRI brain- normal	IVMP	Partially improved	Fulfilled

Table 1 (continued)

Author/country	Age/gender	Type of vaccine	Time duration from vaccination to symptom onset	Clinical presentation	Lab work, CSF, serological and immunologic markers	MRI findings	Managements	Outcomes	Based on *proposed diagnostic criteria of acute transverse myelitis fulfill or not full diagnostic criteria
Das R et. al. (Nepal)	19/M	Typhoid Vi capsular polysaccharide vaccine (ViCPS)	< 1 week	Complete sensory loss from lower abdomen to both legs. Symmetrical weakness of both legs and spastic paraplegia, urine overflow and dribbling	CSF: WBC- 5 / mm3, Protein- 80 mg/ dl, Glucose- 44 mg/dl No oligoclonal bands. NA NMO NA, MOG NA	MRI spine—high intensity signal in the T2 weighted signal extending over several spinal segments at T12-L4 level	IVMP	Improved	Fulfilled
Lim S et. al. (South Korea)	9/F	Measles, Mumps and Rubella vaccine (MMR)	> 2 weeks	Urinary retention, low back pain and lower limb weakness	CSF: WBC- 0/ mm3, Protein- 48 mg/dl, Glucose- 96 mg/ dl. Increased myelin basic protein. NA NMO NA, MOG NA	MRI cervical and thoracic spine- extensive intramedullary high signal intensities in the entire cervical and thoracic spinal cords (C-2 to T-10) without gadolinium enhancement	IVMP	Improved	Fulfilled
Vieira M. et. al. (Brazil)	52/F	Trivalent Influenza (H1N1) vaccine	1 week	Acute urinary hesitancy and constipation. spastic asymmetric paraparesis	CSF: within normal limit. NA NMO NA, MOG NA	MRI spine- T2 hyperintense lesion the spinal cord at T4	NA	NA	Fulfilled
Kozic D. et. al. (Serbia)	7/M	Oral polio vaccine (OPV)	> 2 weeks	Fever and associated ataxia. Progressive muscle pain and weakness	CSF: WBC- 30 / mm3, Protein- normal, Glucose- normal NA NMO NA, MOG NA	MRI Cervical spine—diffusely increased T2W signal from C2-C6 without enhancement. MRI brain- normal	IVIG, Steroid	Improved	Fulfilled

Table 1 (continued)

Author/country	Age/gender	Type of vaccine	Time duration from vaccination to symptom onset	Clinical presentation	Lab work, CSF, serological and immunologic markers	MRI findings	Managements	Outcomes	Based on *proposed diagnostic criteria of acute transverse myelitis fulfill or not full diagnostic criteria
Bartol K. et. al. (USA)	35/M	Yellow Fever vaccine	1 week	Urinary retention and associated sensory disturbances and weakness in extremities. Decreased strength in lower extremities. Ascending paresthesia to elbows and knees	CSF: WBC- 300 / mm3, Protein- 147 mg/dl, IgM antibody positive for Yellow Fever.NA NMO NA, MOG NA	MRI spine- longitudinally extensive signal abnormality in the spinal cord extending from the cervical-medullary junction into the thoracic spinal cord MRI brain- unremarkable	IV Steroids, PLEX	Improved	Fulfilled
Gui L et. al. (China)	13/M	Influenza (H1N1) vaccine	< 1 week	Bilateral motor and sensory impairment in lower extremities. Flaccid paraplegia with retention of urine and feces	CSF: WBC- 10 / mm3, Protein- 28 mg/dl, Glucose- NA NA NMO NA, MOG NA	MRI spine- hyperintensity in the spinal cord from C4 to T6	IVMP	Improved	Fulfilled
Sato N et. al. (Japan)	77/F	Influenza (H1N1) vaccine	< 1 week	Tetraplegia and impaired sensation below spinal C5. Diminished	CSF: WBC- 2/ mm3, Protein- 36 mg/dl, Glucose- NA, IL-6 increased, no oligoclonal band NA NMO NA, MOG NA	MRI spine- longitudinally extensive intramedullary lesion from the C2 level down to the upper thoracic spine with gadolinium enhancement in the lesion at the C3-4 level	IVIG, IVMP	Partially improved	Fulfilled

Table 1 (continued)

Author/country	Age/gender	Type of vaccine	Time duration from vaccination to symptom onset	Clinical presentation	Lab work, CSF, serological and immunologic markers	MRI findings	Managements	Outcomes	Based on *proposed diagnostic criteria of acute transverse myelitis fulfill or not full diagnostic criteria
Chaves M. et. al. (Argentina)	56/M	Yellow fever vaccine (YFV)	> 6 weeks	Paraparesis, urinary retention and constipation. Bilateral symmetric weakness of lower extremities	CSF: WBC- 110 / mm3, Protein- 56 mg/dl, Glucose- normal, NMO NA, MOG NA	MRI spine- hyperintense signal (T5-T12) without gadolinium enhancement MRI brain- normal	None	Improved	Fulfilled

*Transverse myelitis consortium working group. Proposed diagnostic criteria and nosology of acute transverse myelitis. Neurology

IVMP Intravenous methylprednisone; *IVIG* Intravenous immunoglobulin; *PLEX* Plasmapheresis; *CSF* Cerebrospinal fluid; *MRI* magnetic resonance imaging

M Male, *F* Female

These reports may not be able to identify causality as no distinction can be made between infectious and other etiology. However, a higher vigilance may provide further insights of the disease, its pathophysiology and vaccination implications. This may be determined whether any association is the cause of the higher frequency of TM observed post vaccination. It may be required to undergo risk-benefit analysis to determine the continuation of vaccination. However, as of now, vaccination seem to outweigh the risks, and a full-fledged vaccination campaign should be continued.

Conclusion

As the neurologic impact of the COVID-19 pandemic keeps growing, vaccine-related disorders are coming to our notice. Certainly, diligent reporting is needed for a better judgment of the actual relevance and potential risk. We will need to perform a detailed risk-benefit analysis to determine the course of action concerning vaccines if such events increase in significance. The rarity of such an occurrence should currently not deter the use of vaccines, since global vaccination represents the most important strategy to fight this pandemic.

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Author contributions Conceptualization: SS. Drafting the manuscript: EK, AKS, MAC, RL, SS. Editing and final draft: SS.

Declarations

Conflicts of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical approval Patient consent available, IRB approval from West Virginia University protocol Id 2004958561.

Informed consent Informed consent from the patient was also obtained.

Consent for publication Available and IRB approved.

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