Vaccine: X 15 (2023) 100388

Contents lists available at ScienceDirect

Vaccine: X

journal homepage: www.elsevier.com/locate/jvacx

Short-term safety of inactivated SARS-Cov-2 vaccines in Chinese patients with central nervous system inflammatory demyelinating diseases

Daidi Zhao [a,1], Wenting Zhang [b,1], Xue Ma [a,1], Runze Zhao [c], Lingling Yao [d], Jiarui Lu [a], Xu Yan [a], Miao Bai [a], Guoxun Zhang [e,*], Hongzeng Li [a], Jun Guo [a,*,2]

[a] Department of Neurology, Tangdu Hospital, Air Force Medical University, Xi'an 710038, China
[b] Xijing Hospital of Digestive Disease, Air Force Medical University, Xi'an, China
[c] Department of Ophthalmology, Xijing Hospital, Air Force Medical University, Xi'an, China
[d] Department of Rehabilitation Medicine, The Third People's Hospital of Chengdu, Chengdu, China
[e] Department of Neurology, Yan'an University Medical College No. 3 Affiliated Hospital, Xianyang, China

ARTICLE INFO

Keywords:
Coronavirus disease 2019
Inactivated severe acute respiratory syndrome coronavirus 2 vaccines
Central nervous system inflammatory demyelinating diseases
Safety
Relapse rate

ABSTRACT

Objective: This study aims to evaluate the short-term safety of inactivated severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccines in Chinese patients with central nervous system inflammatory demyelinating diseases (CNS IDDs).

Methods: A web-based survey was conducted among patients with CNS IDDs from April 15 to 19, 2022 in China. In total, 645 patients with CNS IDDs were identified, including 425 patients with multiple sclerosis (MS), 194 with neuromyelitis optica spectrum disorder (NMOSD), and 26 with other CNS IDDs. The questionnaire consisted of demographic data, clinical records, history of SARS-CoV-2 vaccination, and vaccination-related symptoms within one month after vaccination. The demographic data, clinical information, and relapse rates between vaccinated and non-vaccinated patients were compared.

Results: Among 645 patients with CNS IDDs, 78 were vaccinated and 567 were non-vaccinated with the vaccination rate of 12.1 %. Compared to non-vaccinated group, a lower percentage of patients on DMDs therapy (41.0 % vs. 71.8 %, $P < 0.001$) and an increased proportion of patients with other vaccination in past 3 years (17.9 % vs. 4.8 %, $P < 0.001$) were observed in vaccinated group. Six patients experienced a relapse within 30 days of a vaccination. Additionally, vaccine-associated relapse rates in vaccinated patients did not significantly differ from these in non-vaccinated patients among 2020, 2021, and from January 1 to October 1, 2022.

Conclusions: No increased risk of vaccination-associated relapses among Chinese patients with CNS IDDs indicated that inactivated SARS-CoV-2 vaccines appear to be safe for this population.

1. Introduction

The on-going Coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a serious threat to public health around the world, leading to the urgent need for a vaccine to prevent and control SARS-CoV-2 infection. Several inactivated vaccines against SARS-CoV-2, including CoronaVac (Sinovac Life Sciences) and BBIBP-CorV (Sinopharm), appeared to be safe among healthy people in China [1,2]. However, in consideration of the potential risk of vaccination-associated relapses in autoimmune diseases, there is a dilemma on whether to vaccinate or not for patients with central nervous system inflammatory demyelinating diseases (CNS IDDs) and their physicians in China.

Central nervous system inflammatory demyelinating diseases (CNS IDDs) are a group of autoimmune disorders that primarily include multiple sclerosis (MS), neuromyelitis optica spectrum disorder (NMOSD), and myelin oligodendrocyte glycoprotein (MOG) antibody-associated disease (MOGAD) [3–6]. Previous study showed that there may be a risk of vaccination-associated relapses among untreated NMOSD patients [7]. Currently, the safety of vaccines against SARS-

* Corresponding authors.
E-mail addresses: guoxun.zhang@hotmail.com (G. Zhang), guojun_81@163.com (J. Guo).
[1] These authors equally contributed to this work and are regarded as co-first authors.
[2] Note: Prof. Jun Guo is lead contact.

https://doi.org/10.1016/j.jvacx.2023.100388
Received 19 May 2023; Received in revised form 20 August 2023; Accepted 18 September 2023
Available online 21 September 2023

CoV-2 in Chinese patients with CNS IDDs has not determined, though many clinicians from Iran [8], Latin American [9], Chile [10], USA [11,12], Italy [13], and Israel [14], recommend vaccines against SARS-CoV-2 for their patients for the benefits outweighed the risks of triggering a relapse. To date, limited study especially focused on the safety of inactivated vaccines among patients with CNS IDDs in China. We evaluated the association of a relapse occurring within 30 days of inactivated COVID-19 vaccines in CNS IDDs. The aim of this study was to determine if vaccines may increase the risk of relapses among Chinese patients with CNS IDDs.

2. Methods and materials

2.1. Study design and participants

A survey using self-administrated and online questionnaire was performed among patients with CNS IDDs in China, from April 15 to 19, 2022 and from October 1 to 5, 2022. Diagnostic criteria for MS, NMOSD, MOGAD, and other CNS IDDs were respectively according to the criteria specified by 2017 McDonald criteria [25], 2015 International consensus diagnostic criteria for NMOSD [3], and diagnostic criteria for MOGAD and CNS IDDs [5,26]. Sixty-seven patients were excluded for having incomplete medical data. Information from 645 cases could be used for analysis, including 425 with MS, 194 with NMOSD and 26 with other IDDs. The study flow diagram is displayed in Fig. 1. The relapse rates of non-vaccinated CNS IDDs patients in 2020, 2021, and from January 1 to October 1, 2022 were investigated by the online survey. Relapses were defined as episodes of transient exacerbations of neurological disability that lasting for $\geq$24 h, and new or enhancing lesions were detected by enhanced magnetic resonance imaging or identified by visual evoked potentials [13,27]. This study was approved by the Ethics Committee of Tangdu Hospital, Air Force Medical University (number: K202204-19), and all methods were implemented in accordance with the relevant guidelines and regulations. All enrolled patients agreed with the participation in the project and the usage of anonymized data.

2.2. Questionnaire

Demographics, clinical information, and data related to SARS-CoV-2 vaccination were collected by an anonymous questionnaire using a "Questionnaire Star" software (https://www.wjx.cn/) (Supplementary material 1). This questionnaire was composed of three parts. (1) Basic information: demographic characteristics, including gender, age, height, weight, residence, educational levels, occupation, and marital status; clinical data, including the diagnosis type of CNS IDDs, disease duration, duration of drug use, DMDs use, history of other diseases, and history of allergy. (2) Whether they received vaccination or not: COVID-19 infection/vaccination; other vaccination history in past 3 years, including hepatitis B vaccine, herpes zoster vaccine and influenza vaccine. (3) COVID-19 vaccination-related factors: the vaccination type, vaccination date, the disease condition before and after COVID-19 vaccination, and adverse symptoms following COVID-19 vaccination.

2.3. Statistical analysis

Continuous and categorical variables were respectively displayed as median (interquartile range) and frequencies (percentages). In non-vaccinated group, the relapse rate was calculated as the number of relapses divided by the number of non-vaccinated patients. In vaccinated group, the relapse rate was calculated as the number of relapses divided by vaccinated patients. Mann–Whitney *U* test was used for continuous variables. Fisher's exact test or Chi-square test was applied for categorical variables. Statistical analysis was conducted using IBM SPSS software. *P* values < 0.05 were considered to be statistically significant.

3. Results

3.1. Subject population

Demographic and basic information of the enrolled patients were presented in Table 1. The median age at onset was 34.9 (28.7–44.8) years, and female was predominant (sex ratio: 3.2:1). The median time of disease duration was 4.1 (2.0–8.9) years. The distribution map of included 645 patients across China was displayed in Fig. 2. Twenty-nine percent of these patients were from Shaanxi Province. Among 645 cases, 41 had other vaccination histories in past 3 years (6.4 %), including hepatitis B vaccine (4.7 %), influenza vaccine (3.9 %), and herpes zoster vaccine (0.8 %). Seventy-one percent of our sample lived in urban areas. Patients with a college degree or a higher educational level occupied 62.3 % of the total.

Among included patients, 439 patients were on disease-modifying drugs (DMDs) therapy (68.1 %), including rituximab (RTX) (23.3 %), siponimod (16.1 %), teriflunomide (15.2 %), mycophenolate mofetil (6.5 %), and fingolimod (4.2 %). Twenty-five percent of MS patients were taking siponimod. The majority of NMOSD patients were using RTX (63.9 %). Consistently, among the 78 vaccinated patients, 7 MS patients were taking siponimod and 13 NMOSD patients receiving RTX accounted for the highest proportion of vaccinated NMOSD patients (76.5 %) (Fig. 3).

3.2. Comparison of demographic and basic data between vaccinated and non-vaccinated patients

The comparison between vaccinated and non-vaccinated patients was summarized in Table 2. There were more patients on DMDs treatment in non-vaccinated group than that in vaccinated group (71.8 % vs.

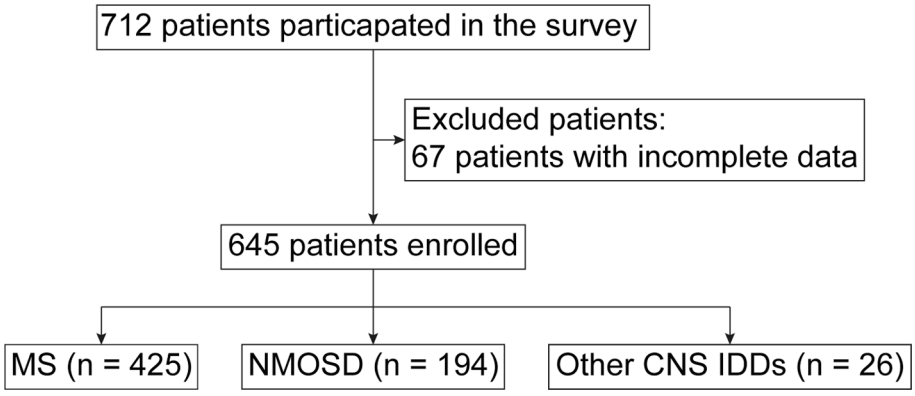

Fig. 1. Study flow diagram. MS, multiple sclerosis; NMOSD, Neuromyelitis Optica Spectrum Disorders; CNS IDDs, central nervous system inflammatory demyelinating diseases.

Table 1
Demographic and clinical data of patients surveyed for this study.

Characteristics	Total (n = 645)
Sex ratio (F:M)	491:154 (3.2:1)
Age, year, median (IQR)	34.9 (28.7–44.8)
Disease duration, year, median (IQR)	4.1 (2.0–8.9)
Disease type, *n* (%)	
MS	425 (65.9)
NMOSD	194 (30.1)
Other IDDs	26 (4.0)
DMDs use, *n* (%)	439 (68.1)
Siponimod	104 (16.1)
Teriflunomide	98 (15.2)
Fingolimod	27 (4.2)
Dimethyl fumarate	9 (1.4)
Rituximab	150 (23.3)
Mycophenolate mofetil	42 (6.5)
Azathioprine	5 (0.8)
Cyclophosphamide	2 (0.3)
Tacrolimus	1 (0.2)
Methotrexate	1 (0.2)
Other vaccination history in past 3 years, *n* (%)	41 (6.4)
Hepatitis B vaccine	30 (4.7)
Influenza vaccine	25 (3.9)
Herpes zoster vaccine	5 (0.8)
Residence, *n* (%)	
Rural	189 (29.3)
Urban	456 (70.7)
Educational level	
Senior high school or lower	243 (37.7)
College degree or higher	402 (62.3)

Abbreviations: MS, multiple sclerosis; NMOSD, neuromyelitis optica spectrum disorder; IDDs, inflammatory demyelinating diseases; DMDs, disease modifying drugs; F, female; M, male; IQR, interquantile range.

41.0 %, $P < 0.001$). A significantly increased proportion of patients receiving other vaccination in past 3 years was noted in vaccinated group (17.9 % vs. 4.8 %, $P < 0.001$). Overall, there were a few differences between demographic features and clinical information of vaccinated and non-vaccinated patients.

3.3. Vaccine-related adverse events and acute relapses

Reported vaccination-related adverse events were shown in Table 3. Among 78 vaccinated patients, the most common vaccine-associated general symptom is fatigue, which is reported by 12 (15.4 %) participants. Neurological symptoms occasionally occurred in these vaccinated participants, including sensory disturbance (n = 8, 10.3 %), motor disorder (n = 8, 10.3 %), vision impairment/diplopia (n = 4, 5.1 %), imbalance (n = 3, 3.8 %), and urinary incontinence (n = 1, 1.3 %).

3.4. Comparison of relapse rates between vaccinated and non-vaccinated patients

In total, 6 patients reported an acute relapse within 30 days of a vaccination. Following the first vaccination dose, an acute relapse was reported by 1 patient (1.3 % of the 78 patients). After the second dose, 3 experienced an acute attack with a relapse rate of 4.1 % five patients (4.1 % of the 74 patients). Following the third dose, disease relapses were observed in 2 subjects (5.7 % of the 35 patients). Four MS patients developed an acute attack within one month among the vaccinated MS group (7.8 % of 51 patients), and an acute relapse occurred in 2 NMOSD patients (8.7 % of 23 patients).

The relapse rate respectively was 3.6 %, 3.1 %, and 3.0 % in non-vaccinated CNS IDDs patients among 2020, 2021, and from January 1 to October 1, 2022. There was no statistical difference between relapse

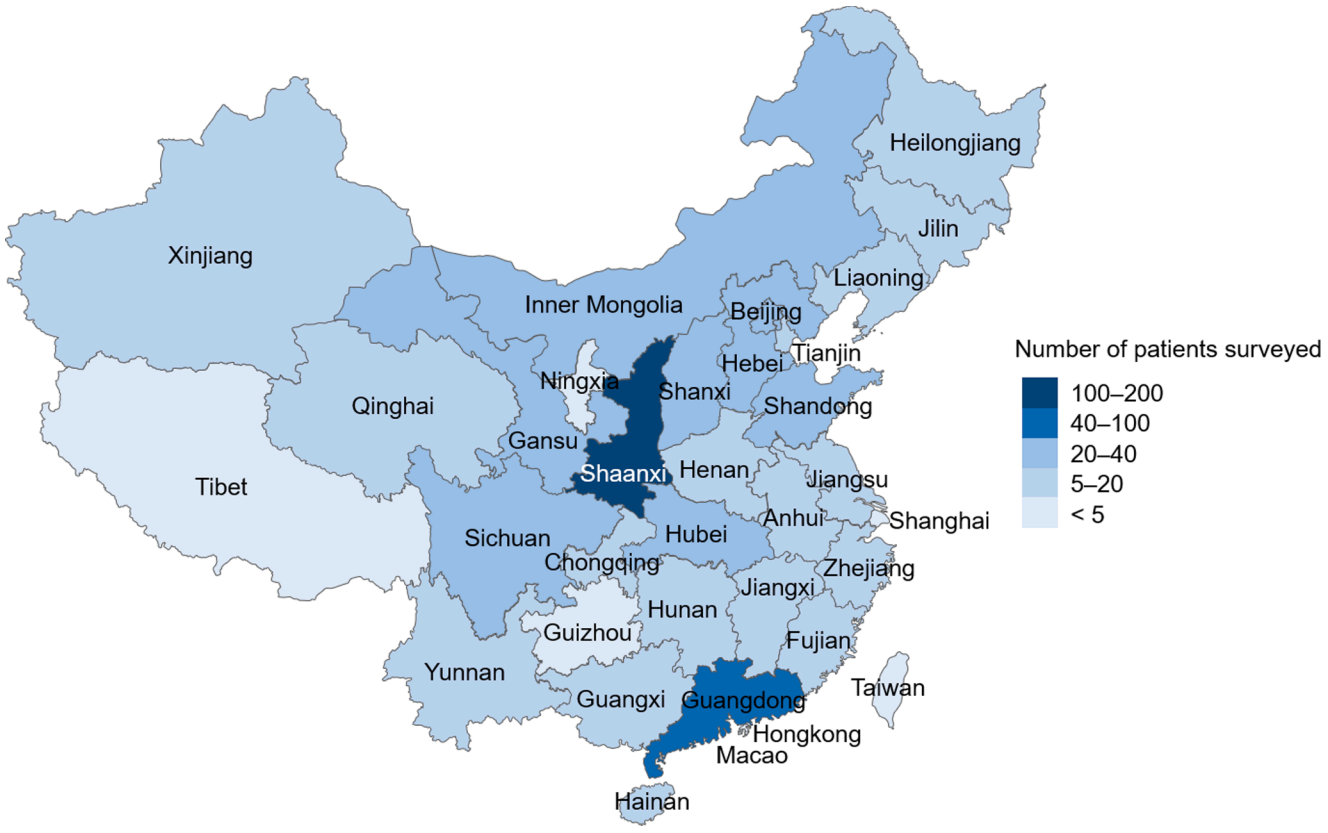

Fig. 2. Distribution map of patients completing this online survey across China, The geographic regions showed that patients from Shaanxi Province constituted the majority of the subjects with 29.1 % (n = 188). Guangzhou Province came in second with 6.4 % (n = 41). The intensity of color reflected the different number of participants from each province.

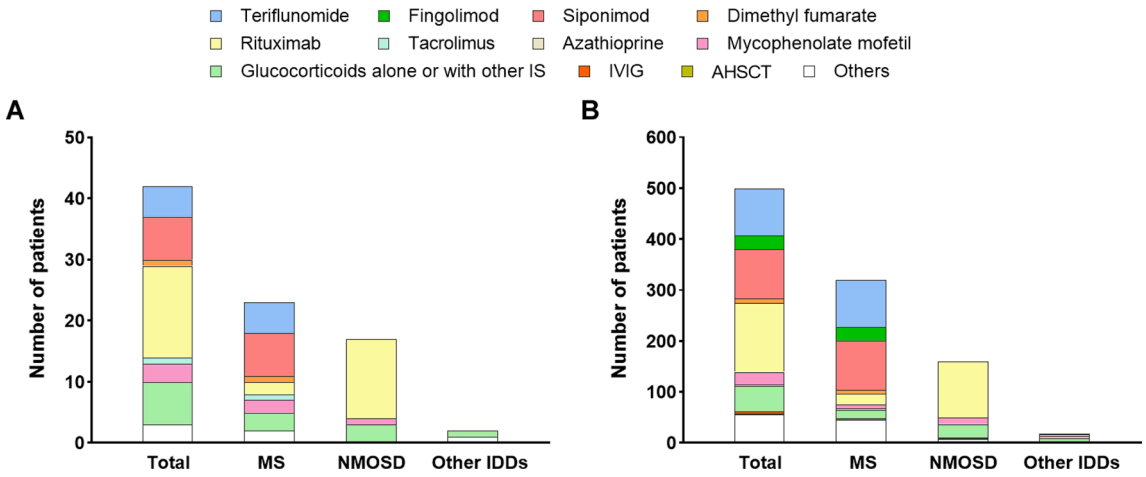

Fig. 3. Detailed treatment of patients with each disease type, these bar graphs exhibited the therapy of vaccinated and unvaccinated participants. (A) Out of 78 vaccinated patients, 42 patients used DMDs, glucocorticoid or other therapies, including rituximab (RTX; n = 15), glucocorticoid (n = 8), siponimod (n = 7), teriflunomide (n = 5), mycophenolate mofetil (n = 3), tacrolimus (n = 1), dimethyl fumarate (n = 1), and other treatments (n = 2), such as traditional Chinese medications. MS patients who were treated with siponimod accounted for 30.4 % of the vaccinated subjects. Among 17 vaccinated NMOSD patients, 13 subjects receiving RTX had a largest proportion of these patients (76.5 %). (B) There are 567 non-vaccinated patients, including 135 patients with RTX, 97 with siponimod, 93 with teriflunomide, and 50 with glucocorticoids alone or with other immunosuppressants (IS), such as tacrolimus, mycophenolate mofetil, and azathioprine. Abbreviations: IVIG, intravenous immunoglobulin; AHSCT, autologous haematopoietic stem cell transplantation.

Table 2
Comparisons of options for COVID-19 vaccination in patients with CNS IDDs.

Characteristics	Vaccinated (*n* = 78)	Non-vaccinated (*n* = 567)	*p* value
Sex, *n* (%)			
Female	57 (73.1)	434 (76.5)	0.501
Male	21 (26.9)	133 (23.5)	
Age, year, *n* (%)			
18–55	70 (89.7)	515 (90.8)	0.757
>55	8 (10.3)	52 (9.2)	
Disease duration, year, median (IQR)	5.0 (2.6–9.4)	4.0 (2.0–8.7)	0.554U
Disease type, *n* (%)			
MS	51 (65.4)	374 (66.0)	0.920
NMOSD	23 (29.5)	171 (30.2)	0.903
Other IDDs	4 (5.1)	22 (3.9)	0.542f
DMDs use, *n* (%)			
Yes	32 (41.0)	407 (71.8)	<0.001
No	46 (59.0)	160 (28.2)	
Other vaccination history in past 3 years, *n* (%)			
Yes	14 (17.9)	27 (4.8)	<0.001f
No	64 (82.1)	540 (95.2)	
Residence, *n* (%)			
Rural	29 (37.2)	160 (28.2)	0.103
Urban	49 (62.8)	407 (71.8)	
Educational level, *n* (%)			
Senior high school or lower	27 (34.6)	216 (38.1)	0.552
College degree or higher	51 (65.4)	351 (61.9)	

Abbreviations: MS, multiple sclerosis; NMOSD, neuromyelitis optica spectrum disorder; CNS, central nervous system; IDDs, inflammatory demyelinating diseases; DMDs, disease modifying drugs; IQR, interquantile range; U, Mann-Whitney U test; f, Fisher exact test.

Table 3
Reported adverse events associated with COVID-19 vaccination.

Participants with adverse events, *n* (%)	Total (*n* = 78)
No symptoms	65 (83.3)
General symptoms	
Fatigue	12 (15.4)
Myalgia	6 (7.7)
Pain at the injection site	5 (6.4)
Fever/chills, flu-like symptoms	3 (3.8)
Headache	3 (3.8)
Swelling at the injection site	2 (2.6)
Joint pain	2 (2.6)
Nausea and vomiting	2 (2.6)
Neurological symptoms	
Sensory	8 (10.3)
Motor	8 (10.3)
Vision impairment/diplopia	4 (5.1)
Imbalance	3 (3.8)
Urinary incontinence	1 (1.3)

Numbers in parentheses represent the percentage of participants who reported at least one episode of the specified adverse event.

rates of the vaccinated and non-vaccinated patients.

4. Discussion

We performed a cross-sectional study to investigate the safety of inactivated SARS-CoV-2 vaccination in CNS IDDs within 30 days after vaccination in China. Neither obvious side effects nor increased relapse rates were observed in vaccinated patients, indicating the safety of inactivated COVID-19 vaccinations for this population.

The inactivated SARS-CoV-2 vaccines, BBIBP-CorV and CoronaVac, were proved to protect against COVID-19 infection, and even reduce the hospitalization rate and risk of death following COVID-19 infection among healthy population [1,2]. Yet in the meantime, vaccines may cause a vaccination-related attack by triggering a rogue autoimmune response. Clinical onset of CNS IDDs after COVID-19 vaccination were reported, such as MS [15,16], NMOSD, MOGAD [17], and other CNS IDDs [18–20]. Thus, it is necessary to assess the relapse rate subsequent to COVID-19 vaccinations administration in these relapsing autoimmune CNS demyelinating syndromes. Consistent with studies from other countries on CNS IDDs [8–14], there is no increased risk of disease relapses among Chinese patients with CNS IDDs following inactivated vaccines in our study. No increased relapse rate was noted in vaccinated MS patients from Iran [8], Israel [14], Chile [10], Latin American [9], and USA [11]. In addition, the safety of the mRNA vaccines against SARS-CoV-2 in NMOSD and MOGAD patients from Italy and USA seemed to be confirmed [11–13], which were in accordance with our data. Our findings had a significant implication that inactivated vaccines against SARS-CoV-2 were recommended for CNS IDDs to protect them from COVID-19 infection.

Our results demonstrated that CNS IDDs patients on DMDs treatment

were more reluctant to be vaccinated than these without DMDs. Indeed, previous study suggested that DMDs, especially cell-depleting agents, such as RTX and ofatumumab, and sphingosine-1-phosphate modulators, may attenuate immunogenicity of vaccines in protecting against COVID-19 infection, and even increased the risk of hospitalization for COVID-19 in CNS IDDs [21–23], despite serum SARS-CoV-2 IgG levels were elevated among MS on DMDs therapy after the third dose of vaccination [14]. On the other hand, although immunosuppressive drugs may reduce the efficacy of vaccines, another study proposed starting preventive immunotherapy for NMOSD prior to any vaccines for enhancing the safety of vaccines [7]. Further prospective and large-scale studies are necessary to delineate the infection risk and clinical severity after COVID-19 infection following vaccines against SARS-CoV-2 among patients with DMDs.

Our results indicated that an increased proportion of patients receiving vaccines against SARS-CoV-2 was noted among patients with other vaccination histories, which implied that these subjects tended to hold similar attitudes towards COVID-19 vaccination and other vaccines. A prior study demonstrated that NMOSD patients in rural areas had more COVID-19 vaccine hesitation than those in urban cities [24]. In our study, patients in urban areas were more likely to accept vaccination, whereas the difference did not reach significance.

There are several limitations in our study. Firstly, though this online survey was conducted among patients with CNS IDDs across China, it is impossible that each patient was investigated. Individuals who could not access to the mobile phone or computer were unable to complete the online questionnaire, like older adults and people of low economic status. Selection bias was inevitable. Secondly, this study is cross-sectional and observational, which was unable to confirm the causality between vaccination and post-vaccination symptoms. Thirdly, in consideration of unpredictable progress of the COVID-19 epidemic, the vaccination rate among Chinese CNS IDDs patients may change over time. Fourthly, we currently merely evaluated the short-term relapse rate among CNS IDDs participants following vaccination, so we are unable to determine the long-term safety. Finally, only Chinese patients were enrolled in our research; hence the findings could not be extrapolated to the global population.

In conclusion, the willingness of in vaccines against SARS-CoV-2 may be associated with DMDs use and a history of other vaccination. The inactivated COVID-19 vaccine seems relatively safe to administer in Chinese patients with CNS IDDs in virtue of the low risk of short-term relapses among these patients following COVID-19 vaccines. The implementation of health education on COVID-19 vaccination in patients with CNS IDDs is a necessity. Additional prospective replication with a large population and on-site clinical evaluations is warranted to further validate our findings.

CRediT authorship contribution statement

Guoxun Zhang: Conceptualization, Formal analysis, Validation. **Hongzeng Li:** Conceptualization, Validation, Writing – review & editing. **Jun Guo:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing.

Funding

This work was supported by the National Natural Science Foundation of China (grant number 82171339), Key Research and Development Project of Shaanxi Province (grant number 2022ZDLSF02-04), and Excellent Personnel Foundation of Tangdu Hospital (to Jun Guo).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jvacx.2023.100388.

References

[1] Xia S, et al. Safety and immunogenicity of an inactivated SARS-CoV-2 vaccine, BBIBP-CorV: a randomised, double-blind, placebo-controlled, phase 1/2 trial. Lancet Infect Dis 2021;21(1):39–51.
[2] Zhang Y, et al. Safety, tolerability, and immunogenicity of an inactivated SARS-CoV-2 vaccine in healthy adults aged 18–59 years: a randomised, double-blind, placebo-controlled, phase 1/2 clinical trial. Lancet Infect Dis 2021;21(2):181–92.
[3] Wingerchuk DM, et al. International consensus diagnostic criteria for neuromyelitis optica spectrum disorders. Neurology 2015;85(2):177–89.
[4] Sechi E, et al. Myelin oligodendrocyte glycoprotein antibody-associated disease (MOGAD): a review of clinical and MRI features, diagnosis, and management. Front Neurol 2022;13:885218.
[5] Banwell B, et al. Diagnosis of myelin oligodendrocyte glycoprotein antibody-associated disease: international MOGAD Panel proposed criteria. Lancet Neurol 2023.
[6] Olek MJ. Multiple sclerosis. Ann Intern Med 2021;174(6):Itc81–96.
[7] Mealy MA, et al. Vaccines and the association with relapses in patients with neuromyelitis optica spectrum disorder. Mult Scler Relat Disord 2018;23:78–82.
[8] Etemadifar M, Abhari AP, Nouri H. Self-Reported safety of the BBIBP-CorV (Sinopharm) COVID-19 vaccine among Iranian people with multiple sclerosis. Hum Vaccin Immunother 2022;18(1):2041945.
[9] Alonso R et al. Evaluation of short-term safety of COVID-19 vaccines in patients with multiple sclerosis from Latin America. Mult Scler J Exp Transl Clin 2021;7(4):20552173211061543.
[10] Ciampi E, et al. Safety and humoral response rate of inactivated and mRNA vaccines against SARS-CoV-2 in patients with Multiple Sclerosis. Mult Scler Relat Disord 2022;59:103690.
[11] Epstein S, et al. Vaccination against SARS-CoV-2 in neuroinflammatory disease: early safety/tolerability data. Mult Scler Relat Disord 2022;57:103433.
[12] Lotan I, Romanow G, Levy M. Patient-reported safety and tolerability of the COVID-19 vaccines in persons with rare neuroimmunological diseases. Mult Scler Relat Disord 2021;55:103189.
[13] Dinoto A, et al. Risk of disease relapse following COVID-19 vaccination in patients with AQP4-IgG-positive NMOSD and MOGAD. Mult Scler Relat Disord 2022;58:103424.
[14] Dreyer-Alster S, et al. COVID-19 vaccination in patients with multiple sclerosis: safety and humoral efficacy of the third booster dose. J Neurol Sci 2022;434:120155.
[15] Kataria S, et al. Multiple sclerosis relapse following COVID-19 vaccination: a case report and literature review. Cureus 2022;14(1):e21374.
[16] Fragoso YD, et al. New relapse of multiple sclerosis and neuromyelitis optica as a potential adverse event of AstraZeneca AZD1222 vaccination for COVID-19. Mult Scler Relat Disord 2022;57:103321.
[17] Francis AG, et al. Acute inflammatory diseases of the central nervous system after SARS-CoV-2 vaccination. Neurol Neuroimmunol Neuroinflamm 2023;10(1).
[18] Vogrig A, et al. Acute disseminated encephalomyelitis after SARS-CoV-2 vaccination. Clin Neurol Neurosurg 2021;208:106839.
[19] Ahmad HR, Timmermans VM, Dakakni T. Acute disseminated encephalomyelitis after SARS-CoV-2 vaccination. Am J Case Rep 2022;23:e936574.
[20] Yazdanpanah F, et al. Acute disseminated encephalomyelitis (ADEM) after SARS-CoV-2 vaccination: a case report. Radiol Case Rep 2022;17(5):1789–93.
[21] Yeo T, et al. COVID-19 infection after two doses of SARS-CoV-2 mRNA vaccine in multiple sclerosis, AQP4-antibody NMOSD and MOGAD. Mult Scler Relat Disord 2022;65:104003.
[22] Kelly H, Sokola B, Abboud H. Safety and efficacy of COVID-19 vaccines in multiple sclerosis patients. J Neuroimmunol 2021;356:577599.
[23] Salter A, et al. Outcomes and risk factors associated with SARS-CoV-2 infection in a North American registry of patients with multiple sclerosis. JAMA Neurol 2021;78(6):699–708.
[24] Xu Y, et al. COVID-19 Vaccination attitudes with neuromyelitis optica spectrum disorders: vaccine hesitancy and coping style. Front Neurol 2021;12:717111.
[25] Thompson AJ, et al. Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria. Lancet Neurol 2018;17(2):162–73.
[26] Hoftberger R, et al. The pathology of central nervous system inflammatory demyelinating disease accompanying myelin oligodendrocyte glycoprotein autoantibody. Acta Neuropathol 2020.
[27] Kalincik T. Multiple sclerosis relapses: epidemiology, outcomes and management. A systematic review. Neuroepidemiology 2015;44(4):199–214.