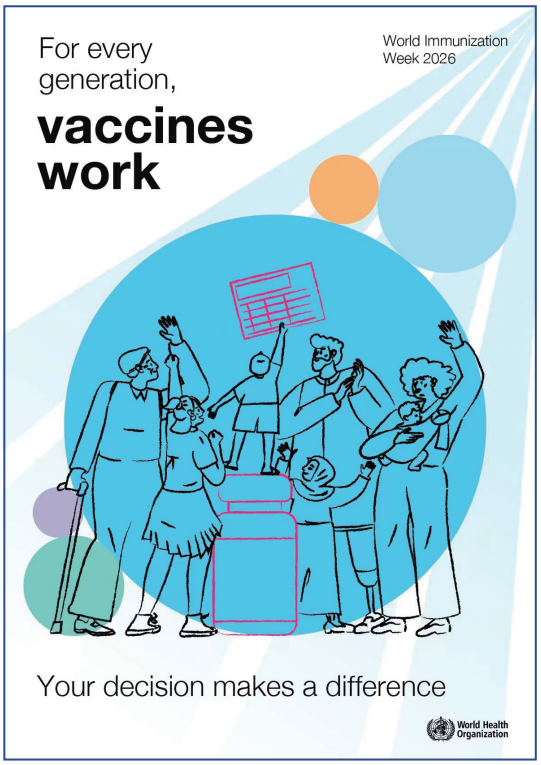
ISSN 2096-7071 (Print)
ISSN 2097-3101 (Online)
CN 10-1629/R1

CHINA CDC WEEKLY

Vol. 8 No. 17 Apr. 24, 2026

中国疾病预防控制中心周报(英文)



WORLD IMMUNIZATION WEEK ISSUE

ISSN 2096-7071

China CDC Weekly

Editorial Board

Editorial Office

Cover Image: credited from the World Health Organization, https://www.who.int/campaigns/world-immunization-week/2026.
This week's issue was organized by Guest Editor Huaqing Wang.

Vital Surveillances

Post-Marketing Surveillance Data of Adverse Events Following Immunization with Human Rabies Vaccine — China, 2021–2024

Lina Zhang[1]; Keli Li[1,#]; Yan Li[1]; Chunxiang Fan[1]; Yuan Li[1]; Minrui Ren[1]; Lei Cao[1]; Wenzhou Yu[1]; Zundong Yin[1]

Summary

What is already known about this topic?

Human rabies vaccine has been in use for many years and has played a vital role in rabies prevention and control in China.

What is added by this report?

From 2021 to 2024, the overall reported rate of adverse events following immunization (AEFI) with human rabies vaccine was 18.57 per 100,000 doses, of which 96.29% were common vaccine reactions. Rare vaccine reactions occurred at a rate of 0.49 per 100,000 doses; allergic rash was the most frequently reported rare reaction and usually was non-serious. The rate of rare and serious vaccine reactions was 0.07 per 100,000 doses.

What are the implications for public health practice?

Human rabies vaccine, one of the most commonly used non-program vaccines in China, its AEFI rate fell within an acceptable range. Continued AEFI surveillance is essential for evaluating the post-marketing immnization safety of this vaccine.

ABSTRACT

Introduction: Human rabies vaccine has been widely used as a non-program vaccine in China for many years. This study analyzed adverse events following immunization (AEFI) with human rabies vaccine from 2021 to 2024.

Methods: AEFI case reports and administered dose counts for human rabies vaccine during 2021–2024 were obtained from the Chinese National Immunization Information System of the China Information System for Disease Prevention and Control. AEFI characteristics and incidence rates were analyzed using descriptive epidemiological methods.

Results: During 2021–2024, a total of 34,684 AEFI cases were reported, yielding an overall incidence rate of 18.57 per 100,000 doses. Common vaccine reactions accounted for 96.29% of cases (17.88 per 100,000 doses), and rare vaccine reactions accounted for 2.62% (0.49 per 100,000 doses). Allergic rash was the most frequently reported rare vaccine reaction, with an incidence rate of 0.32 per 100,000 doses, followed by angioedema, Henoch-Schönlein purpura, anaphylactic shock, and febrile convulsion/convulsion, with incidence rates of 0.04, 0.02, 0.01, and 0.01 per 100,000 doses, respectively.

Conclusions: Most AEFI cases with human rabies vaccine were common vaccine reactions. Allergic reactions, particularly allergic rash, constituted the predominant rare vaccine reactions. Although several cases of anaphylactic shock were reported, the incidence was extremely low. Timely identification and immediate management of post-vaccination serious allergic reactions are important measures for ensuring the immunization safety of human rabies vaccine.

Rabies is an acute neurological infectious disease caused by lyssaviruses that is almost invariably fatal once clinical signs appear. According to the World Health Organization (WHO), rabies caused approximately 59,000 human deaths annually, which was reported in over 150 countries, and 95% of cases occurred in Asia and Africa (*1*). Human rabies vaccine has been used to prevent rabies and avert rabies-related deaths in China since the 1920s (*2*). The National Regulation for the Rabies Exposure Prophylaxis (2023 edition), issued by the National Disease Control and Prevention Administration and the National Health Commission (*3*), stipulated that a full-course rabies vaccination series should be completed on schedule. Standardized, full-course vaccination stimulates protective immunity against rabies virus. Currently, all authorized human rabies vaccines in mainland China are non-program vaccines (voluntary and self-paid). Several types are in use: hamster kidney cell rabies vaccine (HKCV), Vero cell rabies vaccine (VCV) in freeze-dried or liquid formulations, and human diploid

cell rabies vaccine (HDCV). HKCV and VCV were approved in 2005, and HDCV was approved in 2014. We analyzed adverse events following immunization (AEFI) surveillance data from 2021 to 2024 to evaluate the post-marketing immunization safety of human rabies vaccines used in China.

METHODS

Immunization Procedure

Post-exposure prophylaxis (PEP) for rabies follows either a five-dose Essen regimen, with intramuscular injections on days 0, 3, 7, 14, and 28, or a four-dose Zagreb regimen, with two doses on day 0 and single doses on days 7 and 21. If re-exposure occurs during the PEP series, remaining doses should continue to be administered on schedule. No booster dose is needed if vaccination was completed within the preceding 3 months. If re-exposure occurs more than 3 months after series completion, booster doses should be administered on days 0 and 3 relative to the re-exposure date. Pre-exposure prophylaxis (PrEP) consists of a three-dose series administered on days 0, 7, and 21 or 28. A booster dose is recommended one year after PrEP if no animal bite has occurred, followed by additional boosters every 3 to 5 years for individuals with ongoing rabies exposure risk.

Data Sources

AEFI case reports and administered dose data for all authorized human rabies vaccines during 2021–2024 were obtained from the Chinese National Immunization Information System of the China Information System for Disease Prevention and Control.

Case Classification

In accordance with applicable laws, regulations, and guidelines, AEFI cases are preliminarily classified as common vaccine reactions or undetermined classification by responsible reporters, including staff at vaccination clinics, medical institutions, and local Centers for Disease Control and Prevention (CDCs). For cases requiring causality assessment by an expert group, the responsible CDCs or medical associations organize specialists in different fields such as epidemiology and clinical medicine to conduct evaluations based on individual medical records and relevant information. By cause, cases are classified as common vaccine reactions, rare vaccine reactions (including cases not ruled out), anxiety-related events, coincidental events, suspected immunization error-related events, and vaccine quality-related events. By severity, cases are classified as serious or non-serious AEFI.

Statistical Analysis

Descriptive epidemiological methods were used to characterize reported AEFI and calculate incidence rates. Incidence rate was computed by dividing the number of reported AEFI cases by the number of administered doses and multiplying by 100,000. Analysis was performed using the Statistical Analysis System (SAS, version 9.4, SAS Institute Inc., Cary, NC, USA) and Microsoft Excel (version 2016, Microsoft Corporation, Redmond, WA, USA).

RESULTS

General Characteristics

During 2021–2024, a total of 34,684 AEFI reports were received for human rabies vaccine. Of these, 46.33% involved males and 53.67% involved females; 16.65% occurred among children younger than 3 years, 42.84% among those aged 3–17 years, 32.42% among those aged 18–59 years, and 8.09% among individuals aged 60 years or older. By region, 32.96% were from eastern China, 54.26% were from central China and 12.78% were from western China. By quarter, 17.74%, 28.59%, 29.33% and 24.34% occurred in the first through fourth quarters, respectively. By dose number, 66.34% followed the first dose, 12.68% followed the second dose, 10.51% followed the third dose and <11% followed more than three doses (Table 1).

Reporting Rate and Classification

The reported AEFI incidence rate for human rabies vaccine during 2021–2024 was 18.57 per 100,000 doses, based on over 186.78 million administered doses. Both the number of AEFI cases and incidence rates increased year by year, peaking in 2024 (Table 2).

By cause, there were 33,393 common vaccine reactions (17.88 per 100,000 doses) and 910 rare vaccine reactions (0.49 per 100,000 doses), accounting for 96.29% and 2.62% of cases, respectively. An additional 292 cases were classified as coincidental events (0.84%, 0.16 per 100,000 doses), 78 as anxiety-related events (0.22%, 0.04 per 100,000 doses), and 11 remained pending classification (0.03%, 0.01 per

TABLE 1. General Characteristics of Rabies Vaccine AEFI Reports, 2021–2024.

Characteristics	Serious		Non-serious		Total	
	N	Proportion (%)	*N*	Proportion (%)	*N*	Proportion (%)
Sex						
Male	92	43.60	15,978	46.35	16,070	46.33
Female	119	56.40	18,495	53.65	18,614	53.67
Age (years)						
<3	31	14.69	5,748	16.67	5,779	16.65
3–17	70	33.18	14,787	42.89	14,857	42.84
18–59	72	34.12	11,171	32.41	11,243	32.42
≥60	38	18.01	2,767	8.03	2,805	8.09
Region						
Eastern	78	36.97	11,357	32.95	11,435	32.96
Central	77	36.49	18,741	54.36	18,818	54.26
Western	56	26.54	4,375	12.69	4,431	12.78
Quarter of year						
1st	46	21.80	6,105	17.71	6,151	17.74
2nd	68	32.23	9,848	28.57	9,916	28.59
3rd	63	29.86	10,111	29.33	10,174	29.33
4th	34	16.11	8,409	24.39	8,443	24.34
Dose number						
1st	94	44.55	22,914	66.47	23,008	66.34
2nd	20	9.48	4,377	12.70	4,397	12.68
3rd	41	19.43	3,606	10.46	3,647	10.51
4th	36	17.06	2,401	6.96	2,437	7.03
5th	19	9.00	1,072	3.11	1,091	3.15
≥6th	1	0.48	103	0.30	104	0.29
Total	211	100.00	34,473	100.00	34,684	100.00

Abbreviation: AEFI=adverse events following immunization.

100,000 doses). No suspected immunization error-related or vaccine quality-related events were reported. By severity, 211 cases were serious (0.11 per 100,000 doses) and 34,473 were non-serious (18.46 per 100,000 doses). Among these, 131 were classified as rare and serious vaccine reactions (0.07 per 100,000 doses).

Vaccine Reaction Diagnoses

During the study period, among common vaccine reactions, 12,034 cases involved fever (axillary temperature ≥38.6 ℃), 5,505 involved injection site redness and swelling (diameter >2.5 cm) and 2,791 involved injection site induration (diameter >2.5 cm), representing 36.04%, 16.49%, and 8.36% of common reactions, with incidence rates of 6.44, 2.95 and 1.49 per 100,000 doses, respectively.

The most frequently diagnosed rare vaccine reaction was allergic rash, with 597 cases and an incidence rate of 0.32 per 100,000 doses. Angioedema, Henoch-Schönlein purpura (HSP), anaphylactic shock, and febrile convulsion/convulsion followed, with 75, 34, 24 and 16 cases and incidence rates of 0.04, 0.02, 0.01 and 0.01 per 100,000 doses, respectively. No vaccine lots were clustered associated with anaphylactic shock or laryngeal edema. The rates of thrombocytopenic purpura (TP) and other neurological diseases were no more than 0.01 per 100,000 doses (Table 3).

DISCUSSION

Advances in production technology — including strain selection, cell substrate development, and improved concentration and purification processes —

TABLE 2. Number of AEFI cases and incidence per 100,000 doses of human rabies vaccine by cause, severity, and year, 2021–2024.

Variables	*N*	Proportion (%)	Incidence
Cause			
Common vaccine reactions	33,393	96.29	17.88
Rare vaccine reactions	910	2.62	0.49
Coincidental events	292	0.84	0.16
Anxiety-related events	78	0.22	0.04
Pending determination	11	0.03	0.01
Severity			
Serious	211	0.61	0.11
Non-serious	34,473	99.39	18.46
Year			
2021	3,871	11.16	11.12
2022	6,256	18.04	14.28
2023	10,541	30.39	20.30
2024	14,016	40.41	24.93
Total	34,684	100.00	18.57

Note: Incidence was calculated by dividing the number of reported AEFI cases by the number of administered human rabies vaccine doses, then multiplying by 100,000.
Abbreviation: AEFI=adverse events following immunization.

have yielded mature, stable manufacturing of human rabies vaccines with reduced adverse effects (*2*). The 2018 WHO position paper on rabies vaccines noted that minor, transient injection site reactions such as erythema, pain, and swelling may occur in 35%–45% of vaccinees, while mild systemic adverse events such as fever, headache, dizziness, and gastrointestinal symptoms may occur in 5%–15% (*4*). Two meta-analyses reported AEFI rates for human rabies vaccine in China of 9.82% (*5*) and 5.6% (*6*), covering the periods 2006–2016 and 2012–2016, respectively. In contrast, our study found that the AEFI incidence rate during 2021–2024 was 18.57 per 100,000 doses (0.019%). Most cases occurred among children and adolescents, followed the first dose, and were reported during the second and third quarters. Both AEFI case counts and incidence rates increased annually, consistent with national AEFI trends in China (*7*–*8*). The proportion of AEFI reported among adults was higher than the national average for all vaccines, likely reflecting greater exposure opportunities for adults through pet contacts, outdoor activities, and occupational risks, as well as the broad age coverage of this vaccine. The higher rabies disease burden in central China may also have contributed to the higher proportion of AEFI reported from this region (*9*).

The majority of AEFI were common vaccine reactions, including fever and injection site redness and swelling, consistent with findings from studies in the United States (*10*) and India (*11*). These transient symptoms generally require no treatment. Rare vaccine reactions accounted for 2.62% of AEFI (0.49 per 100,000 doses), with the most common diagnoses being allergy-related conditions such as allergic rash and angioedema. The rates of allergic rash and angioedema were 0.32 and 0.04 per 100,000 doses, respectively — lower than or comparable to the national rates for all vaccines in China (*7*–*8*). These allergic reactions typically resolve within a few days without treatment, or more rapidly with appropriate therapy. The rates of anaphylactic shock and laryngeal edema, both life-threatening allergic reactions, were comparable to the national average reporting rates for all vaccines and fell below the WHO threshold for very rare events (*12*), as well as below the rate of anaphylaxis (1.31 per million doses) reported in the United States (*13*). Because rabies vaccine has no contraindications for post-exposure administration, an increased risk of allergic reactions cannot be excluded. Although extremely rare, anaphylactic shock and laryngeal edema can develop rapidly and require immediate treatment.

HSP, also known as immunoglobulin A vasculitis, is a condition predominantly affecting children with a complex and multifactorial etiology. HSP is generally self-limited. A systematic review covering 1994–2014 found no causal association between vaccination and

TABLE 3. Symptoms and diagnoses of adverse reactions for human rabies vaccine, 2021–2024.

Symptom or diagnosis	*N*	Proportion (%)	Incidence
Common vaccine reactions	33,393	100.00	17.88
Fever	22,754	68.14	12.18
37.1–37.5 ℃	2,554	7.65	1.37
37.6–38.5 ℃	8,166	24.45	4.37
≥38.6 ℃	12,034	36.04	6.44
Injection site redness/swelling	9,208	27.57	4.93
Diameter≤2.5 cm	3,703	11.09	1.98
Diameter>2.5 cm	5,505	16.49	2.95
Injection site induration	5,358	16.05	2.87
Diameter≤2.5 cm	2,567	7.69	1.37
Diameter>2.5 cm	2,791	8.36	1.49
Rare vaccine reactions	910	100.00	0.49
Allergic rash	597	65.60	0.32
Angioedema	75	8.24	0.04
HSP	34	3.74	0.02
Anaphylactic shock	24	2.64	0.01
Febrile convulsion/ convulsion	16	1.76	0.01
Laryngeal edema	11	1.21	0.01
TP	7	0.77	0.004
Arthus reactions	4	0.44	0.002
Lymphangitis/lymphadenitis	2	0.22	0.001
Sterile abscess	1	0.11	0.001
Other allergic reactions	88	9.67	0.05
Other neurological diseases	16	1.76	0.009
Other diagnosis	35	3.84	0.02
Total	34,303	100.00	18.37

Note: Incidence was calculated by dividing the number of reported AEFI cases by the number of administered human rabies vaccine doses, then multiplying by 100,000.
Abbreviation: HSP=Henoch-Schönlein purpura; TP=thrombocytopenic purpura/thrombocytopenia.

vasculitis, including HSP (*14*). Febrile convulsions can be triggered by fever, a common post-vaccination symptom; although alarming to parents, they are benign (*15*). Monitoring body temperature and providing antipyretic treatment can be beneficial. Certain neurological diseases were previously linked to older formulations of human rabies vaccines cultured in mammalian brain tissues; however, studies have found no association between neurological conditions such as acute disseminated encephalomyelitis and Guillain-Barré syndrome and newer vaccine formulations (*16–18*). The WHO position paper further stated that serious adverse events rarely occur with human rabies vaccine and that no causal relationship has been established between the vaccine and neurological symptoms (*4*). In our study, a few isolated cases of neurological symptoms were classified as rare vaccine reactions by local causality assessment expert panels based on individual clinical circumstances; however, these cases were insufficient to establish a definitive association between the vaccines and these conditions.

This study has several limitations. The AEFI data were derived from a passive surveillance system, which tends to underestimate the reporting rates. Additionally, variations in reporting sensitivity, investigation quality, and diagnostic accuracy across jurisdictions may have affected the results.

In conclusion, post-marketing AEFI surveillance in China demonstrated that the AEFI rates with human rabies vaccine were very low and within an acceptable range. The most common reactions were fever and

injection site reactions. Allergic rash was the most frequently reported rare vaccine reaction, while anaphylactic shock and laryngeal edema were extremely rare. These findings provide continued reassurance regarding the immunization safety of human rabies vaccine.

Conflicts of interest: No conflicts of interest.

Acknowledgements: The adverse event surveillance staff at all Centers for Disease Control and Prevention, vaccination clinics, and hospitals for their assistance with data collection and case classification. Lance Rodewald, senior consultant at Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine, for assistance with English language editing.

Ethical Statement: The AEFI surveillance and disposal of individual cases is a requirement of the existing law, regulation and guideline. This study is a retrospective analysis with surveillance data, and there is no need for ethical review.

Funding: Supported by the Comprehensive Disease Control and Prevention (102393260020010000011).

doi: 10.46234/ccdcw2026.079

[#] Corresponding author: Keli Li, likl@chinacdc.cn.

[1] National Key Laboratory of Intelligent Tracking and Forecasting for Infectious Diseases (NITFID), Center for National Immunization Program, Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine, Beijing, China.

Submitted: January 04, 2026
Accepted: April 17, 2026
Issued: April 24, 2026

REFERENCES

1. World Health Organization. Rabies. 2025. https://www.who.int/health-topics/rabies#tab=tab_1. [2025-3-31].
2. Shi LT, Yu YX. Brief history of development of rabies vaccine for human use in China. Prog Microbiol Immunol 2024;52(1):1 – 8. https://doi.org/10.13309/j.cnki.pmi.2024.01.001.
3. General Department of the National Disease Control and Prevention Administration, General Office of the National Health Commission. The National Regulation for the Rabies Exposure Prophylaxis (2023 Edition). 2023. https://www.ndcpa.gov.cn/jbkzzx/c100014/common/content/content_1706569159854649344.html.[2026-4-21].(In Chinese).
4. World Health Organization. Rabies vaccines: WHO position paper – April 2018. Wkly Epidemiol Rec 2018;93(16):201-19. https://iris.who.int/server/api/core/bitstreams/b3f08b00-3107-4643-a0b2-b473f9599540/content
5. Zhang XR, Wu ZG, Zhang WS. Adverse reaction caused by rabies vaccine in China: a Meta-analysis. Chin J Epidemiol 2017;38(6):821 – 7. https://doi.org/10.3760/cma.j.issn.0254-6450.2017.06.026.
6. Li WM, Liu SY, Qian SY, Zhu JH, Selvaraj JN, Zhang XY. Is the rate of adverse reaction to rabies vaccine in China really as the public thinks?—based on a meta analysis. Hum Vaccin Immunother 2021;17(3):714 – 22. https://doi.org/10.1080/21645515.2020.1794218.
7. Zhang LN, Li KL, Li Y, Fan CX, Li Y, Ren MR, et al. Surveillance of adverse events following immunization in China, 2023. Chin J Vaccines Immun 2025;31(2):121 – 31. https://doi.org/10.19914/j.CJVI.2025021.
8. Zhang LN, Li Y, Li KL, Li Y, Fan CX, Ren MR, et al. Surveillance of adverse events following immunization in China, 2021-2022. Chin J Vaccines Immun 2024;30(4):470 – 84. https://doi.org/10.19914/j.CJVI.2024079.
9. Zhang N, Xu XN, Zhang MH, Yu PC, Liu SQ, Liu Q, et al. Rabies surveillance and epidemiological analysis in China, 2019-2023. Chin J Virol 2025;41(3):757 – 64. https://doi.org/10.13242/j.cnki.bingduxuebao.250087.
10. Moro PL, Woo EJ, Paul W, Lewis P, Petersen BW, Cano M. Post-marketing surveillance of human rabies diploid cell vaccine (Imovax) in the vaccine adverse event reporting system (VAERS) in the United States, 1990−2015. PLoS Negl Trop Dis 2016;10(7):e0004846. https://doi.org/10.1371/journal.pntd.0004846.
11. Kang G, Lakhkar A, Bhamare C, Dharmadhikari A, Narwadkar J, Kanujia A, et al. Active safety surveillance of rabies monoclonal antibody and rabies vaccine in patients with category III potential rabies exposure. Lancet Reg Health Southeast Asia 2023;14:100207. https://doi.org/10.1016/j.lansea.2023.100207.
12. World Health Organization. Global manual on surveillance of adverse events following immunization. Geneva (Switzerland): WHO; 2016. https://www.who.int/publications/i/item/9789241507769.
13. McNeil MM, Weintraub ES, Duffy J, Sukumaran L, Jacobsen SJ, Klein NP, et al. Risk of anaphylaxis after vaccination in children and adults. J Allergy Clin Immunol 2016;137(3):868 – 78. https://doi.org/10.1016/j.jaci.2015.07.048.
14. Bonetto C, Trotta F, Felicetti P, Alarcón GS, Santuccio C, Bachtiar NS, et al. Vasculitis as an adverse event following immunization - Systematic literature review. Vaccine 2016;34(51):6641 – 51. https://doi.org/10.1016/j.vaccine.2015.09.026.
15. Verity CM, Greenwood R, Golding J. Long-term intellectual and behavioral outcomes of children with febrile convulsions. N Engl J Med 1998;338(24):1723 – 8. https://doi.org/10.1056/NEJM199806113382403.
16. Haber P, Sejvar J, Mikaeloff Y, DeStefano F. Vaccines and Guillain-Barré syndrome. Drug Saf 2009;32(4):309 – 23. https://doi.org/10.2165/00002018-200932040-00005.
17. Chen Y, Zhang JL, Chu XH, Xu YL, Ma FB. Vaccines and the risk of Guillain-Barré syndrome. Eur J Epidemiol 2020;35(4):363 – 70. https://doi.org/10.1007/s10654-019-00596-1.
18. Chen Y, Ma FB, Xu YL, Chu XH, Zhang JL. Vaccines and the risk of acute disseminated encephalomyelitis. Vaccine 2018;36(26):3733 – 9. https://doi.org/10.1016/j.vaccine.2018.05.063.

Preplanned Studies

Combination Vaccines in Routine Childhood Immunization Programs — Worldwide, 2024

Fan Zheng[1,2,&]; Guzainuer Abudurusuli[1,&]; Linlin Gong[1,2]; Jiayuan Xie[1,2]; Huaqing Wang[1,2,3,#]

Summary

What Is Already Known About This Topic?

Combination vaccines enhance health system efficiency and caregiver compliance by reducing the number of clinic visits and injections required for routine childhood immunization.

What Is Added by This Report?

In 2024, eight types of combination vaccines were in use worldwide, grouped into two categories: diphtheria-tetanus-pertussis (DTP)-containing vaccines (trivalent, quadrivalent, pentavalent, and hexavalent) and measles-containing vaccines (two bivalent types, trivalent, and quadrivalent). Pentavalent DTP-containing vaccines and measles-mumps-rubella (MMR) vaccines were the most widely used globally, yet 15 countries still lacked any measles-containing combination vaccine. Significant coverage gaps and service drop-offs persisted in low-income countries in Africa and the Americas, reflecting economic disparities in access to advanced formulations such as hexavalent vaccines.

What Are the Implications for Public Health Practice?

To align with Immunization Agenda 2030 (IA2030), tailored strategies should integrate combination vaccines with strengthened primary healthcare delivery and sustainable financing mechanisms. This approach is essential for improving service continuity and reducing dropout rates in underperforming regions.

ABSTRACT

Introduction: Optimizing and streamlining immunization schedules through the use of combination vaccines can advance post-pandemic vaccination recovery and "The Big Catch-up" initiative. This study assessed the global landscape of combination vaccine use and its association with immunization coverage in 2024.

Methods: Using 2024 World Health Organization/United Nations International Children's Emergency Fund (WHO/UNICEF) Joint Reporting Form (JRF) data and official national coverage estimates, we conducted a cross-sectional descriptive analysis of diphtheria-tetanus-pertussis (DTP)-containing and measles-containing combination vaccine use patterns; countries were stratified by WHO region and World Bank income classification.

Results: In 2024, eight types of combination vaccines were in use worldwide, divided into two categories: DTP-containing vaccines, including trivalent, quadrivalent, pentavalent, and hexavalent formulations; and measles-containing vaccines, including two bivalent types, trivalent, and quadrivalent formulations. Among DTP-containing vaccines, pentavalent formulations were the most widely used globally (151 of 194 Member States), while hexavalent vaccine use was concentrated in high-income countries. The trivalent formulation was the most commonly used measles-containing combination vaccine (119 countries), but 15 countries relied exclusively on monovalent measles vaccine. Significant regional and economic disparities were observed: low-income countries in Africa and the Americas experienced substantial coverage drop-off between the first and third DTP doses, suggesting service continuity bottlenecks despite high initial access.

Conclusion: Although combination vaccines are widely used, their potential to bridge immunization equity gaps remains unrealized due to systemic barriers in low-resource settings. Strengthening primary healthcare and ensuring sustainable financing for advanced vaccine formulations are essential to achieving global immunization targets.

Routine immunization ranks among the most cost-effective public health interventions for preventing and controlling vaccine-preventable diseases (VPDs). However, the coronavirus disease 2019 (COVID-19) pandemic caused unprecedented disruptions to routine

immunization services worldwide (*1*–*2*). In the context of post-pandemic immunization recovery and implementation of The Big Catch-up initiative, optimizing immunization schedules and promoting combination vaccine use are widely recognized as key strategies to strengthen health system resilience and improve vaccination service performance (*3*). By conferring protection against multiple diseases in a single visit, combination vaccines reduce the vaccination burden on caregivers while enabling more efficient allocation of limited health resources through fewer required clinic visits — particularly in settings with constrained service capacity (*4*).

Despite the well-established clinical advantages of combination vaccines, previous studies have largely focused on single-country analyses or evaluations of specific products (*5*–*6*). Few systematic assessments have examined global patterns of combination vaccine use and their association with immunization coverage recovery. Moreover, inherent reporting lags in global vaccine utilization databases mean that analyses reflecting the most recent data (2024) have not yet been reported. Using 2024 global monitoring data, this study aims to systematically assess the status of combination vaccine use worldwide and explore its potential associations with immunization coverage recovery, thereby providing evidence to inform the development of more resilient immunization strategies in the post-pandemic era.

This cross-sectional descriptive study analyzed publicly available, country-level data to systematically assess combination vaccine use patterns in routine childhood immunization programs across 194 WHO Member States and to examine the association between these patterns and immunization coverage.

Vaccine use data were extracted from the 2024 WHO/UNICEF Joint Reporting Form (JRF) (*7*), which documents vaccine types, formulations, and schedules implemented in national routine childhood immunization programs. Coverage data were obtained from the 2024 official national coverage estimates published by UNICEF (*8*). The two datasets were merged by country code. Countries and areas that reported complete routine childhood immunization information in the 2024 JRF and had corresponding coverage estimates were included in the final analysis.

Based on antigen components reported in the JRF, combination vaccines were categorized into two main groups: DTP-containing and measles-containing combination vaccines. DTP-containing combination vaccines were defined as those used in routine immunization that include diphtheria, tetanus, and pertussis antigens, either alone or combined with additional antigens such as hepatitis B, *Haemophilus influenzae* type b (Hib), or inactivated poliovirus vaccine (IPV). Measles-containing combination vaccines were defined as those containing measles vaccine virus in combination with at least one other vaccine virus — rubella, mumps, or varicella.

Three indicators were used to assess immunization program performance: coverage with the first dose of DTP-containing vaccine (DTP1), as an indicator of access to basic immunization services; coverage with the third dose of DTP-containing vaccine (DTP3), reflecting completion of the primary series and service continuity; and coverage with the first dose of measles-containing vaccine (MCV1), serving as a core indicator of control capacity for highly transmissible diseases and overall program reach.

To examine global disparities, countries were stratified by WHO region (geographic dimension) (*9*) and World Bank income classification for the 2026 fiscal year based on 2024 financial data (economic dimension) (*10*). All analyses were descriptive, intended to characterize current patterns and distributions without causal inference.

Four types of DTP-containing combination vaccines were in use: trivalent (DTwP or DTaP), quadrivalent (DTaP-IPV), pentavalent (DTwP-Hib-HepB or DTaP-Hib-IPV), and hexavalent (DTaP-Hib-HepB-IPV). Among these, pentavalent vaccines were the most widely used formulations (Figure 1). By 2024, 151 countries had introduced pentavalent vaccines into routine immunization programs, with 120 using whole-cell pertussis (wP) formulations, 30 using acellular pertussis (aP) formulations, and 1 country using both. Quadrivalent and hexavalent vaccine use was largely concentrated in countries employing acellular pertussis formulations, indicating a technological link between formulation type and valency.

Four types of measles-containing combination vaccines were in use: measles-mumps (MM), measles-rubella (MR), measles-mumps-rubella (MMR), and measles-mumps-rubella-varicella (MMRV). For measles prevention and control, MMR was the predominant global choice, incorporated into routine immunization programs in 119 countries. Fifty-eight countries used MR and 15 countries used MMRV. Fifteen countries exclusively used monovalent measles vaccines and, as of 2024, had not yet introduced any measles-containing combination vaccine — all were

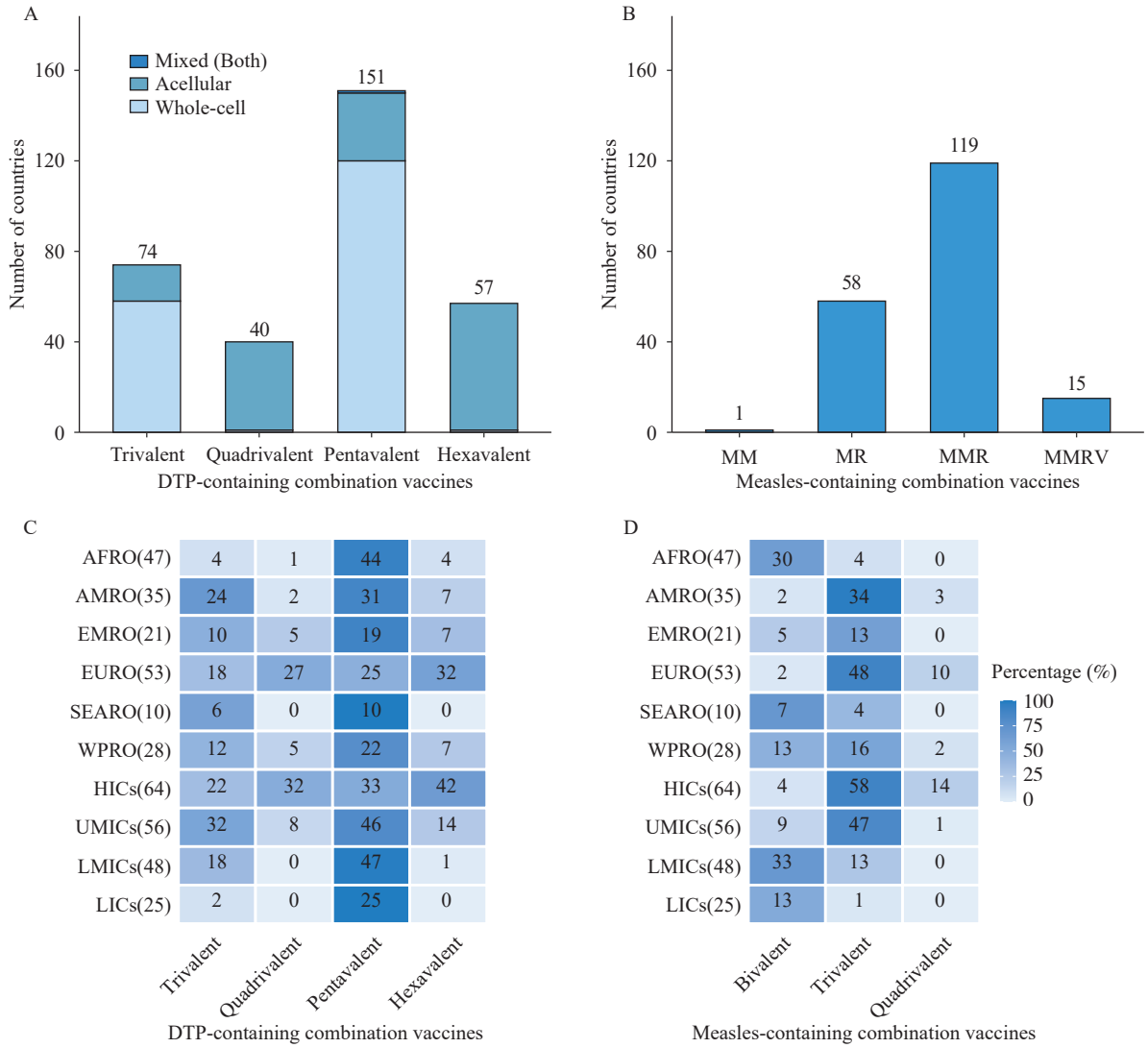


FIGURE 1. Number of countries using different combination vaccines in routine childhood immunization, 2024. (A) Number of countries using various DTP-containing vaccines; (B) Number of countries using various measles-containing vaccines; (C) Distribution of DTP-containing vaccines by WHO region and income level; (D) Distribution of measles-containing vaccines by WHO region and income level.

Abbreviation: DTP=diphtheria-tetanus-pertussis; MM=measles-mumps; MR=measles-rubella; MMR=measles-mumps-rubella; MMRV=measles-mumps-rubella-varicella; AFRO=Regional Office for Africa; AMRO=Regional Office for the Americas; EMRO=Regional Office for the Eastern Mediterranean; EURO=Regional Office for Europe; SEARO=Regional Office for South-East Asia; WPRO=Regional Office for the Western Pacific; HICs=High-income countries; UMICs=Upper-middle-income countries; LMICs=Lower-middle-income countries; LICs=Low-income countries.

low- and middle-income countries, primarily in Africa and the Middle East. Continued reliance on monovalent measles vaccine in these settings highlights an opportunity to strengthen rubella and mumps control through adoption of combination formulations.

Significant heterogeneity emerged in combination vaccine use patterns across WHO regions and income groups (Figure 1). In the African Region (AFRO) and the Eastern Mediterranean Region (EMRO), pentavalent vaccines predominated among DTP-containing formulations, with limited adoption of higher-valent options such as hexavalent vaccines. Countries in the European Region (EURO) and the Western Pacific Region (WPRO) more frequently used higher-valent DTP-containing combination vaccines. The Region of the Americas (AMRO) and the South-East Asia Region (SEARO) appeared to be in transitional stages, with gradual expansion toward higher-valent combinations.

Use of measles-containing combination vaccines correlated positively with national income level. High-

income countries (HICs) and upper-middle-income countries (UMICs), particularly in the EURO and WPRO regions, widely implemented trivalent or quadrivalent formulations. In contrast, low-income countries (LICs) and lower-middle-income countries (LMICs) continued to rely on bivalent or monovalent measles vaccines. MMRV vaccine use was greatest in HICs and nearly absent in LICs, underscoring the critical role of economic capacity in determining access to technologically advanced vaccines.

Global immunization coverage data for 2024 revealed substantial regional and economic disparities (Figure 2). Worldwide, DTP1 coverage was generally high, indicating broad initial access to immunization services. However, pronounced regional variation in DTP3 and MCV1 coverage pointed to marked differences in the completion of full vaccination schedules.

The EMRO, EURO, SEARO, and WPRO regions maintained high DTP3 and MCV1 coverage levels, with low dropout rates between DTP1 and DTP3 and relatively small inter-country variation. In contrast, the AFRO and AMRO regions experienced substantial declines from DTP1 to DTP3 coverage alongside lower overall MCV1 coverage, accompanied by marked inter-country disparities. HICs and UMICs consistently achieved high, stable coverage across all three indicators, whereas LMICs and LICs exhibited lower overall coverage and wider gaps between DTP1 and DTP3, suggesting bottlenecks in service continuity. DTP3 and MCV1 coverage displayed clear stepwise gradients across income groups, with greater dispersion and inequality in non-high-income groups.

DISCUSSION

This study provides a comprehensive overview of global combination vaccine use in 2024, highlighting significant disparities across WHO regions and income groups. While DTP1 coverage remains relatively robust worldwide, the pronounced drop-off between DTP1 and DTP3 — particularly in AFRO and

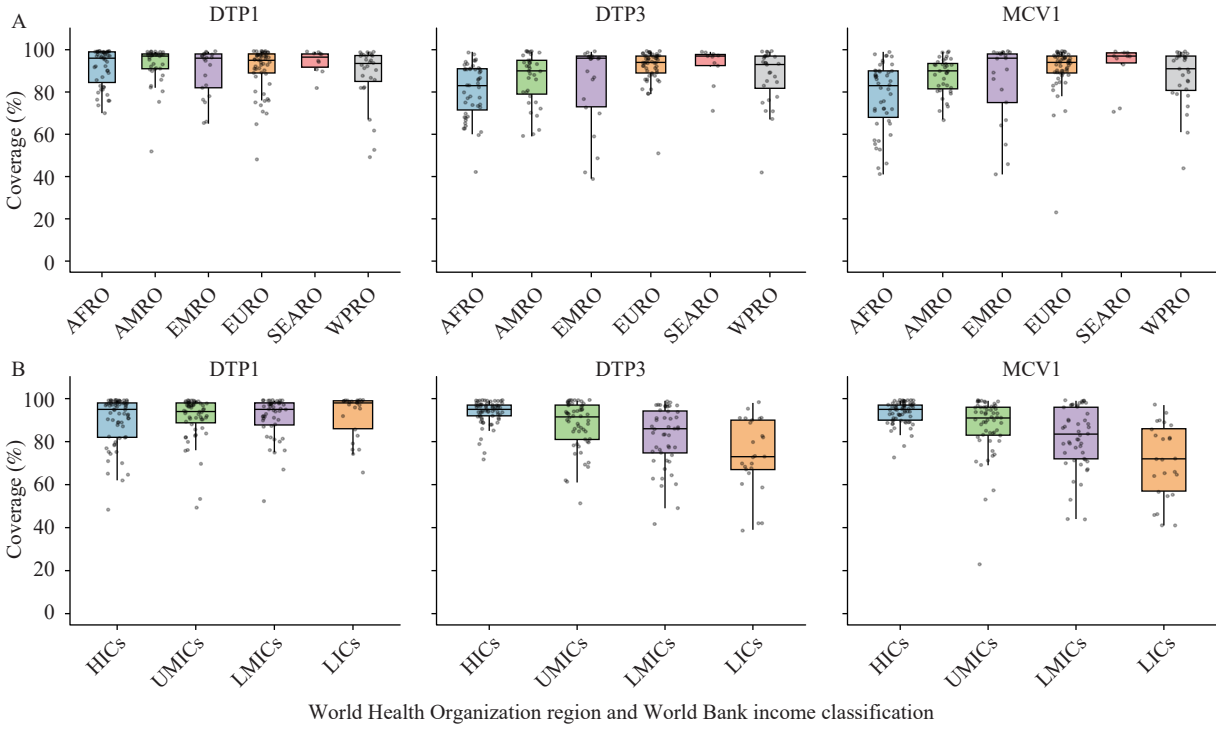


FIGURE 2. Vaccination coverage of DTP1, DTP3, and MCV1 by WHO region and income level in 2024. (A) Distribution of DTP1, DTP3, and MCV1 coverage across WHO regions; (B) Distribution of DTP1, DTP3, and MCV1 coverage across income levels.

Abbreviation: DTP1=diphtheria-tetanus-pertussis, first dose; DTP3=diphtheria-tetanus-pertussis, third dose; MCV1=measles-containing vaccine, first dose; AFRO=Regional Office for Africa; AMRO=Regional Office for the Americas; EMRO=Regional Office for the Eastern Mediterranean; EURO=Regional Office for Europe; SEARO=Regional Office for South-East Asia; WPRO=Regional Office for the Western Pacific; HICs=High-income countries; UMICs=Upper-middle-income countries; LMICs=Lower-middle-income countries; LICs=Low-income countries.

AMRO — underscores persistent challenges in health system retention and service continuity. These findings align with the "backsliding" trends observed in the post-pandemic era, during which immunization coverage recovery has been uneven (*11–12*). Widespread adoption of combination vaccines, including pentavalent and hexavalent formulations, represents a critically important strategy to mitigate these gaps by reducing the number of injections and potential dropout points, consistent with the Immunization Agenda 2030 (IA2030) priority of leaving no one behind (*13*).

Our analyses demonstrate that HICs and UMICs maintained high, stable DTP3 and MCV1 coverage rates, largely benefiting from mature immunization programs and extensive hexavalent vaccine use. In contrast, LICs and LMICs experienced significant coverage gaps and higher dropout rates. This economic gradient suggests that, despite support from global initiatives such as Gavi, the Vaccine Alliance, financial and logistical barriers remain significant obstacles. Recent studies have shown that introducing combination vaccines in LICs effectively improves timely vaccination rates, yet supply chain fragility and workforce shortages continue to prevent realization of their full potential (*14*). Furthermore, the disparities highlight the particular vulnerability of middle-income countries that have transitioned out of Gavi or other donor support (*15*). Notably, regional variation in priority diseases included in immunization programs may drive differences in combination vaccine adoption, and disparities in economic capacity further influence the range of diseases that public funding can cover.

Maximizing combination vaccine use extends beyond product introduction — it demands strengthening underlying health systems. The substantial gap between DTP1 and DTP3 in specific regions indicates that, while initial access is achievable, retaining children in the system to complete the immunization schedule remains a key bottleneck. Combination vaccines offer a major advantage: by delivering multiple antigens in a single visit, they maximize the protective impact of every contact between the child and the health system. This is particularly relevant for "zero-dose" and under-immunized children in conflict-affected or remote settings, as emphasized by "The Big Catch-up" initiative launched in 2023 (*16*). The value of combination vaccines should therefore be re-evaluated at the systemic level, recognizing them as essential tools for enhancing immunization service efficiency, improving population compliance, and optimizing overall immunization outcomes.

Although combination vaccines offer significant advantages, their widespread adoption in low-income countries remains constrained by multiple barriers, including economic, supply chain, and infrastructure challenges. Financial limitations and stringent cold chain requirements prevent resource-limited regions from absorbing the high upfront costs. Context-specific strategies are therefore needed, including alleviating financial pressures through international tiered pricing and joint procurement, promoting technology transfer for regional production, and prioritizing introduction in areas with high dropout rates to maximize health benefits per dose.

The global disparities revealed by this study offer important insights for China's immunization program development. As a country transitioning toward a higher-level public health system, China urgently needs to improve immunization service efficiency and optimize vaccination delivery models. Experience from high-income countries demonstrates that advanced combination vaccines enhance system efficiency and sustain high coverage levels. Against this backdrop, China should strengthen its combination vaccine development and production capabilities while encouraging domestic enterprises to increase investment, thereby reducing reliance on external supply chains and enhancing vaccine accessibility and affordability to better serve the National Immunization Program (NIP). Simultaneously, aligning vaccine innovation with the Expanded Program on Immunization (EPI) will drive the transformation of immunization services toward a more efficient, integrated model. By bolstering combination vaccine development and production systems, China can meet domestic public health needs while playing a more active role in the global vaccine supply system, thereby advancing immunization equity.

Findings in this report are subject to at least four limitations. First, the analysis relied on aggregated national-level data, which may obscure subnational inequalities in immunization coverage and mask localized pockets of under-immunization. Second, as 2024 represents a critical stage in the post-pandemic recovery of routine immunization services, the long-term stability of the observed patterns requires continued monitoring. Third, since only 2024 data were analyzed, tracking temporal changes in global combination vaccine use was not possible. Finally, this

study describes current patterns and distributions of combination vaccine use and immunization coverage; its cross-sectional design limits causal inference.

In conclusion, while combination vaccines were widely used in 2024, their potential to close the immunization equity gap has not been fully realized due to systemic challenges. To align with IA2030 and global vaccination targets, tailored strategies are needed. For lower-performing regions, integrating combination vaccines with strengthened primary healthcare delivery and community engagement is essential. Policymakers should prioritize sustainable financing and supply chain optimization to ensure that the efficiency advantages of combination vaccines translate into tangible improvements in full, timely immunization coverage.

Ethical statement: This study used publicly available national-level summary data published by WHO/UNICEF and did not involve personal information or human subjects research. Ethical review committee approval was not required.

Conflicts of interest: No conflicts of interest.

doi: 10.46234/ccdcw2026.081

[#] Corresponding author: Huaqing Wang, wanghq@chinacdc.cn.

[1] State Key Laboratory of Vaccines for Infectious Diseases, Xiang An Biomedicine Laboratory, School of Public Health, Xiamen University, Xiamen City, Fujian Province, China; [2] National Innovation Platform for Industry-Education Integration in Vaccine Research, Xiamen University, Xiamen City, Fujian Province, China; [3] National Key Laboratory of Intelligent Tracking and Forecasting for Infectious Diseases (NITFID), Center for National Immunization Program, Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine, Beijing, China.
[&] Joint first authors.

Submitted: April 15, 2026
Accepted: April 17, 2026
Issued: April 24, 2026

REFERENCES

1. Dalton M, Sanderson B, Robinson LJ, Homer CSE, Pomat W, Danchin M, et al. Impact of COVID-19 on routine childhood immunisations in low- and middle-income countries: a scoping review. PLoS Global Public Health 2023;3(8):e0002268. https://doi.org/10.1371/journal.pgph.0002268.
2. Shet A, Carr K, Danovaro-Holliday MC, Sodha SV, Prosperi C, Wunderlich J, et al. Impact of the SARS-CoV-2 pandemic on routine immunisation services: evidence of disruption and recovery from 170 countries and territories. Lancet Global Health 2022;10(2):e186 – 94. https://doi.org/10.1016/S2214-109X(21)00512-X.
3. O'Brien KL, Lemango E. The big catch-up in immunisation coverage after the COVID-19 pandemic: progress and challenges to achieving equitable recovery. Lancet 2023;402(10401):510 – 2. https://doi.org/10.1016/s0140-6736(23)01468-x.
4. Hausdorff WP, Madhi SA, Kang G, Kaboré L, Tufet Bayona M, Giersing BK. Facilitating the development of urgently required combination vaccines. Lancet Global Health 2024;12(6):e1059 – 67. https://doi.org/10.1016/S2214-109X(24)00092-5.
5. Romero M, Góngora DS, Caicedo ML, Benchabane D, Lopez JG. Cost-minimization and budget impact analysis of a hexavalent vaccine (Hexaxim®) in the colombian expanded program on immunization. Value Health Reg Issues 2021;26:150 – 9. https://doi.org/10.1016/j.vhri.2021.06.001.
6. Kurosky SK, Davis KL, Krishnarajah G. Effect of combination vaccines on completion and compliance of childhood vaccinations in the United States. Hum Vaccines Immunother 2017;13(11):2494 – 2502. https://doi.org/10.1080/21645515.2017.1362515.
7. World Health Organization. Vaccination schedule. 2025. https://immunizationdata.who.int/global?topic=Vaccination-schedule&location. [2026-4-11].
8. United Nations International Children's Emergency Fund. UNICEF data warehouse. 2025. https://data.unicef.org/dv_index/?q=immunization. [2026-4-11].
9. World Health Organization. Country groupings. 2026. https://www.who.int/observatories/global-observatory-on-health-research-and-development/classifications-and-standards/country-groupings. [2026-4-11].
10. The World Bank. World bank country and lending groups. 2025. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. [2026-04-11].
11. World Health Organization. Progress and challenges with achieving universal immunization coverage. 2025. https://www.who.int/publications/m/item/progress-and-challenges. [2026-4-11].
12. GBD 2023 Vaccine Coverage Collaborators. Global, regional, and national trends in routine childhood vaccination coverage from 1980 to 2023 with forecasts to 2030: a systematic analysis for the Global Burden of Disease Study 2023. Lancet 2025;406(10500):235 – 60. https://doi.org/10.1016/s0140-6736(25)01037-2.
13. World Health Organization. Immunization agenda 2030: a global strategy to leave no one behind. 2020. https://www.who.int/teams/immunization-vaccines-and-biologicals/strategies/ia2030. [2026-4-11].
14. Duan YQ, Shi JY, Wang ZB, Zhou SD, Jin YZ, Zheng ZJ. Disparities in COVID-19 vaccination among low-, middle-, and high-income countries: the mediating role of vaccination policy. Vaccines (Basel) 2021;9(8):905. https://doi.org/10.3390/vaccines9080905.
15. Kallenberg J, Mok W, Newman R, Nguyen A, Ryckman T, Saxenian H, et al. Gavi's transition policy: moving from development assistance to domestic financing of immunization programs. Health Aff 2016;35(2):250 – 8. https://doi.org/10.1377/hlthaff.2015.1079.
16. World Health Organization. The big catch-up: an essential immunization recovery plan for 2023 and beyond. 2023. https://www.who.int/publications/i/item/9789240075511. [2026-4-11].

Preplanned Studies

The Current Status of Simultaneous Vaccination of Children Aged 0–3 Years — China, 2022–2024

Xin Liu[1]; Yuan Liang[1]; Zhaonan Zhang[1]; Sha Zhang[1]; Jiakai Ye[1]; Ruyue Hu[2]; Lei Cao[1]; Huixin Peng[1]; Li Li[1]; Yifan Song[1]; Wenzhou Yu[1,#]

Summary

What is already known about this topic?

Simultaneous vaccination improves coverage and reduces clinic visits. In China, administering multiple vaccines during a single visit is widely practiced; studies have evaluated the safety and immunogenicity of specific vaccine combinations. However, systematic nationwide analyses remain limited.

What is added by this report?

During 2022–2024, 46.27% of vaccinations involved two vaccines administered simultaneously, 2.36% involved three, and 0.003% involved four or more. Most two-vaccine combinations included only National Immunization Program (NIP) vaccines, while combinations of three or more often included both NIP and non-NIP vaccines.

What are the implications for public health practice?

Real-world vaccination patterns provide evidence to inform research on multi-vaccine administration and combined vaccine development, supporting improvements in immunization service efficiency.

ABSTRACT

Introdution: To describe simultaneous vaccination among children aged 0–3 years in China during 2022–2024 and provide evidence to improve vaccination service efficiency and timely immunoprotection.

Methods: Individual-level vaccination records from the National Immunization Program Information System were analyzed for all vaccines administered to children aged 0–3 years nationwide from January 1, 2022, to December 31, 2024, focusing on same-visit vaccination practices.

Results: A total of 748.30 million vaccine doses were administered. Among these, 46.27% were given as two-vaccine simultaneous combinations, 2.36% as three-vaccine combinations, and 0.003% as four or more vaccines. Two-vaccine combinations mainly involved only National Immunization Program (NIP) vaccines (74%–78%), whereas three- and four-vaccine combinations more often included both NIP and non-NIP vaccines. Common combinations included diphtheria, tetanus, and acellular pertussis (DTaP) with inactivated poliovirus vaccine (IPV), HepB, or BCG.

Conclusion: Simultaneous vaccination in China is predominantly characterized by the co-administration of two vaccines, with three or more used less frequently. These findings provide evidence to guide optimization of immunization practices, research prioritization, and improvements in vaccination efficiency.

Vaccination is among the most cost-effective strategies for preventing infectious diseases (*1*). Children aged 0-3 years are a priority population in China's immunization programs, and timely, safe vaccination is essential for maximizing protection and program impact. As the number and variety of recommended vaccines increase, simultaneous vaccination, the administration of two or more different vaccines during the same visit, has become an important approach for optimizing immunization schedules (*2*). Widely used internationally when safety and immunogenicity requirements are met, this practice improves coverage and reduces clinic visits (*3*). In China, simultaneous vaccination is recommended: vaccines included in the National Immunization Program (NIP vaccines) may be administered simultaneously according to routine and catch-up schedules. Parents may also choose non-NIP vaccines in place of NIP vaccines, expanding the combinations eligible for simultaneous administration (*4–5*). Although studies in China have evaluated the safety and immunogenicity of specific combinations (*6–8*),

nationwide real-world descriptions remain limited. This study uses National Immunization Program Information System (NIPIS) data to describe same-visit administration of two, three, and four or more vaccines among children aged 0–3 years in China during 2022–2024.

Individual-level vaccination records for children aged 0–3 years vaccinated between January 2022 and December 2024 across 32 provincial-level administrative divisions (PLADs) in China were extracted from NIPIS. Simultaneous vaccination was defined as administration of two or more different vaccines during one clinic visit at separate anatomical sites (*9*). Combinations were classified as NIP-only, non-NIP-only, or mixed NIP and non-NIP vaccines.

NIP vaccines included hepatitis B (HepB), Bacillus Calmette-Guérin (BCG), inactivated poliovirus vaccine (IPV), oral poliomyelitis attenuated live vaccine (OPV), DTaP, measles-mumps-rubella (MMR), Japanese encephalitis attenuated live vaccine (JEV-L), group A meningococcal polysaccharide vaccine (MenA), group A-C meningococcal polysaccharide vaccine (MenAC), inactivated hepatitis A (HepA-I), and hepatitis A live attenuated vaccine (HepA-L). Non-NIP vaccines included trivalent rotavirus vaccine, pentavalent rotavirus vaccine, rotavirus vaccine, 13-valent pneumococcal conjugate vaccine (PCV13), 23-valent pneumococcal polysaccharide vaccine (PPSV23), DTaP-Hib vaccine, DTaP-IPV/Hib vaccine, Enterovirus Type 71 Vaccine (EV71), group A and C meningococcal polysaccharide conjugate vaccine (MPCV-AC), ACYW135 meningococcal polysaccharide vaccine, ACYW135 meningococcal conjugate vaccine, and Influenza vaccine, varicella vaccine, Hib vaccine, Japanese Encephalitis Inactivated Vaccine (JEV-I), Measles and Mumps vaccine(MM), etc. Quadrivalent and pentavalent vaccines were considered as single vaccines. COVID-19 vaccines were excluded because they were not licensed for children aged 0–3 years during the study period.

Descriptive statistics summarized simultaneous vaccination practices, with categorical variables presented as percentages. Data were curated using Microsoft Excel (version 2016, Microsoft Office, Washington, USA) and analyzed with R (version 4.2.1, R Statistical Computing Foundation, Vienna, Austria).

During 2022–2024, 748.30 million vaccine doses were administered to children aged 0–3 years. Among these, 346.21 million (46.27%) involved simultaneous administration of two vaccines, 17.68 million (2.36%) involved three vaccines, 24,460 (0.003%) involved four or more vaccines (Table 1).

Overall, 363.91 million doses were administered simultaneously. Two-vaccine combinations accounted for 95.14% of these doses, with 75.02% involving pairs of NIP vaccines. Three-vaccine combinations represented 4.86%, of which 53.82% included both NIP and non-NIP vaccines. Administration of four or more vaccines occurred in less than 0.01% of all doses (Table 2).

The seven most common two-vaccine combinations were pairs of NIP vaccines (Figure 1). The most frequent pairings were DTaP with IPV at three and four months of age, BCG with HepB at birth, and MMR with JEV-L at 8 months (Figure 1). The most common mixed combinations were MenA with influenza vaccine and RV5 with IPV.

Among three-vaccine combinations, the most frequent were IPV, HepB, and BCG; IPV, DTaP, and pentavalent rotavirus vaccine; and OPV, HepB, and DTaP (Figure 2). For four-vaccine combinations, the most common were OPV, HepB, DTaP, and MenA; IPV, HepB, DTaP, MenA; and OPV, HepB, DTaP, and pentavalent rotavirus vaccine (Figure 3).

DISCUSSION

This study used vaccination records of children aged 0–3 years during 2022–2024 in the NIPIS to describe real-world simultaneous vaccination practices in China. Simultaneous vaccination was common, with two

TABLE 1. Simultaneous administration of two or more vaccines during a visit to children aged 0–3 years in China, 2022–2024.

Year	Single vaccine		Two vaccines		Three vaccines		≥4 vaccines		Total doses	
	N (million)	Proportion (%)	*N* (million)	Proportion (%)	*N* (million)	Proportion (%)	*N*	Proportion (%)	*N* (million)	Proportion (%)
2022	130.94	50.47	121.66	46.89	6.84	2.64	9,840	0.004	259.46	100
2023	129.99	50.13	122.62	47.29	6.68	2.58	9,100	0.004	259.30	100
2024	123.45	53.78	101.93	44.41	4.16	1.81	5,520	0.003	229.54	100
Total	384.39	51.36	346.21	46.27	17.68	2.36	24,460	0.003	748.30	100

TABLE 2. Vaccines administered together by study year, combination type, and number of vaccines administered at a visit.

Year	Two vaccines			Three vaccines			≥4 vaccines		
	Only NIP vaccines *N* (million doses) (%)	Only non-NIP vaccines *N* (million doses) (%)	Mixed combination *N* (million doses) (%)	Only NIP vaccines *N* (million doses) (%)	Only Non-NIP vaccines *N* (million doses) (%)	Mixed combination *N* (million doses) (%)	Only NIP vaccines *N* (doses) (%)	Only non-NIP vaccines *N* (doses) (%)	Mixed combination *N* (doses) (%)
2022	90.12 (74.07)	8.41 (6.91)	23.13 (19.01)	2.87 (42.00)	0.23 (3.37)	3.74 (54.62)	1,700 (17.60)	540 (5.50)	7,600 (76.90)
2023	90.70(73.97)	8.71 (7.10)	23.21 (18.93)	2.68 (40.12)	0.29 (4.41)	3.70 (55.47)	1,900 (21.08)	400 (4.37)	6,800 (74.55)
2024	78.90 (77.41)	7.06 (6.93)	15.96 (15.66)	1.92 (46.24)	0.16 (3.90)	2.07 (49.86)	1,700 (31.34)	20 (0.36)	3,800 (68.30)
Total	259.72 (75.02)	24.18 (6.98)	62.30 (17.99)	7.48 (42.29)	0.69 (3.89)	9.52 (53.82)	5,300 (21.67)	960 (3.92)	18,200 (74.41)

Abbreviation: NIP=national immunization program.

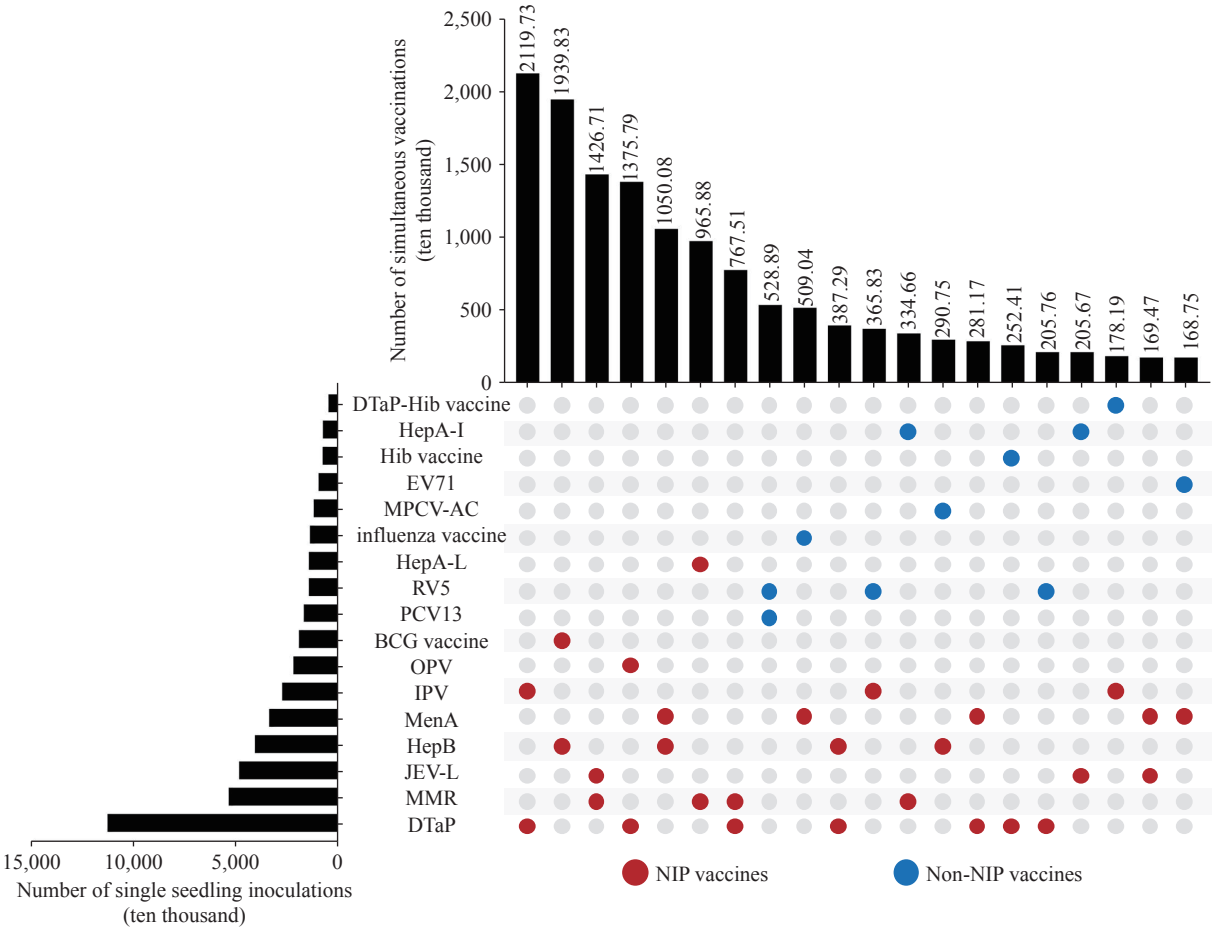


FIGURE 1. Vaccine combinations for simultaneous administration of two vaccines.
Abbreviation: DTaP-Hib=diphtheria, tetanus, acellular pertussis and Haemophilus influenzae type b combined vaccine; HepA-I=hepatitis A inactivated vaccine; Hib vaccine=Haemophilus influenzae type b vaccine; EV71=Enterovirus Type 71 Vaccine, Inactivated; MPCV-AC=group A and group C meningococcal polysaccharide conjugate vaccine; HepA-L=hepatitis A live attenuated vaccine; RV5=pentavalent rotavirus vaccine; PCV13=pneumococcal polysaccharide conjugate vaccine (13-valent); BCG vaccine=Bacillus Calmette-Guérin vaccine; OPV=oral poliovirus vaccine; IPV=inactivated poliovirus vaccine; MenA=group A meningococcal vaccine; HepB=hepatitis B vaccine; JEV-L=Japanese encephalitis live attenuated vaccine; MMR=measles, mumps and rubella combined vaccine; DTaP=diphtheria, tetanus, and acellular pertussis vaccine.

vaccines administered during the same visit as the predominant pattern, whereas three or more vaccines were administered much less frequently. Some simultaneous vaccination events involved both NIP and non-NIP vaccines, indicating concurrent use of different vaccine categories in routine practice.

The predominance of two-vaccine administration likely reflects clustering within China's national

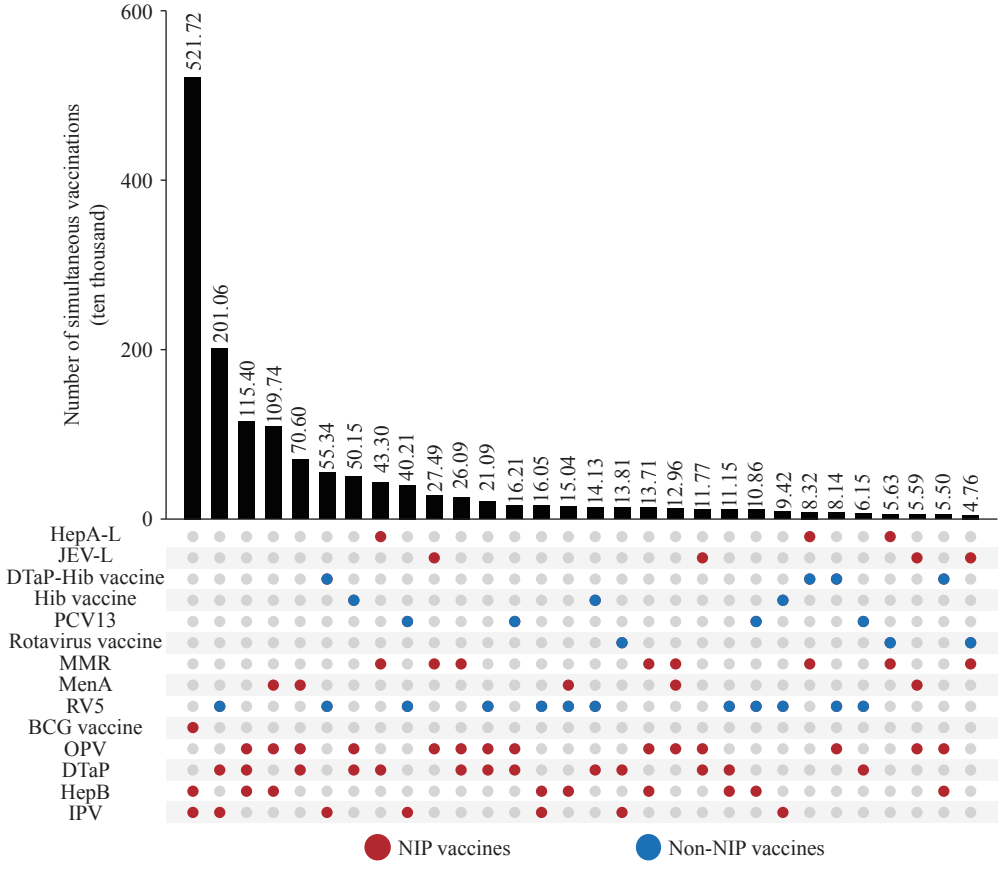


FIGURE 2. Vaccine combinations for simultaneous administration of three vaccines.
Abbreviation: HepA-L=hepatitis A vaccine (live attenuated); JEV-L=Japanese encephalitis vaccine (live attenuated); DTaP-Hib vaccine=diphtheria, tetanus, acellular pertussis and Haemophilus influenzae type b combined vaccine; Hib vaccine=Haemophilus influenzae type b vaccine; PCV13=pneumococcal polysaccharide conjugate vaccine (13-valent); MMR=measles, mumps and rubella combined vaccine; MenA=group A meningococcal vaccine; RV5=pentavalent rotavirus vaccine; BCG vaccine=Bacillus Calmette-Guérin vaccine; OPV=oral poliovirus vaccine; DTaP=diphtheria, tetanus and acellular pertussis vaccine; HepB=hepatitis B vaccine; IPV=inactivated poliovirus vaccine.

immunization schedule. Several vaccines are scheduled at the same or adjacent ages, at birth and during early infancy (e.g., at 2 months, 3–4 months, and 6–8 months of age), creating opportunities for simultaneous administration. Common combinations included BCG with hepatitis B at birth and DTaP with IPV during infancy. These pairings align with the national schedule and may support adherence, reduce missed doses, and lower service burdens for families and clinics.

In contrast, simultaneous administration of three or more vaccines was far less frequent. Increasing the number of vaccines administered during a single visit raises operational demands and requires vaccinators to manage contraindications and precautions across multiple vaccines (*10*). Parental acceptance also influences implementation. Previous studies suggest parents generally accept two simultaneous vaccines, whereas willingness declines when three or more are administered, often due to concerns about discomfort, adverse reactions, or effectiveness (*11–13*).

Despite the low overall proportion, three-vaccine combinations showed recognizable patterns. Most involved NIP vaccines combined with a single non-NIP vaccine, such as DTaP, IPV, and rotavirus vaccine, typically at ages when vaccination schedules overlapped. This pattern suggests that some three-vaccine strategies are adopted when schedule requirements and children's vaccination needs coincide.

As the number of vaccines increased, combinations consisting only of non-NIP vaccines were uncommon, whereas those including NIP vaccines were more frequent. This pattern may reflect the self-paid nature and accessibility of non-NIP vaccines, as well as financial considerations. In addition, technical guidance on simultaneous administration of some non-NIP vaccines remains limited (*2*), which may

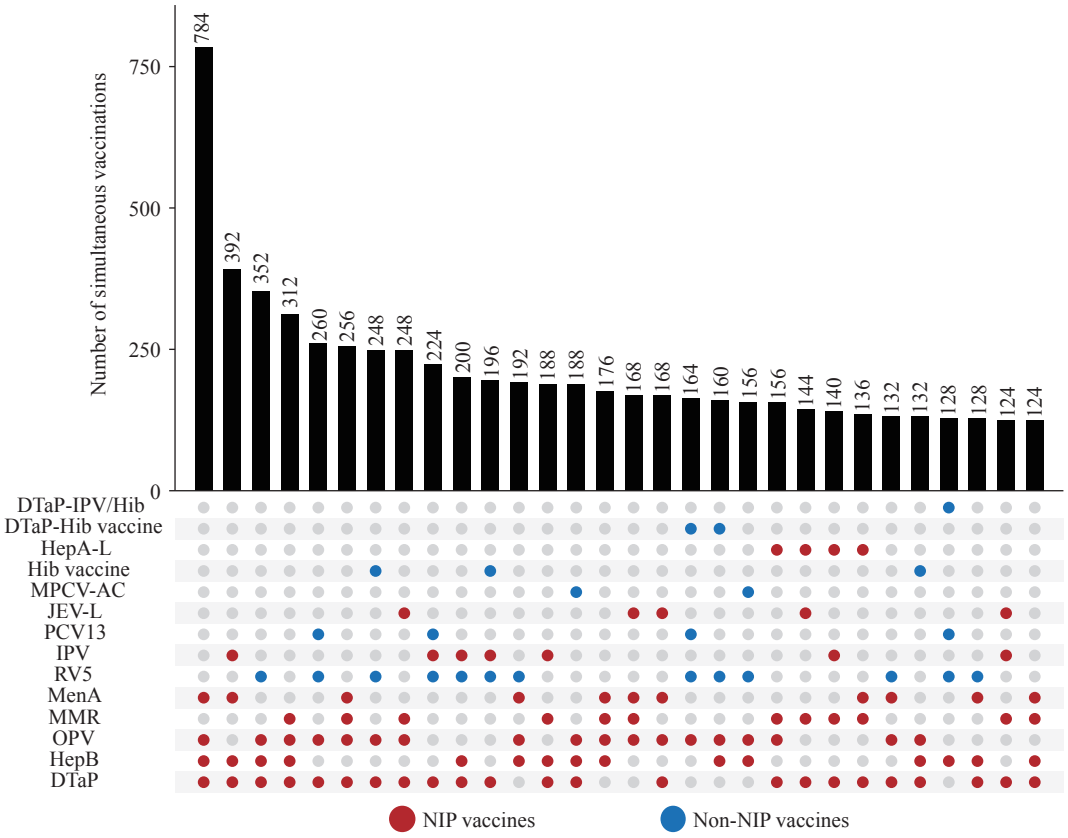


FIGURE 3. Vaccine combinations for simultaneous administration of four or more vaccines.
Abbreviation: DTaP-IPV/Hib=diphtheria, tetanus, and acellular pertussis, inactivated poliovirus vaccine and Haemophilus influenzae type b combined vaccine; DTaP-Hib vaccine=diphtheria, tetanus, acellular pertussis and Haemophilus influenzae type b combined vaccine; HepA-L=hepatitis A live attenuated vaccine; Hib vaccine=Haemophilus influenzae type b vaccine; MPCV-AC=group A and group C meningococcal polysaccharide conjugate vaccine; JEV-L=Japanese encephalitis live attenuated vaccine; PCV13=pneumococcal polysaccharide conjugate vaccine (13-valent); IPV=inactivated poliovirus vaccine; RV5=pentavalent rotavirus vaccine; MenA=group A meningococcal vaccine; MMR=measles, mumps and rubella combined vaccine; OPV=oral poliovirus vaccine; HepB=hepatitis B vaccine; DTaP=diphtheria, tetanus and acellular pertussis vaccine.

encourage cautious implementation by clinics. Consequently, non-NIP vaccines are often administered alongside NIP vaccines rather than concentrated in a single visit.

Simultaneous administration of four or more vaccines was extremely rare. This finding may indicate a practical upper limit on the number of vaccines administered during one visit under current service conditions and levels of parental acceptance. Future adjustments to immunization schedules or the introduction of new vaccines may therefore require balancing increased clinic visits with greater simultaneous administration unless combination vaccines reduce injection numbers.

An important contribution of this study lies in its use of nationwide vaccination records to disaggregate simultaneous vaccination events by number and combination type, identifying recurring patterns in routine practice. Such structural analysis of actual vaccination behavior may help define priorities for studies on the safety, reactogenicity, and immunogenicity of multi-vaccine administration. The stable combination patterns observed may also inform vaccine product optimization and the development of combination vaccines to improve immunization efficiency by reducing injections.

Several limitations should be noted. First, as a retrospective observational study, it could not assess parental or vaccinator knowledge, attitudes, or preferences in vaccination decision-making. Second, reliance on immunization information system records may introduce incomplete entries or data entry errors.

In summary, simultaneous vaccination among young children aged 0-3 years in China is characterized by two-vaccine administration as the dominant pattern, with three or more vaccines administered

under specific conditions. By describing vaccine numbers and combination structures using real-world data, this study provides a foundation for optimizing immunization practices, guiding targeted research, and improving vaccination efficiency.

Conflicts of interest: No conflicts of interest.

Acknowledgements: All staff members who contributed to data collection and participated in this study.

Ethical statement: The Survey on the Current Status of Simultaneous Vaccination received approval from the Chinese Center for Disease Control and Prevention Institutional Review Board in May 2025 (Approval Notice No. 202515).

Funding: Supported by the Emergency Response Mechanism Operation Program of China CDC (102393220020010000017-251705) and the Comprehensive Disease Control and Prevention (10239326002001000011).

doi: 10.46234/ccdcw2026.082

[#] Corresponding author: Wenzhou Yu, yuwz@chinacdc.cn.

[1] National Key Laboratory of Intelligent Tracking and Forecasting for Infectious Diseases (NITFID), Center for National Immunization Program, Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine, Beijing, China; [2] Sichuan Provincial Center for Disease Control and Prevention, Chengdu City, Sichuan Province, China.

Submitted: November 20, 2025
Accepted: February 25, 2026
Issued: April 24, 2026

REFERENCES

1. Wang CF, Lai XZ, Abbas K, Pouwels KB, Zhang HJ, Jit M, et al. Health impact and economic evaluation of the Expanded Program on Immunization in China from 1974 to 2024: a modelling study. Lancet Public Health 2025;10(12):e1045 – 54. https://doi.org/10.1016/S2468-2667(25)00039-8.
2. Immunization Service Guidance and Evaluation Committee, China Association for Vaccines. Expert consensus on the use of combination vaccine and simultaneous immunization in children aged 0-12 months. Chin J Prev Med 2022;56(8):1035 – 41. https://doi.org/10.3760/cma.j.cn112150-20220429-00427.
3. WHO. Table 2: summary of WHO position papers - recommended routine immunizations for children. 2025. https://www.who.int/publications/m/item/table-2-summary-of-who-position-papers-recommended-routine-immunizations-for-children. [2025-04-02]
4. National Health Commission of the People's Republic of China. Childhood immunization schedule for national immunization program vaccines — China (Version 2021). China CDC Wkly 2021;3(52):1101 – 8. https://doi.org/10.46234/ccdcw2021.270.
5. National Administration of Disease Control and Prevention Comprehensive Department, General Office of the National Health Commission. National Administration of Disease Control and Prevention Comprehensive Department, General Office of the National Health Commission on issuing the standard operating procedures for preventive vaccination (2023 Edition). 2023. https://www.gov.cn/zhengce/zhengceku/202312/content_6920274.htm. [2025-10-05] (In Chinese).
6. Chen JY, Pang H. Suspected adverse events following immunization associated with seperate/combined administration of 13-valent pneumococcal polysaccharide conjugate vaccine and oral pentavalent human rotavirus live attenuated vaccine in age-eligible children in a district of Shanghai. Shanghai J Prev Med 2025;37(3):234 – 8,243. https://doi.org/10.19428/j.cnki.sjpm.2025.24256.
7. Su JL, Tang Y, Shen HJ, Zhang JK, Ma YL, Huang QX, et al. Immunogenicity and safety of a booster dose of Japanese encephalitis vaccine co-administered with live attenuated varicella vaccine. Chin J Microbiol Immunol 2016;36(3):189 – 96. https://doi.org/10.3760/cma.j.issn.0254-5101.2016.03.006.
8. Tang XW, Yan R, Zhou Y, Deng X, He HQ. Immunogenicity and safety of combined vaccination with domestic measles-rubella combined attenuated live vaccine and Japanese encephalitis attenuated live vaccine. Chinese Journal of Preventive Medicine. 2021;55(7):835 – 839 https://doi.org/10.3760/cma.j.cn112150-20200713-01000.
9. Robinson CL, Romero JR, Kempe A, Pellegrini C, Szilagyi P. Advisory committee on immunization practices recommended immunization schedule for children and adolescents aged 18 years or younger — United States, 2018. MMWR Morb Mortal Wkly Rep 2018;67(5):156 – 157. https://doi.org/10.15585/mmwr.mm6705e2.
10. Liu X, Hu RY, Ye JK, Cao L, Zhang S, Song YF, et al. Current status, challenges, and prospects of simultaneous vaccine administration in China's childhood immunization strategy. Chin J Prev Med 2025;59(9):1462 – 5. https://doi.org/10.3760/cma.j.cn112150-20250512-00415.
11. Yang WQ, Zeng QS, Huang YQ. Survey on awareness and vaccination willingness of simultaneous inoculation among parents in Xinhui District. Chin Primary Health Care 2023;37(12):85 – 8. https://doi.org/10.3969/j.issn.1001-568X.2023.12.0022.
12. Kaaijk P, Kleijne DE, Knol MJ, Harmsen IA, Ophorst OJ, Rots NY. Parents' attitude toward multiple vaccinations at a single visit with alternative delivery methods. Hum Vaccin Immunother 2014;10(8):2483 – 9. https://doi.org/10.4161/hv.29361.
13. Wallace AS, Mantel C, Mayers G, Mansoor O, Gindler JS, Hyde TB. Experiences with provider and parental attitudes and practices regarding the administration of multiple injections during infant vaccination visits: lessons for vaccine introduction. Vaccine 2014;32(41):5301 – 10. https://doi.org/10.1016/j.vaccine.2014.07.076.

Preplanned Studies

A Randomized, Double-Blind, Positive-Controlled Phase III Clinical Trial of an Anti-Rabies Monoclonal Antibody for Category III Rabies Exposure in Individuals Under 18 Years — China, 2021–2023

Jingyu Li[1,&]; Yu Zhao[2,&]; Yan Zheng[1]; Xuexia Zhang[2]; Ya Jiang[3]; Jiangshu Guo[4]; Wenmei Bao[5]; Yinfeng Ma[6]; Yaoyuan Zhang[2]; Shuyuan Yin[2]; Yirui Ma[2]; Lijie Wang[2,#]; Xiaoqiang Liu[1,7,#]

Summary

What is already known about this topic?

Anti-rabies monoclonal antibodies in combination with rabies vaccines have demonstrated safety and immunogenicity as alternatives to rabies immunoglobulins for category III post-exposure prophylaxis in adults.

What is added by this report?

This randomized, double-blind, active-control phase III trial demonstrates the immunogenicity and safety of an anti-rabies monoclonal antibodies in individuals aged <18 years with category III rabies exposure.

What are the implications for public health practice?

These findings support the use of recombinant human monoclonal antibodies in pediatric populations and their potential role as alternative passive immunization options for category III rabies post-exposure prophylaxis in individuals aged <18 years.

ABSTRACT

Introduction: Rabies is an animal-borne infectious disease caused by the rabies virus, with a case fatality rate of nearly 100%. This study aimed to evaluate the safety and efficacy of an anti-rabies virus monoclonal antibody ormutivimab in patients aged <18 years with category III rabies exposure.

Methods: This randomized, double-blind, non-inferiority clinical trial was conducted in individuals aged <18 years with category III rabies exposure. Participants were randomized in a 1∶1 ratio to the omertivir monoclonal antibody or human rabies immunoglobulin (HRIG) group. On the day of enrollment (day 0), after thorough wound cleaning, participants received either the monoclonal antibody or HRIG, along with human rabies vaccine co-administration. Follow-up was conducted for 1 year after completion of the full vaccination regimen. Venous blood samples were collected on days 0, 3, 7, 14, and 42 to compare seroconversion rates and rabies virus-neutralizing antibody activity between the two groups. Survival status within 1 year after completion of vaccination and the incidence of adverse events within 30 days were also assessed.

Results: A total of 240 participants were enrolled. The safety results showed that the incidences of adverse events in the ormutivimab and HRIG groups were 53.78% and 59.17%, respectively, with related adverse event rates of 40.34% and 48.33%, respectively. The efficacy results demonstrated the following: 1) For individuals with serum rabies virus neutralizing antibody activity <0.5 IU/mL prior to drug administration (mFAS1), on day 3 post-administration, the antibody seroconversion rate in the omeltivir group was similar to that in the HRIG group. By day 7, the omeltivir group showed significantly higher antibody seroconversion rates than the HRIG group (P=0.0312). By days 14 and 42 post-administration, both groups achieved 100% seroconversion rates. Additionally, on day 3 post-administration, the geometric mean concentrations (GMC) levels in the omeltivir group were significantly lower than those in the HRIG group (P=0.0087). By day 7, GMC levels in both groups were comparable with no significant difference (P=0.2540). By days 14 and 42, omeltivir group antibody GMC levels were significantly higher than those in the HRIG group (P<0.0001). 2) Survival rates remained 100% up to 1 year in both groups after completing the full vaccination regimen.

Conclusions: The combination of ormutivimab and the human rabies vaccine achieved an efficacy endpoint for post-exposure prophylaxis in individuals <18 years of age with category III rabies exposure and

demonstrated a favorable safety profile.

Rabies is a severe zoonotic infectious disease that remains almost uniformly fatal once clinical symptoms onset (*1*). Despite the availability of effective post-exposure prophylaxis (PEP), rabies continues to pose a substantial public health burden, particularly in low- and middle-income settings (*2*). Children and adolescents are at high risk for rabies exposure and have a high incidence of the disease. According to the World Health Organization (WHO) statistics, individuals aged <15 years account for 40% of rabies cases (*3*). Furthermore, children are more likely than adults to suffer severe injuries from rabies exposure, particularly those affecting the head, face, neck, and perineal regions. These areas are more vulnerable than other areas to viral invasion due to their proximity to the brain and high neural innervation. The WHO recommends that exposure in these areas be classified as category III exposure (*4*), requiring comprehensive PEP.

Category III rabies exposure in this clinical trial was defined as single or multiple penetrating skin bites or scratches, licking of broken skin, contamination of mucous membranes by animal saliva, or exposure to bats on the head, face, neck, hands, and external genitalia; this aligns with the national technical guidelines (*5*), and requires a combination of immediate wound management, passive immunization, and active vaccination.

Passive immunization plays a critical role during the early post-exposure period by providing neutralizing antibodies immediately before vaccine-induced immunity is established. Traditionally, passive immunization relies on human or equine rabies immunoglobulins. However, the availability, cost, and batch-to-batch variability of immunoglobulin products limit their widespread use. Since 2018, the WHO has recommended the use of monoclonal antibodies as an alternative to immunoglobulins for PEP (*1*). Recombinant monoclonal antibodies offer several potential advantages, including standardized manufacturing, consistent potency, and improved supply security.

Currently, clinical evidence for anti-rabies monoclonal antibodies (mAbs) is largely limited to adults. In China, only two types of rabies mAbs are available for individuals aged ≥18 years with category III exposure, leaving an important evidence gap in children and adolescents. To address this gap, we conducted a randomized, double-blind, active-controlled phase III clinical trial to evaluate the immunogenicity and safety of ormutivimab, a recombinant human anti-rabies monoclonal antibody, compared with human rabies immunoglobulin (HRIG) when administered in combination with standard rabies vaccination in individuals aged <18 years with category III rabies exposure.

This study was approved by the Vaccine Clinical Trial Ethics Committee of the Yunnan Provincial Centre for Disease Control and Prevention. The trial was registered in the Drug Clinical Trial Registration and Information Disclosure Platform (CTR20201247).

This randomized, double-blind, active-controlled phase III clinical trial was conducted at four centers for disease control and prevention in Yunnan Province, China, between August 2021 and June 2023. Eligible participants were individuals aged <18 years with category III rabies exposure who had not previously received a rabies vaccination. The inclusion and exclusion criteria are listed in Supplementary Table S1 (available at https://weekly.chinacdc.cn/).

Participants were randomized in a 1∶1 ratio to receive either ormutivimab (treatment group) or HRIG (control group). Randomization was stratified by study site.

On day 0, participants received either ormutivimab or HRIG as passive immunization. Both groups received the same batch of a commercially available human rabies vaccine administered intramuscularly on days 0, 3, 7, 14, and 28 in accordance with the national guidelines. Participants were followed up for 1 year after completion of the full vaccination regimen.

Ormutivimab and HRIG were administered via wound infiltration injection at a dose of 20 IU/kg. If residual volume remained after infiltration injection of all wounds, it was injected into muscle away from the vaccination site (recommended injection sites: for wounds above the waist, into the ipsilateral back muscle group; for wounds below the waist, into the ipsilateral middle lateral thigh muscle group).

In accordance with the requirements of the Center for Drug Evaluation of the National Medical Products Administration and the results of previous studies, the sample size was determined based on safety considerations. Enrolling 100 participants in the experimental group yielded an 80% likelihood of detecting at least one adverse event, with an incidence rate of 1.6%. Accounting for a 20% dropout rate, the trial and control groups planned to enroll 120 participants each, totaling 240 participants.

All adverse events occurring within 30 days of

completion of the full immunization regimen were recorded. Adverse events were graded according to the adverse event grading guidelines issued by the National Medical Products Administration (*6*) and coded using the Medical Dictionary for Regulatory Activities (version 25.0, ICH, Herndon, USA).

Safety analyses included all participants who received at least one dose of the study drug.

Venous blood samples were collected from all the participants on days 0, 3, 7, 14, and 42. Blood samples were collected on day 0 before the trial drug and vaccine administration, and on days 3, 7, and 14 before vaccine administration. The Rapid Fluorescent Foci Inhibition Test, recommended by the WHO, was then performed to determine rabies virus neutralizing antibody (RVNA) activity (*1*). RVNA was measured by JOINN Laboratories Co. Ltd. (China).

Seroconversion rates and corresponding 95% confidence intervals were calculated for each group on days 3, 7, 14, and 42 post-administration. The geometric mean concentrations (GMCs) of RVNA were calculated after logarithmic transformation of the antibody titers.

Seroconversion rates between the groups were compared using the chi-square test or Fisher's exact test, as appropriate. All statistical analyses were performed using SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA). Statistical significance was assessed using two-sided tests, with a significance level of 0.05.

A total of 240 participants were randomized between August 2021 and June 2023, as shown in Figure 1. One participant in the treatment group who had received outpatient immunoglobulin was excluded, resulting in 239 participants.

No significant differences were noted in sex, body mass index, type of biting animal, wound location, and exposure duration between the two groups (P>0.05), indicating a balanced distribution. The primary animal species involved in exposure was dogs (73.95% and

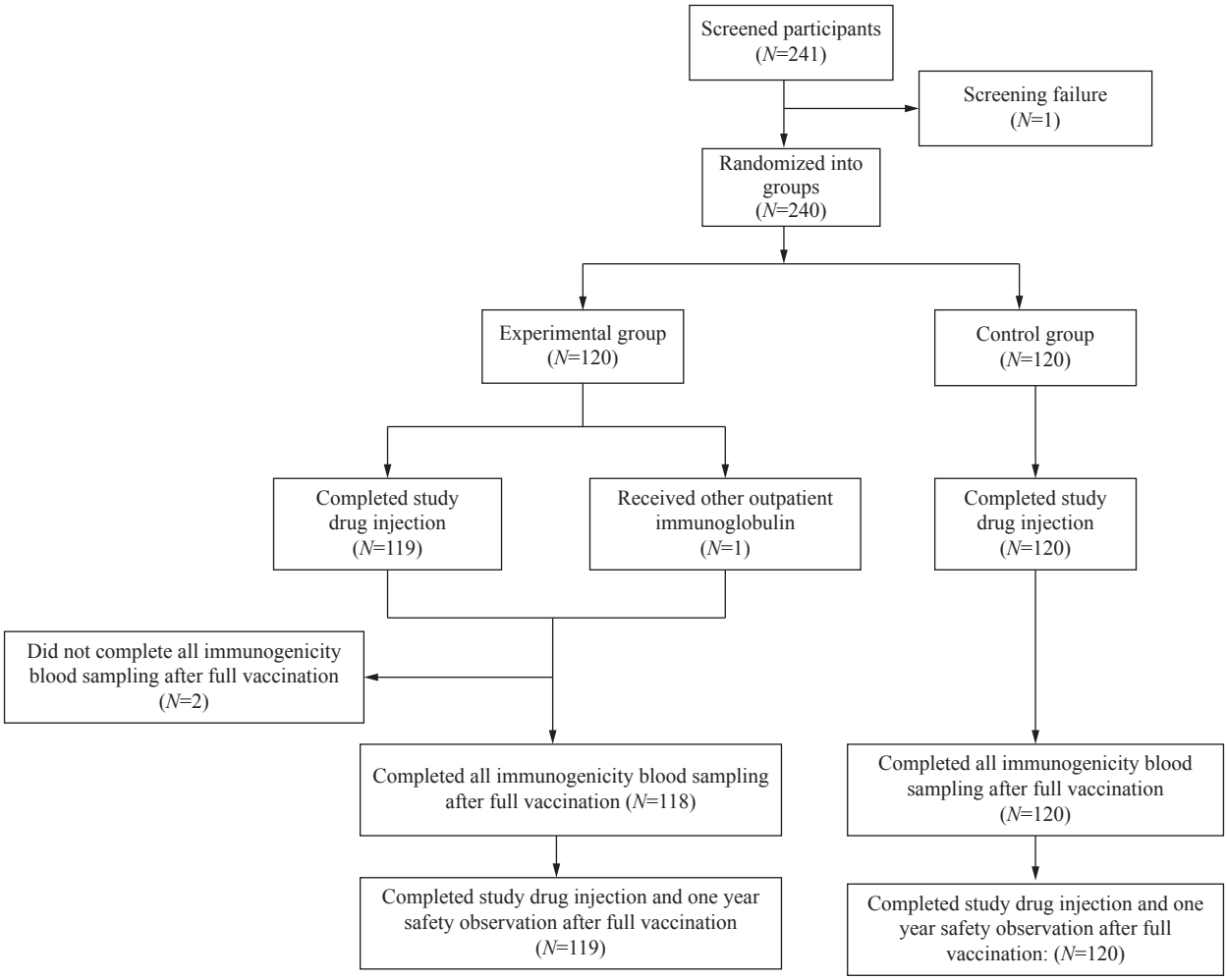


FIGURE 1. Distribution diagram of participants.

73.33%, respectively), with the most common exposure sites being the limbs, particularly the right upper limb (36.97%). The detailed statistical results are presented in Table 1.

The mean ages of the participants in the ormutivimab and HRIG groups were 7 and 8 years, respectively, with a significant age difference between the two groups (P<0.05). In the following analysis, the participants were divided into three subgroups: 1–5, 6–11, and 12–17 years. No significant difference was noted in positivity rates among age groups at 3 days post-administration; however, at 7 days post-administration, the positivity rate in the 12–17 age group was significantly lower than that in the 1–5 and 6–11 age groups. At 14 and 42 days post-administration, the antibody positivity rate was 100.00% in both the experimental and control groups across all age groups (Supplementary Table S2, available at https://weekly.chinacdc.cn/). On days 3 and 7 post-administration, no significant difference in antibody GMC was observed between the two groups across different age groups, with similar trends. On days 14 and 42 post-administration, the antibody GMC in the 1–5 age group of the experimental group showed a difference of more than 18 IU/mL compared with the 6–11 and 12–17 age groups. No significant differences were observed between age groups in the control group (Supplementary Table S3, available athttps://weekly.chinacdc.cn/).

Within 30 days of treatment, the overall incidence of adverse events, treatment-related adverse events, and the distribution of adverse event severity were similar between the groups, with lower rates observed in the ormutivimab group (Table 2). Most adverse events

TABLE 1. Baseline characteristics of all enrolled participants (FAS1, *N*=239).

Variables	Ormutivimab (*N*=119)	HRIG (*N*=120)	*P*
Sex, *n* (%)			0.4784
Male	64 (53.78)	70 (58.33)	
Female	55 (46.22)	50 (41.67)	
Age			
Mean (SD)	7.23 (3.46)	8.58 (3.98)	0.0057
Median	6.75	8.44	
BMI (kg/m^2)			0.3496
Mean (SD)	16.62 (2.57)	16.95 (2.96)	
Median	15.94	16.01	
Biting animals			0.9139
Dog	88 (73.95)	88 (73.33)	
Cat	31 (26.05)	32 (26.67)	
Duration between exposure and informed consent (h)			0.5659
Mean (SD)	13.32 (6.79)	12.81 (7.02)	
Median	15.40	15.29	
Wound site, *n* (%)			
Head	0 (0.00)	0 (0.00)	1.0000
Face	3 (2.52)	9 (7.50)	0.0780
Neck	0 (0.00)	0 (0.00)	1.0000
Truncus	7 (5.88)	4 (3.33)	0.3471
Left upper limb	36 (30.25)	35 (29.17)	0.8543
Right upper extremity	44 (36.97)	36 (30.00)	0.2533
Left lower extremity	10 (8.40)	22 (18.33)	0.0242
Right lower limb	19 (15.97)	19 (15.83)	0.9776
Others	2 (1.68)	1 (0.83)	0.6218

Note: FAS1 means the full analytical set for neutralizing antibody activity consisted of 239 participants, including 119 in the ormutivimab group and 120 in the HRIG group.
Abbreviation: HRIG=human rabies immunoglobulin.

were mild or moderate (grade 1 or 2). No grade 4 or 5 adverse events were reported in either group. The most frequently reported adverse reactions (incidence ≥10%) in both groups were injection-site swelling and pyrexia.

Among participants with baseline RVNA levels <0.5 IU/mL (mFAS1 population), the seroconversion rates increased over time in both groups following administration of passive immunization and rabies vaccination (Table 3). On day 3 after administration, seroconversion rates were comparable between the ormutivimab and HRIG groups; however, the rate on day 7 was significantly higher in the ormutivimab than in the HRIG group (69.8% *vs*. 55.6%, *P*=0.0312). Both groups reached 100% seroconversion rates by days 14 and 42, respectively.

Among participants with baseline RVNA levels <0.5 IU/mL (mFAS1 population), the GMC of RVNA increased substantially over time in both treatment groups (Table 3, Figure 2). At day 3 post-administration, the GMCs in the ormutivimab group were significantly lower than those in the HRIG group (*P*=0.0087). At day 7, the GMC levels in both groups were not significantly different (*P*=0.2540). However, on days 14 and 42 post-administration, the GMC in the ormutivimab group was significantly higher than that in the HRIG group (*P*<0.0001).

All participants who completed the follow-up were alive 1 year after completion of the full rabies vaccination course.

In this randomized, double-blind, active-control phase III trial involving individuals aged <18 years with category III rabies exposure, ormutivimab demonstrated a favorable safety profile and immunogenicity comparable to that of HRIG when

TABLE 2. Summary of adverse events (FAS1, *N*=239).

Adverse events	Ormutivimab (*N*=119)		HRIG (*N*=120)	
	Number	Incidence rate (%)	Number	Incidence rate (%)
Adverse events, overall	64	53.78	71	59.17
Severity of adverse events				
Adverse events of category I severity	24	20.17	27	22.50
Adverse events of category II severity	36	30.25	40	33.33
Adverse events of category III severity	4	3.36	4	3.33
Adverse events of category IV severity	0	0.00	0	0.00
Adverse events of category V severity	0	0.00	0	0.00
Adverse reactions with an incidence rate of ≥10%				
Injection-site swelling	28	23.53	31	25.83
Pyrexia	18	15.13	16	13.33
Injection site pain	11	9.24	14	11.67
Injection site erythema	6	5.04	12	10.00

Note: FAS1 means the full analytical set for neutralizing antibody activity consisted of 239 participants, including 119 in the ormutivimab group and 120 in the HRIG group.
Abbreviation: HRIG=human rabies immunoglobulin.

TABLE 3. Antibody seroconversion rates and GMC of rabies virus neutralizing antibody at each testing time point (mFAS1).

Time	Ormutivimab (*N*=106)				HRIG (*N*=108)				*P*	
	Seroconversion rates*		Control for GMC		Seroconversion rates*		Control for GMC			
	N (%)	95% *CI*	GMC	95% *CI*	*N* (%)	95% *CI*	GMC	95% *CI*	Positive†	GMC
Day 3	12 (11.32)	5.99, 18.94	0.29	0.27, 0.31	14 (12.96)	7.27, 20.79	0.32	0.30, 0.34	0.7131	0.0087
Day 7	74 (69.81)	60.13, 78.35	0.75	0.64, 0.88	60 (55.56)	45.68, 65.12	0.67	0.57, 0.78	0.0312	0.2540
Day 14	106 (100.00)	96.58, 100.00	61.05	50.36, 74.00	108 (100.00)	96.64, 100.00	24.07	19.92, 29.08	1.0000	<0.0001
Day 42	106 (100.00)	96.58, 100.00	42.62	36.22, 50.16	108 (100.00)	96.64, 100.00	21.70	18.49, 25.46	1.0000	<0.0001

Note: mFAS1 means a subset of FAS1, excluding subjects with pre-treatment neutralizing antibody levels ≥0.5 IU/mL.
Abbreviation: HRIG=human rabies immunoglobulin; GMC=geometric mean concentration; *CI*=confidence interval.
* represents the proportion of individuals with post-treatment RVNA levels ≥0.5 IU/mL among those with pre-treatment levels <0.5 IU/mL.
† represents the percentage of participants with RVNA levels ≥0.5 IU/mL.

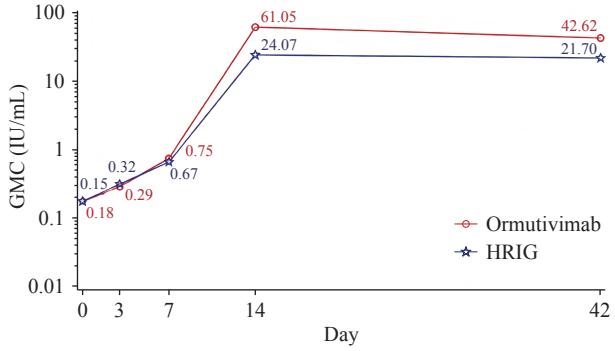


FIGURE 2. Semi-logarithmic plot of rabies virus neutralizing antibody levels over time before and after immunization for each group (mFAS1).
Note: mFAS1 means a subset of the full dataset for antibody level analysis, excluding subjects with pre-treatment neutralizing antibody levels ≥0.5 IU/mL.
Abbreviation: HRIG=human rabies immunoglobulin; GMC=geometric mean concentrations.

administered in combination with standard rabies vaccination. The incidence and severity of adverse events were comparable between groups, with most events being mild or moderate.

DISCUSSION

The positivity rate in the 12–17 years age group was lower than that in the 1–5 years and 6–11 years age groups at 7 days post-administration, suggesting slower initiation of active immunity in the 12–17 years age group, which could not promptly compensate for the decline in passive antibodies. Ormutivimab is metabolized through neonatal Fc Receptor (FcRn)-mediated circulation, and the FcRn expression in adolescents (12–17 years) is similar to that in adults (*7*–*8*). Although the initiation of active immunity in the 12–17 years age group was delayed compared with the 1–5 and 6–11 years age groups, it caught up by day 14, achieving a 100% positivity rate. On days 3 and 7 post-administration, no significant difference in antibody GMCs was observed between the ormutivimab and HRIG groups across different age groups. On days 14 and 42 post-administration, the GMC in the 1–5 years age group of the ormutivimab group showed a difference of more than 18 IU/mL compared with the 6–11 and 12–17 years age groups. This may be due to the younger age and lower body weight of the participants in the 1–5 years age group, which could amplify differences in the inhibitory effects of ormutivimab and HRIG on the vaccine, resulting in less inhibition with the trial drug. Additionally, the homogeneous Fc segment of anti-rabies monoclonal antibodies (human IgG1 subtype) can enhance active immunity through multiple mechanisms (*9*), and this enhancing effect is more pronounced in immunologically immature and highly plastic 1–5 year old children. No significant differences were observed between the control groups across different age groups, likely because HRIG provides only passive neutralizing antibodies and lacks immunomodulatory effects.

Here, participants receiving ormutivimab achieved higher seroconversion rates on day 7 than those receiving HRIG, and all participants in both groups reached seroprotective RVNA levels by day 14. Compared with the results of a phase III clinical trial of ormutivimab in individuals aged ≥18 years, a higher seroconversion rate was achieved in the sub-18 population within 7 days (*10*). Our findings suggest that ormutivimab provides timely passive immune support during the early post-exposure period when vaccine-induced immunity has not yet fully developed.

This study has several limitations. First, the rabies infection status of the biting animals could not be confirmed due to the logistical and safety challenges of capture and virological testing, preventing a direct assessment of protection against confirmed exposure. Second, only two participants aged <2 years were enrolled, limiting conclusions in very young children; therefore, ormutivimab is not recommended for children aged <2 years. Third, because no universally accepted method exists for detecting the local neutralization effect at the wound site, only RVNA levels were used as an indirect pharmacodynamic indicator. Finally, the RVNA titers were measured only up to day 42, preventing evaluation of immune persistence and limiting guidance on immunization strategies for re-exposure.

In conclusion, this phase III trial provides evidence supporting the immunogenicity and safety of ormutivimab as an alternative to HRIG for category III post-exposure prophylaxis in individuals aged <18 years. Anti-rabies mAbs are not restricted by raw material sources and can be produced stably, at scale, and sustainably, providing reliable passive immunization support in rabies-endemic regions. The development of anti-rabies mAbs enhances the standardization and coverage of PEP, facilitates the implementation of regional rabies elimination programs, contributes to the comprehensive and efficient operation of the national rabies prevention and control network, strengthens the emergency

response and long-term prevention capabilities of the public health system, and supports the Global Strategic Plan to End Human Deaths from Dog-mediated Rabies by 2030 (Zero by 30).

Conflicts of interest: No conflicts of interest.

doi: 10.46234/ccdcw2026.083

[#] Corresponding authors: Xiaoqiang Liu, liuxqms@163.com; Lijie Wang, wanglijie@ncpc.com.

[1] Yunnan Provincial Center for Disease Control and Prevention, Kunming City, Yunnan Province, China; [2] State Key Laboratory of Antibody Research and Development, North China Pharmaceutical Company (NCPC) New Drug Research and Development Co., Ltd., Shijiazhuang City, Hebei Province, China; [3] Mile Center for Disease Control and Prevention, Honghe Hani and Yi Autonomous Prefecture, Yunnan Province, China; [4] Gejiu Center for Disease Control and Prevention, Honghe Hani and Yi Autonomous Prefecture, Yunnan Province, China; [5] Kaiyuan Center for Disease Control and Prevention, Honghe Hani and Yi Autonomous Prefecture, Yunnan Province, China; [6] Qiubei County Center for Disease Control and Prevention, Wenshan Zhuang and Miao Autonomous Prefecture, Yunnan Province, China; [7] School of Public Health, Kunming Medical University, Kunming City, Yunnan Province, China.
[&] Joint first authors.

Submitted: January 12, 2026
Accepted: April 14, 2026
Issued: April 24, 2026

REFERENCES

1. World Health Organization. Rabies vaccines: WHO position paper, April 2018 - Recommendations. Vaccine 2018;36(37):5500 – 3. https://doi.org/10.1016/j.vaccine.2018.06.061.
2. Yang CX, Dang M, Wu LJ, Jin GL, Deng QQ, Chen YH, et al. Disparities in Global Rabies Burden from GBD 2021: children, older adults, and low-SDI countries at continued risk. PLoS Negl Trop Dis 2025;19(10):e0013630. https://doi.org/10.1371/journal.pntd.0013630.
3. World Health Organization. Rabies. 2024. Available online: https://www.who.int/news-room/fact-sheets/detail/rabies (accessed on 21 April 2026).
4. World Health Organization. WHO expert consultation on rabies. Second report. Geneva: WHO; 2013. https://www.who.int/publications/i/item/WHO-TRS-982.
5. Zhou H, Li Y, Chen RF, Tao XY, Yu PC, Cao SC, et al. Technical guideline for human rabies prevention and control (2016). Chin J Epidemiol 2016;37(2):139 – 63. https://doi.org/10.3760/cma.j.issn.0254-6450.2016.02.001.
6. National Medical Products Administration. Guidelines for grading criteria for adverse events in clinical trials of prophylactic vaccines. Beijing: NMPA; 2019. Available from: https://www.nmpa.gov.cn/xxgk/ggtg/ypggtg/ypqtggtg/20191231111901460.html. (In Chinese).
7. Barber J, Al-Majdoub ZM, Couto N, Howard M, Elmorsi Y, Scotcher D, et al. Toward systems-informed models for biologics disposition: covariates of the abundance of the neonatal Fc Receptor (FcRn) in human tissues and implications for pharmacokinetic modelling. Eur J Pharm Sci 2023;182:106375. https://doi.org/10.1016/j.ejps.2023.106375.
8. Hardiansyah D, Ng CM. Effects of the FcRn developmental pharmacology on the pharmacokinetics of therapeutic monoclonal IgG antibody in pediatric subjects using minimal physiologically-based pharmacokinetic modelling. mAbs 2018;10(7):1144 – 56. https://doi.org/10.1080/19420862.2018.1494479.
9. Temrikar ZH, Suryawanshi S, Meibohm B. Pharmacokinetics and clinical pharmacology of monoclonal antibodies in pediatric patients. Pediatr Drugs 2020;22(2):199 – 216. https://doi.org/10.1007/s40272-020-00382-7.
10. Liu XQ, Li YF, Li JY, Zhou JM, Guo JS, Pu Y, et al. Comparing recombinant human rabies monoclonal antibody (ormutivimab) with human rabies immunoglobulin (HRIG) for postexposure prophylaxis: a phase III, randomized, double-blind, non-inferiority trial. Int J Infect Dis 2023;134:53 – 62. https://doi.org/10.1016/j.ijid.2023.05.017.

SUPPLEMENTARY MATERIALS

The Double-Blind Design of this Clinical Trial

Both participants and investigators were blinded to the treatment allocation throughout the study period, and ormutivimab and HRIG were packaged in identical sealed boxes by designated, unblinded study drug administrators. The study drug boxes could be opened by designated unblinded study drug injectors. The study drug administrators and injectors did not disclose the treatment allocation and were not involved in any other aspects of the study. All other investigator staff members were not allowed to have contact with unsealed boxes or their contents. The study drug syringes were shielded to prevent patients from viewing the color or volume of their contents.

About Data Statistics

Covariance analysis was used to compare the GMCs between groups, with post-administration log-transformed RVNA values as the dependent variable, baseline log-transformed RVNA values as covariates, and the treatment group and study site as fixed effects. Least-squares adjusted GMCs and group ratios with 95% confidence intervals

SUPPLEMENTARY TABLE S1. Inclusion and exclusion criteria.

Criteria
Inclusion criteria:
1. Under 18 years of age and provide legal identification.
2. Rabies virus exposure category III within less than 24 h.
3. Legal guardians of volunteers voluntarily consent to participate and sign the informed consent form. Specifically: For volunteers aged <8 years, legal guardians sign the informed consent form while fully respecting the child's opinions; for volunteers aged 8–17, legal guardians sign the informed consent form, and the volunteers themselves sign the informed consent form for minors.
4. Volunteers and/or their legal guardians are able to understand the study protocol and participate in all planned follow-ups.
5. Axillary temperature <37.1 °C.
6. Female volunteers who have reached menarche agree to undergo a urine pregnancy test with a negative result, are not breastfeeding, and have no plans to become pregnant within 7 months.
Exclusion criteria:
1. Previous exposure to rabies vaccine or rabies immunoglobulin.
2. Used any specific or non-specific immunoglobulin or antiserum products within 6 months, or plan to use them during the study.
3. History of bites from rabies virus-exposed animals (e.g., dogs and cats) within the past 6 months.
4. Wound closed after category III rabies virus exposure.
5. Suspected rabies symptoms and/or signs.
6. History of severe allergic reactions to vaccines, medications, or foods, with severity reaching category III or higher according to the 2019 classification criteria.
7. Known allergy to any ingredients in the trial drug or vaccine.
8. Volunteers with clinically significant acute illnesses, acute exacerbations of chronic diseases, or infectious diseases, as determined by the investigator, within 2 weeks prior to the initial administration.
9. Congenital disease or defect.
10. Medical history indicating heart, liver, kidney, blood, digestive tract, nervous system, mental abnormalities, or metabolic abnormalities, as judged by the investigator to affect study evaluation.
11. Volunteers with immune dysfunction or autoimmune diseases (e.g., AIDS and systemic lupus erythematosus).
12. Injection or oral use of glucocorticoids within 3 days before the injection of the test drug.
13. Receipt of glucocorticoid injections or oral administration for at least 14 days within the 3 months prior to enrollment, with a daily dose ≥2 mg/kg or ≥20 mg of prednisone, or an equivalent dose.
14. Use of other systemic immunosuppressants (other than glucocorticoids) within 3 months before enrollment.
15. Vaccinate with live attenuated vaccines (e.g., measles) within 14 days before the trial drug or vaccine is administered, or plan to use such vaccines within 3 months after the trial drug is administered.
16. Get other inactivated vaccines within 7 days before receiving the trial drug or vaccine.
17. Receipt of other investigational or unregistered product (drug, vaccine, biological product, or device) other than the investigational product within 1 month prior to the injection of the investigational drug or vaccine, or plan to use it during the study.
18. History of thrombocytopenia or other coagulation disorders that may contraindicate intramuscular injection.
19. History of convulsions, epilepsy, mental, or neurological diseases, or a family history of epilepsy.
20. Any other circumstance that the investigator considers likely to affect trial assessment.

SUPPLEMENTARY TABLE S2. Seropositivity rates of rabies virus neutralizing antibodies at various time points after administration in different age subgroups (FAS1, *N*=239).

Day	Age	Ormutivimab (*N*=119)			HRIG (*N*=120)			*P*
		N	*n* (%)	95% *CI*	*N*	*n* (%)	95% *CI*	
Pre-administration	1–5	50	4 (8.00)	2.22, 19.23	41	3 (7.32)	1.54, 19.92	1.0000
	6–11	57	7 (12.28)	5.08, 23.68	57	6 (10.53)	3.96, 21.52	0.7683
	12–17	12	2 (16.67)	2.09, 48.41	22	3 (13.64)	2.91, 34.91	1.0000
3	1–5	50	8 (16.00)	7.17, 29.11	41	9 (21.95)	10.56, 37.61	0.4686
	6–11	57	14 (24.56)	14.13, 37.76	57	12 (21.05)	11.38, 33.89	0.6553
	12–17	12	3 (25.00)	5.49, 57.19	22	5 (22.73)	7.82, 45.37	1.0000
7	1–5	50	39 (78.00)	64.04, 88.47	41	29 (70.73)	54.46, 83.87	0.4273
	6–11	57	43 (75.44)	62.24, 85.87	57	35 (61.40)	47.57, 74.00	0.1070
	12–17	12	5 (41.67)	15.17, 72.33	22	8 (36.36)	17.20, 59.34	1.0000
14	1–5	50	50 (100.00)	92.89, 100.00	41	41 (100.00)	91.40, 100.00	1.0000
	6–11	57	57 (100.00)	93.73, 100.00	57	57 (100.00)	93.73, 100.00	1.0000
	12–17	12	12 (100.00)	73.54, 100.00	22	22 (100.00)	84.56, 100.00	1.0000
42	1–5	50	50 (100.00)	92.89, 100.00	41	41 (100.00)	91.40, 100.00	1.0000
	6–11	57	57 (100.00)	93.73, 100.00	57	57 (100.00)	93.73, 100.00	1.0000
	12–17	12	12 (100.00)	73.54, 100.00	22	22 (100.00)	84.56, 100.00	1.0000

Note: FAS1 means the full analytical set for neutralizing antibody activity consisted of 239 participants, including 119 in the Ormutivimab group and 120 in the HRIG group.
Abbreviation: HRIG=human rabies immunoglobulin; *CI*=confidence interval.

(*CIs*) were obtained following inverse logarithmic transformation.

Definitions in this Clinical Trial

Positivity: the RVNA levels ≥0.5 IU/mL.

Rabies seroconversion rate: the proportion of individuals with post-treatment anti-RVNA levels ≥0.5 IU/mL among those with pre-treatment levels <0.5 IU/mL.

SUPPLEMENTARY TABLE S3. GMC of rabies virus neutralizing antibodies at various time points after administration in each age subgroup (FAS1, *N*=239).

Time	Age (years)	Group	*N*	GMC	95% *CI**	Control for GMC	95% *CI*	Calibrated GMC ratio†		*P*
								Estimated	95% *CI*	
Pre-administration	1−5	Ormutivimab	50	0.20	0.17, 0.25	/	/	/	/	/
		HRIG	41	0.25	0.19, 0.34	/	/			
	6−11	Ormutivimab	57	0.24	0.19, 0.30	/	/	/	/	/
		HRIG	57	0.20	0.17, 0.25	/	/			
	12−17	Ormutivimab	12	0.23	0.13, 0.42	/	/	/	/	/
		HRIG	22	0.22	0.15, 0.33	/	/			
3	1−5	Ormutivimab	50	0.30	0.27, 0.35	0.34	0.30, 0.38	0.87	0.77, 1.00	0.0456
		HRIG	41	0.40	0.31, 0.53	0.39	0.34, 0.44			
	6−11	Ormutivimab	57	0.35	0.29, 0.42	0.34	0.32, 0.37	0.88	0.79, 0.99	0.0284
		HRIG	57	0.36	0.31, 0.43	0.39	0.36, 0.42			
	12−17	Ormutivimab	12	0.30	0.20, 0.45	0.30	0.26, 0.36	0.91	0.75, 1.11	0.3542
		HRIG	22	0.34	0.26, 0.45	0.33	0.30, 0.38			
7	1−5	Ormutivimab	50	0.80	0.66, 0.96	0.90	0.70, 1.15	1.11	0.82, 1.50	0.5047
		HRIG	41	0.85	0.57, 1.28	0.81	0.61, 1.08			
	6−11	Ormutivimab	57	1.03	0.77, 1.37	1.03	0.82, 1.29	1.00	0.74, 1.37	0.9772
		HRIG	57	0.93	0.66, 1.32	1.02	0.82, 1.28			
	12−17	Ormutivimab	12	0.72	0.32, 1.61	0.69	0.43, 1.10	1.06	0.58, 1.93	0.8459
		HRIG	22	0.66	0.38, 1.13	0.65	0.45, 0.93			
14	1−5	Ormutivimab	50	72.42	56.04, 93.58	73.18	51.55, 103.89	3.21	2.07, 4.98	<0.0001
		HRIG	41	22.77	15.93, 32.55	22.78	15.10, 34.36			
	6−11	Ormutivimab	57	47.65	37.11, 61.18	47.39	36.46, 61.60	1.66	1.16, 2.37	0.0061
		HRIG	57	28.52	22.03, 36.93	28.58	22.14, 36.90			
	12−17	Ormutivimab	12	54.42	35.93, 82.42	58.16	35.01, 96.61	2.71	1.42, 5.18	0.0038
		HRIG	22	23.14	14.81, 36.15	21.45	14.54, 31.66			
42	1−5	Ormutivimab	50	54.01	42.07, 69.33	49.38	37.68, 64.72	2.38	1.69, 3.34	<0.0001
		HRIG	41	24.01	18.87, 30.54	20.77	15.12, 28.53			
	6−11	Ormutivimab	57	35.56	28.22, 44.81	34.29	27.03, 43.51	1.41	1.02, 1.96	0.0372
		HRIG	57	25.04	19.81, 31.65	24.26	19.24, 30.60			
	12−17	Ormutivimab	12	29.21	18.60, 45.89	30.22	18.77, 48.64	1.40	0.76, 2.57	0.2668
		HRIG	22	22.62	15.99, 32.00	21.59	14.99, 31.10			

Abbreviation: mFAS1=a subset of FAS1, excluding subjects with pre-treatment neutralizing antibody levels ≥0.5 IU/mL; HRIG=human rabies immunoglobulin; GMC=geometric mean concentration; *CI*=confidence interval.

* Based on descriptive statistical analysis results without model adjustment.

† Based on the least-squares estimates and *P* from the covariance analysis model; corrected GMC ratio = experimental group / control group.

Outbreak Reports

Epidemiological Investigation of a Tuberculosis Cluster Outbreak at a University — Changsha City, Hunan Province, China, September 2023–November 2025

Cifu Xie[1]; Pengliang Yin[1]; Linxin Song[1]; Zi Xiong[1,#]; Liqiong Bai[2,#]

Summary

What is already known about this topic?

Tuberculosis (TB) is prone to cause clustered transmission in schools.

What is added by this report?

Following outbreak, the university conducted terminal disinfection of epidemic sites; however, *Mycobacterium tuberculosis* was detected (including air conditioner filters and air). Individuals with latent TB infection who receive preventive immunotherapy with Mycobacterium vaccae can develop active TB. Active cases were not identified promptly after preventive treatment, leading to renewed transmission.

What are the implications for public health practice?

Guidelines should add disinfection effectiveness evaluations and cover easily overlooked items, such as air conditioner filters. Follow-up examinations for individuals with LTBI who have completed preventive treatment remain necessary, as they still face a significant risk of developing active TB.

ABSTRACT

Introduction: From September 2023 to November 2025, a cluster outbreak of active tuberculosis (TB) was identified at a university in Changsha City, Hunan Province, China.

Methods: Contacts were screened, and patients with positive etiological results underwent sputum culture and drug susceptibility testing. Environmental samples (from air conditioners and air) were collected after terminal disinfection for polymerase chain reaction testing. A quantitative analysis of the infection risk was performed using linear regression models. Preventive intervention treatment effectiveness was evaluated using the log-rank test and Cox proportional hazards regression model.

Results: Of 671 contacts [110: latent tuberculosis infection (LTBI); 25: new active TB], all 26 cases, including the index case, were students. Whole-genome sequencing of five culture-positive cases showed high homology with ≤3 single nucleotide polymorphisms for four of them. For each additional hour of contact with the index patient, the prevalence of LTBI among contacts increased by 0.48%, and the TB incidence among individuals with LTBI increased by 0.20%. Developing active TB among individuals with LTBI who received Mycobacterium vaccae immunotherapy was 0.10 times that of the control group, the cumulative incidence within 2 years remained as high as 10.67%. Terminal disinfection of the epidemic sites was incomplete, and *M. tuberculosis* was detected in the air conditioner filters and air samples from the index case classroom and dormitory.

Conclusion: Contributing factors were failure to detect the index case during the new student entrance health examination, incomplete terminal disinfection of epidemic sites, and lack of follow-up monitoring of individuals with LTBI who received preventive immunotherapy.

Tuberculosis (TB) is a chronic infectious respiratory disease that poses a serious threat to public health. In 2024, the number of new TB cases worldwide reached 10.7 million, with 1.23 million deaths, ranking as the leading cause of death among infectious diseases (*1*). In crowded school settings with enclosed spaces, students have frequent close contact, which can facilitate the transmission of TB on campus (*2*). China has long attached great importance to TB prevention and control in schools. A series of documents have been issued to promote standardized and systematic prevention and control efforts to achieve significant results (*3*). However, several weaknesses remain in the current practice: first, accreditation standards and quality evaluation mechanisms for institutions conducting TB screening during new student entrance

health examinations are not yet robust (*4*); second, there is a lack of scientific evaluation of the effectiveness of terminal disinfection at epidemic sites after an outbreak occurs (*5*); and third, requirements for long-term follow-up and effective monitoring for individuals with latent tuberculosis infection (LTBI) who have completed preventive treatment are not clearly defined (*6*). Evaluating the effectiveness of terminal disinfection is important because *M. tuberculosis* can persist at overlooked sites (e.g., air conditioner filters) and continue to pose infection risks in enclosed spaces if disinfection is incomplete (*7*). Likewise, evaluating the long-term outcomes of preventive immunotherapy is necessary as the durability of protection remains unclear and individuals who complete preventive treatment may still develop active TB without adequate follow-up (*8*). Between September 2023 and November 2025, a prolonged, large-scale cluster outbreak of TB was reported at a university in Changsha City, Hunan Province, China. Through an in-depth investigation of the outbreak, this study aimed to systematically describe its epidemiological characteristics, evaluate the effectiveness of terminal disinfection at epidemic sites and preventive treatment, analyze the relationship between infection/incidence risk and exposure duration, use empirical evidence to reveal key issues in current school TB prevention and control, and provide scientific evidence and management recommendations for optimizing prevention and control strategies.

INVESTIGATION AND RESULTS

Description of the Index Case

The index case was an 18-year-old male freshman majoring in physical education in class 2301, residing in room 419, Building 11 West. During his entrance health examination on September 10, 2023, the examination institution determined that his chest radiograph showed no abnormalities. However, upon re-reading by experts from the local municipal CDC and designated TB hospital, abnormal findings were identified on the chest radiographs.

He developed a productive cough on November 15, 2023, followed by progressive worsening of the cough and hemoptysis. From December 3 to December 18, 2023, he was treated for influenza A and pneumonia at two non-TB designated hospitals; however, his symptoms worsened. On December 19, 2023, he sought treatment at Hunan Provincial Chest Hospital and was diagnosed with cavitary pulmonary TB (sputum smear-positive 2+, rifampicin-susceptible), where his chest imaging findings revealed patchy high-density opacities in the dorsal segment of the right lower lobe, accompanied by a thick-walled cavity with smooth walls and no visible air-fluid level, surrounded by patchy satellite lesions. On December 22, 2023, the Centers for Disease Control and Prevention initiated an epidemiological investigation after receiving the report. The investigation revealed that he had classmates with TB in high school.

Distribution of Cases and LTBI

Among the 671 contacts, 110 individuals with LTBI were identified (Table 1), including 70 males, 40 females, 103 students, and seven staff members.

In total, 26 active TB cases (including the index case) were identified (13 confirmed pulmonary TB, 11 clinically diagnosed pulmonary TB, 2 extrapulmonary TB), all were students (18 males, 8 females), of whom 17 were asymptomatic (65.38%). The outbreak began with the first case identified in September 2023 and was followed by a gradual increase.

Two secondary case peaks occurred in January and April 2024. The outbreak subsided from August 2024 to July 2025 but resurged in August 2025, with a third peak in September 2025. The last case occurred in November 2025, with an outbreak duration of 28 months (Figure 1). The temporal distribution of cases was closely aligned with the timing of each screening round. Most individuals with LTBI and secondary cases were identified during the first and second rounds of screening, suggesting that contact identification was accurate. During the third round, the infection rate among contacts was only 6.96%, indicating that further expansion of screening is of limited necessity.

Evaluation of Preventive Treatment Effectiveness

Among individuals with LTBI, 35 did not receive preventive treatment (control group), with a 2-year cumulative incidence of 45.71%, which was concentrated in the early follow-up period. Seventy-five patients received Mycobacterium vaccae immunotherapy (intervention group), with a 2-year cumulative incidence rate of 10.67%. The intervention group had a lower risk in the early follow-up period; however, this risk increased significantly in the later period. log-Rank test results showed that the 2-year cumulative incidence in the intervention group was lower than that in the control group (χ^2=23.27,

TABLE 1. Details of contact screening.

Screening	Contact type	Number of contacts (*n*)	Number of LTBI (*n*)	Prevalence of LTBI among contacts (%)	Number of secondary cases (*n*)	TB incidence among individuals with LTBI (%)	Average exposure duration (hours)
First-round	Class 2301: Classmates of the index case	24	23	95.83	10	43.48	213.0
	Class 2301: Teachers of the index case	8	2	25.00	0	0.00	14.8
	Class 2302: Shared a classroom concurrently and self-study together	23	20	86.96	8	40.00	172.5
Second-round	Class 2307: Shared a classroom concurrently	24	18	75.00	3	16.67	100.5
	Class 2306: Shared a classroom concurrently	22	6	27.27	1	16.67	73.5
	Class 2303: Shared a classroom concurrently	24	3	12.50	0	0.00	73.5
Third-round	Same dormitory floor; Used the classroom later; Dormitory management staff	546	38	6.96	3	7.89	–
	Total	671	110	16.4	25	22.7	–

Note: "–" means no direct contact with the index case.
Abbreviation: LTBI=latent tuberculosis infection; TB=tuberculosis.

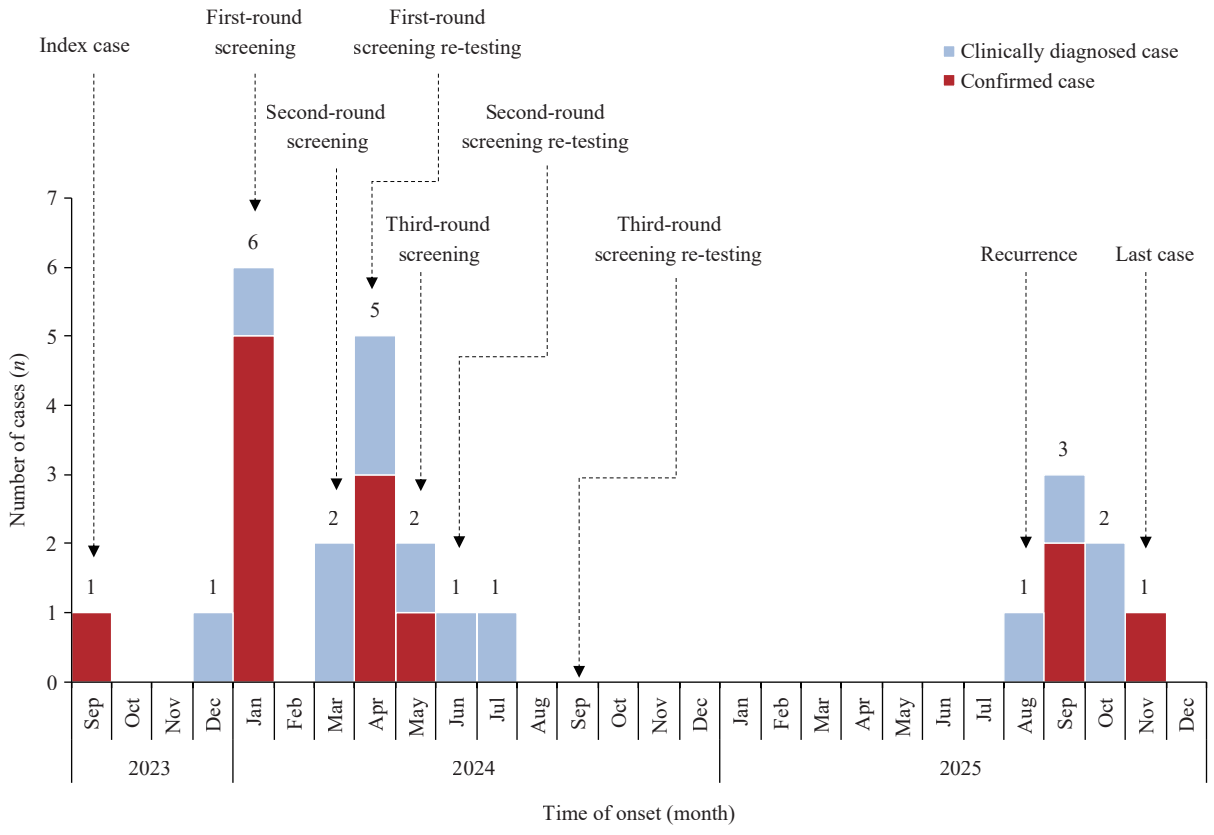


FIGURE 1. Epidemiological curve of a TB outbreak in Changsha City, Hunan Province, China, September 2023–November 2025.
Abbreviation: TB=tuberculosis.

P<0.01). The multivariable Cox proportional hazards regression model results, after adjusting for gender and age, showed that the hazard ratio (*HR*) in the intervention group was 0.10 [95% confidence interval

(*CI*): 0.04, 0.25] compared with the control group, indicating that the 2-year cumulative incidence risk in the intervention group was 0.10 times or 90.04% reduced risk that of the control group (Figure 2).

Environmental Health Investigation

The ventilation conditions in the classrooms and dormitory where the cases occurred were poor, with no fans or air conditioners installed. In April 2024, the local CDC investigation found that the university had completed terminal disinfection of the epidemic sites but had missed air conditioner filters, suggesting that *M. tuberculosis* may persist in the environment. To test this hypothesis, laboratory staff collected environmental samples (air conditioner filters and air) from four of the nine classrooms and five of the 15 dormitory rooms involved in the outbreak. *M. tuberculosis* was detected in air conditioner filter samples from all 4 classrooms and 5 dormitory rooms, and in air samples from 2 dormitory rooms. Among the 25 secondary cases, all were contacts of the index case, sharing the same classroom, dormitory, or dormitory floor, or using the same classroom after the index case. Their environmental exposure settings were identical or similar to those of the index case; therefore, the environmental hygiene conditions were not described separately.

PUBLIC HEALTH RESPONSE

The ventilation conditions in the classrooms and dormitory where the cases occurred were poor, with no fans or air conditioners installed. In April 2024, the local CDC investigation found that the university had completed terminal disinfection of the epidemic sites but had missed the air conditioner filters, suggesting that M. tuberculosis may persist in the environment. To test this hypothesis, laboratory staff collected environmental samples (air conditioner filters and air) from four of the nine classrooms and five of the 15 dormitory rooms involved in the outbreak. *M. tuberculosis* was detected in air conditioner filter samples from all 4 classrooms and 5 dormitory rooms, and in air samples from 2 dormitory rooms. Among the 25 secondary cases, all were contacts of the index case, sharing the same classroom, dormitory, or dormitory floor, or using the same classroom after the index case. Their environmental exposure settings were identical or similar to those of the index case; therefore, the environmental hygiene conditions were not described separately.

DISCUSSION

The school TB outbreak involved 26 cases. After its occurrence, comprehensive prevention and control

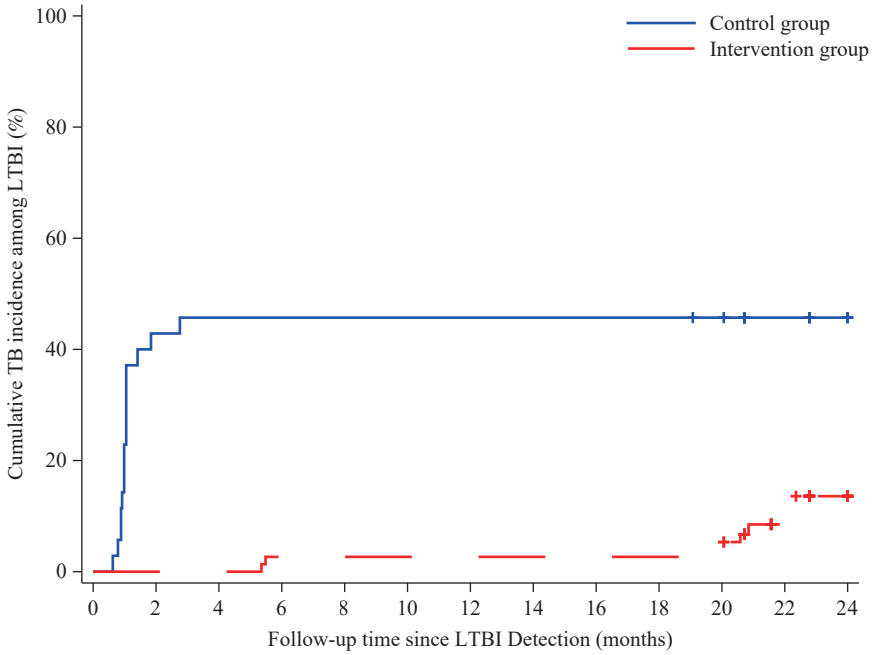


FIGURE 2. Survival analysis of preventive treatment in individuals with LTBI.
Abbreviation: LTBI=latent tuberculosis infection; TB=tuberculosis.

measures were implemented, resulting in no deaths or serious negative social impacts. According to the *Chinese School Tuberculosis Prevention and Control Guidelines (2020 Edition)* (*Guidelines 2020*) (*3*), this incident was determined to be a cluster outbreak of PTB in schools.

This outbreak reflects three urgent issues that need to be addressed:

First, the accreditation standards and quality evaluation mechanisms for institutions conducting TB screening during new student entrance health examinations are not yet robust (*4*). Since 2017, TB screening has been included as a mandatory component of entrance health examinations in China for new students, and routine health examinations for faculty and staff in all types of schools, effectively preventing patients with TB from transmitting the disease on campus (*9*). However, it is noteworthy that the current accreditation standards for entrance health examination institutions are low, leading to uneven quality. TB cluster outbreaks caused by lax screening at entrance examination institutions are common. The health examination institution involved in this outbreak did not participate in the quality control training organized by the local CDC. It conducted TB screening for approximately 9,000 new students at this university but reported no abnormalities. This institution's failure to detect abnormalities in the index patient's chest radiograph was a key reason for the development of this cluster outbreak. Therefore, it is necessary to issue national or local regulations to raise the accreditation threshold for health examination institutions, clarify their capacity limits, participate in mandatory local CDC training for TB screening institutions, and establish penalty standards for missed diagnoses.

Second, there are no requirements for evaluating the effectiveness of terminal disinfection at epidemic sites (*5*). *M. tuberculosis* is resistant to acid, alkali, natural environments, and drying and can survive in dried sputum for 6 to 8 months. Failure to disinfect air conditioner filters during terminal disinfection at schools was a significant factor in the prolonged outbreak. When teachers and students at the epidemic sites turned on air conditioners and closed windows and doors, classrooms and dormitory spaces became enclosed, creating favorable conditions for disease transmission. Environmental sample testing results showed that *M. tuberculosis* was detected in air conditioner filters and air from classrooms and dormitories where cases occurred (*7*), indicating that individuals at these sites faced a continued risk of infection. Currently, the *Guidelines 2020* do not mention air conditioner filters in their list of disinfection targets and do not require an evaluation of terminal disinfection effectiveness (*5*).

Third, the follow-up monitoring requirements for individuals with LTBI who have completed preventive treatment require urgent revision. According to the *Guidelines 2020*, individuals with LTBI who refuse preventive treatment should undergo chest radiography examinations at 3, 6, and 12 months after screening. However, patients who complete preventive treatment are only required to undergo one chest radiography at the end of the treatment course (*3*). This outbreak investigation found that compared with the control group, the intervention group receiving preventive immunotherapy had a 90.04% reduced risk of developing active TB. However, the cumulative incidence within two years in the intervention group was still as high as 10.67%. The risk in the intervention group was low in the early intervention period, but rebounded significantly after one year. As an immunomodulator, the protective effect of Mycobacterium vaccae depends on the quantity and function of memory T cells in the body. In the absence of sustained stimulation by pathogens or antigens, memory T cells gradually undergo apoptosis (*8*). Therefore, it is necessary to increase the frequency of follow-up monitoring of individuals who have completed preventive immunotherapy to prevent renewed outbreaks due to delayed case detection.

Therefore, we propose: 1) Raise accreditation threshold for entrance screening institutions, enforce penalties for missed diagnoses, and strengthen quality control. 2) Require environmental sampling, including air conditioner filters, after terminal disinfection at outbreak sites to confirm *M. tuberculosis* elimination. 3) For LTBI individuals completing preventive immunotherapy, conduct chest imaging follow-ups (e.g., at 6, 12, and 24 months) to detect active TB cases that may arise due to waning immunity. 4) Tier contact management by exposure duration: longer exposure warrants more frequent screening and prioritization for preventive treatment, whereas shorter exposure allows a simplified protocol.

For details on Methods, Overview of the School, Spatial Distribution Description, Quantitative Analysis of Infection Risk and Disease Onset Risk, Laboratory Investigation, Supplementary Discussion, see the supplementary materials (available at https://weekly.chinacdc.cn).

Conflicts of interest: No conflicts of interest

Acknowledgments: All field epidemiologists, laboratory personnel and imaging staff involved in the investigation and response to this outbreak.

Funding: Supported by Health Research Project of Hunan Provincial Health Commission (grant number: W20243059).

doi: 10.46234/ccdcw2026.084

[#] Corresponding authors: Zi Xiong, changshajfk@163.com; Liqiong Bai, liqiong99@126.com.

[1] Department of Tuberculosis Prevention and Control, Changsha Center for Disease Control and Prevention, Changsha City, Hunan Province, China; [2] Department of Director's Office, Hunan Chest Hospital, Changsha City, Hunan Province, China.

Submitted: February 10, 2026
Accepted: March 30, 2026
Issued: April 24, 2026

REFERENCES

1. World Health Organization. Global tuberculosis report 2025. Geneva: World Health Organization; 2025. https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2025.
2. Yuan Y, Wang X, Zhou Y, Zhou C, Li S. Prevalence and risk factors of latent tuberculosis infection among college students: a systematic review and meta-analysis. Public Health 2022;213:135–46. doi: 10.1016/j.puhe.2022.10.003.
3. National Health Commission of the People's Republic of China, Ministry of Education of the People's Republic of China. Guidelines for tuberculosis prevention and control in schools in China. 2020. http://www.moe.gov.cn/jyb_xxgk/moe_1777/moe_1779/202102/t20210218_513576.html. [2025-12-9]. (In Chinese).
4. Cheng J, Gao L. Application of Mycobacterium tuberculosis infection testing in school populations. Chin J Antituberc 2022;44(8):757-61. doi: 10.19982/j.issn.1000-6621.20220193. (In Chinese).
5. Luo Y, Tao FX, Li GF, Zhang HH, Peng P, Ren Y, et al. Environmental monitoring and analysis of Mycobacterium tuberculosis and discussion on the effect of disinfection equipment in a tuberculosis hospital. J Tuberc Lung Dis 2023;4(2):135–40. doi: 10.19983/j.issn.2096-8493.20230017. (In Chinese).
6. Qiu ML, Jiang Y, Li MY, Pan XY. Latent tuberculosis infection and preventive treatment among in-school students: a review. Prev Med 2024;36(1):70–3, 77. doi: 10.19485/j.cnki.issn2096-5087.2024.01.008. (In Chinese).
7. Bunyasi EW, Middelkoop K, Koch A, Hoosen Z, Mulenga H, Verver S, et al. Molecular detection of airborne Mycobacterium tuberculosis in South African high schools. Am J Respir Crit Care Med 2022;205(3):350–6. doi: 10.1164/rccm.202102-0405OC.
8. Gao DJ, Huo LL, Lao HL, Wei HD, Ma Q. Cellular immunology mechanism of Mycobacterium vaccae in the preventive treatment of latent tuberculosis infection. Chin J Nosocomiol 2016;26(7):1480–2. doi: 10.11816/cn.ni.2016-151316. (In Chinese).
9. National Health Commission of the People's Republic of China, Ministry of Education of the People's Republic of China. Notice on issuing the guidelines for tuberculosis prevention and control in schools (2017 Edition). 2017. http://www.moe.gov.cn/srcsite/A17/moe_943/s3285/201707/t20170727_310182.html. [2025-12-9]. (In Chinese).

SUPPLEMENTARY MATERIALS

Methods

Contact screening was conducted as follows: simultaneous screening for tuberculosis (TB) symptoms, recombinant Mycobacterium tuberculosis fusion protein (EC) skin testing, and chest radiography; etiological examination of patients with abnormalities; and strain identification and drug susceptibility testing of etiologically positive cases. EC-negative individuals were retested after three months. EC-positive individuals receiving preventive treatment underwent chest radiography upon completion; those declining treatment were followed by chest radiography at 3, 6, and 12 months. Immunoprophylaxis with *Mycobacterium vaccae* (six doses) was administered.

Culture-positive strains underwent whole-genome sequencing. Using high-throughput next-generation sequencing technology, single nucleotide polymorphism (SNP) variation information of the target genome relative to the reference genome was obtained. Environmental samples (from air conditioners and air) were collected after terminal disinfection of epidemic sites for polymerase chain reaction (PCR) testing.

The data collection methods were as follows: contact information was provided by the school; the duration of exposure between contacts and the index case was calculated based on class schedules and evening self-study arrangements, with one class period equivalent to 45 minutes [The index case class (2301) shared a fixed classroom for evening self-study with class 2302 and shared classes to varying degrees with classes 2303, 2306, and 2307. Based on the course schedule and evening self-study duration assessment, the average exposure durations between the index case (from enrollment on September 10, 2023, to leaving school on December 8, 2023) and students from classes 2301, 2302, 2303, 2306, and 2307 were 213.00 hours, 172.50 hours, 73.50 hours, 73.50 hours, and 100.50 hours, respectively; for staff in class 2301, the average contact hours were 14.81 hours.]; information on latent tuberculosis infection (LTBI) was provided by the screening institutions; and case information was obtained from investigations by the Centers for Disease Control and Prevention, school follow-up, and case reports from medical institutions.

Data were processed and analyzed using SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA). Quantitative analyses of the prevalence of LTBI among contacts (Y_1) and the incidence of TB among individuals with LTBI (Y_2) in relation to exposure duration (X) were performed using linear regression models, as defined below. The Shapiro–Wilk test was used to examine whether the residuals satisfied normality, and the White test was used to examine whether the residuals satisfied homoscedasticity. Survival analysis was conducted with the time of LTBI diagnosis as the starting point and the onset of active TB as the endpoint, with a follow-up period of 24 months. The log-rank test was used to compare the cumulative incidences between the intervention and control groups. The hazard ratios (HRs) between the groups were evaluated using the Cox proportional hazards regression model under the proportional hazards assumption.

$$Y_1 = \frac{Number\ of\ individuals\ with\ LTBI}{Number\ of\ contacts}$$

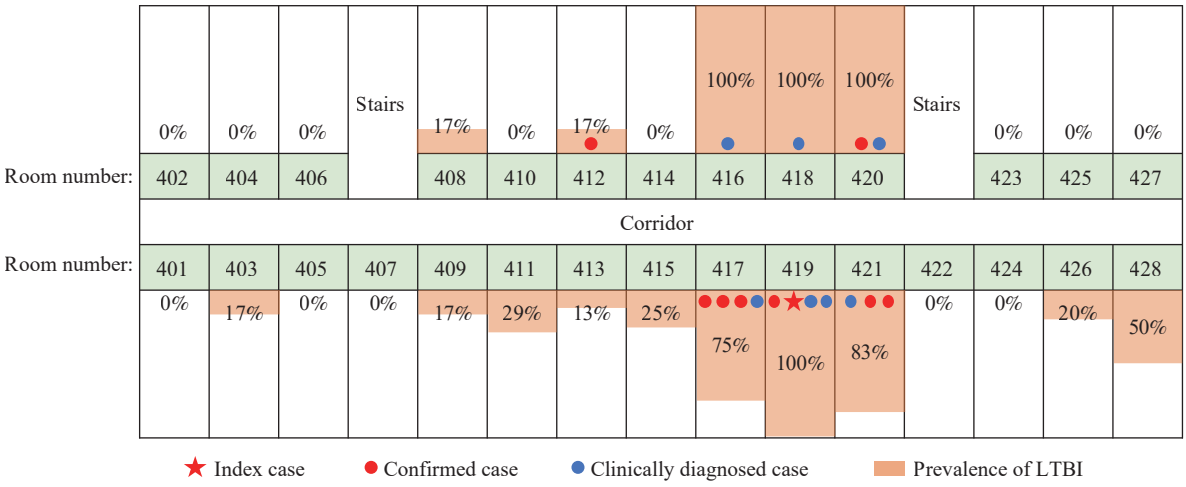
$$Y_2 = \frac{Number\ of\ secondary\ TB\ cases}{Number\ of\ individuals\ with\ LTBI}$$

Overview of the School

The outbreak occurred at a private undergraduate university (three-year academic system and open management model), comprising 1,800 faculty and staff and 31,200 students, with the majority from Hunan Province. Infirmary included three doctors, six nurses, and one staff. In 2023, a new student entrance health examination was contracted to a local hospital through university bidding. Approximately 9,000 new students underwent the examination; however, no abnormalities were reported. The investigation revealed that this hospital did not participate in the quality control training organized by the local CDC.

Spatial Distribution Description

Spatial clustering was observed in the dormitory, with higher infection and progression risks closer to those of the index case (Supplementary Figure S1).



SUPPLEMENTARY FIGURE S1. Screening results on the same floor of the male dormitory where the index case resided. Abbreviation: LTBI=latent tuberculosis infection.

Quantitative Analysis of Infection Risk and Disease Onset Risk

Scatter plots showed that the prevalence of LTBI among contacts (Y_1) in each class was linearly distributed with exposure duration (X). Linear regression analysis revealed that the linear regression equation was Y_1=0.48%X, which was statistically significant (F=79.46, P<0.01). For each additional hour of exposure, the prevalence of LTBI among contacts increased by 0.48% (Supplementary Figure S2).

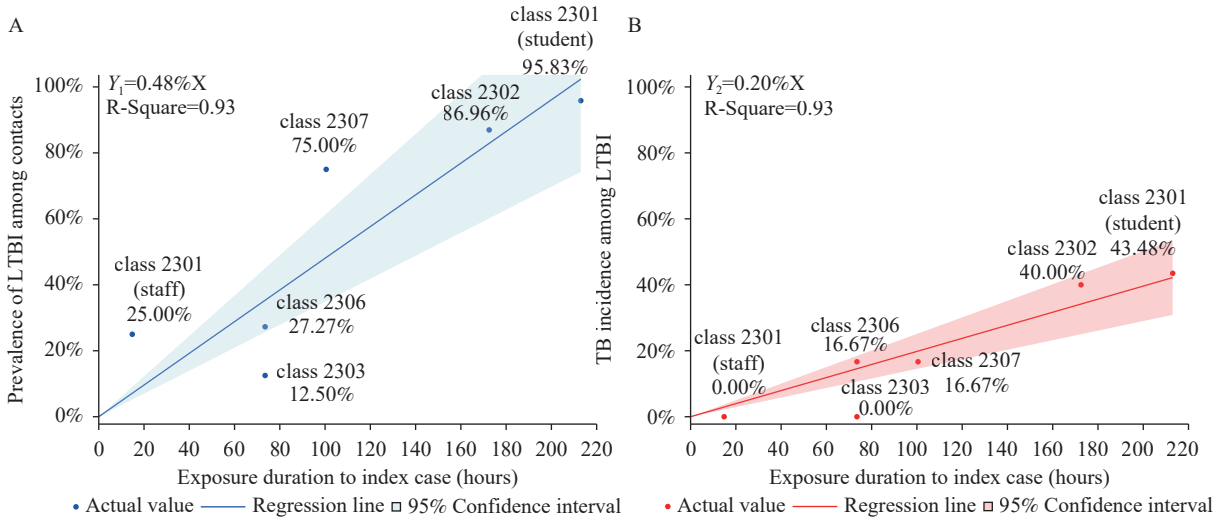
Scatter plots showed that the secondary incidence rate (Y_2) among individuals with LTBI in each class was linearly distributed with exposure duration (X). Linear regression analysis revealed that the linear regression equation was Y_2=0.20%X, which was statistically significant (F=83.53, P<0.01). For each additional hour of exposure, the incidence of TB among individuals with LTBI increased by 0.20% (Supplementary Figure S2).

Laboratory Investigation

Whole-genome sequencing was performed on five culture-positive strains. Testing revealed that all five strains belonged to the Beijing genotype (rifampicin-susceptible). Among them, four exhibited high homology (SNPs≤3), while the remaining one showed significant SNP divergence from the other four (SNPs from 450 to 452), suggesting the possible presence of two different sources of infection in this outbreak. For the four cases with high genomic homology, epidemiological investigation confirmed that they shared classroom and evening self-study sessions with the index case, with cumulative exposure durations ranging from 172.50 to 213.00 hours, and no other identifiable sources of infection, establishing a clear epidemiological link. The case with the non-homologous strain was in the same class as the index case, resided in a dormitory adjacent to that of the index case, and shared the same contact population as the index case.

Supplementary Discussion

The outbreak exhibited three key characteristics, including high transmissibility. The infection rate among the contacts identified in the first round of screening was 81.8%, which is extremely rare in other school TB outbreaks (*1*–*2*). This was primarily because the index case was sputum smear-positive 2+ with cavitary lesions, presenting obvious symptoms of cough and hemoptysis, and was highly infectious, transmitting the disease on campus for nearly three months from September 10 to December 8, 2023. Simultaneously, genotypic homology analysis results indicated the presence of two sources of infection in this outbreak, which suggests the possible presence of other sources of infection, in addition to the index case, contributing to transmission within the school. Second, the strains were highly pathogenic. The incidence of TB among 110 individuals with LTBI was 22.73% during the 2-year follow-up period. The incidence of TB among individuals with LTBI in classes 2301 and 2302 was even higher, reaching 43.48% and 40.00%, respectively, significantly exceeding the previously understood lifetime risk of 5%–10% for individuals with LTBI to develop active disease (*3*). Whole-genome sequencing results revealed that



SUPPLEMENTARY FIGURE S2. Linear regression analysis of the prevalence of LTBI among contacts and incidence of TB among individuals in relation to exposure duration. (A) Linear regression analysis of the prevalence of LTBI among contacts in relation to exposure duration. (B) Linear regression analysis of the incidence of TB among individuals with LTBI in relation to exposure duration.
Abbreviation: LTBI=latent tuberculosis infection; TB=tuberculosis.

the strain responsible for this outbreak was the Beijing genotype, providing laboratory evidence supporting its high pathogenicity and transmissibility (*4*). Third, there was a wide range of impacts, with 671 contacts identified. Owing to the index case-sharing classes and evening self-study sessions with other classes, and not using a fixed classroom, the outbreak spread across multiple classes.

Notably, there was a one-year period with no new cases between the early and late stages of this outbreak. There are two possible reasons for this finding. Preventive treatment reduces the risk of disease progression in patients with LTBI. In this study, immunoprophylaxis with Mycobacterium vaccae (6 doses) was used in individuals with LTBI, and Cox regression analysis showed a protective efficacy of 90.04%. Among the 110 patients with LTBI, 75 (68.18%) received preventive treatment, representing a high coverage rate that enhanced their short-term immunity and lowered their risk of developing active disease. Second, case detection may have been delayed. The individuals involved in this outbreak were primarily sports-related majors in good physical condition, and their symptoms at disease onset were often subtle. Of the 26 patients with TB, 17 presented with no obvious symptoms. Moreover, individuals with LTBI who received preventive treatment were not subjected to additional follow-up examinations, which may have led to subsequent cases being detected only when symptoms appeared. Therefore, the actual period without new cases may be shorter than one year.

Limitations include, regular immunological monitoring (e.g., T-cell responses) in individuals with LTBI who received Mycobacterium vaccae immunization was not performed. As environmental samples were tested using PCR without concurrent culture, the viability of the detected *M. tuberculosis* could not be determined. Finally, linear regression analysis included only six data points, resulting in limited statistical power.

REFERENCES

1. Wang SL, Cui Y, Liu NQ, Wang XJ, Wang XQ, Wu WD, et al. A tuberculosis outbreak at a school — Xinjiang Uygur autonomous Region, China, 2019. China CDC Wkly. 2020;2(46):881 – 3. https://doi.org/10.46234/ccdcw2020.240.
2. Li D, Peng XW, Hou SY, Li T, Yu XJ. A tuberculosis outbreak during the COVID-19 pandemic — Hubei Province, China, 2020. China CDC Wkly 2021;3(26):562 – 5. https://doi.org/10.46234/ccdcw2021.145.
3. World Health Organization. WHO consolidated guidelines on tuberculosis. Module 1: Prevention – Tuberculosis preventive treatment, second edition. Geneva: World Health Organization; 2024. https://www.who.int/publications/i/item/9789240097773.
4. Hanekom M, Van Pittius NCG, McEvoy C, Victor TC, Van Helden PD, Warren RM. *Mycobacterium tuberculosis* Beijing genotype: a template for success. Tuberculosis 2011;91(6):510 – 23. https://doi.org/10.1016/j.tube.2011.07.005.

Erratum

Vol. 7 No. 4

In the article entitled *Respiratory Pathogen Profiles of Patients — Beijing Municipality, China, November 2023–April 2024* [2025, 7(4): 113–120. doi: 10.46234/ccdcw2025.018], two corrections should be made. Correction to author affiliations: The superscript for the corresponding author Rui Song should be changed from "2,*" to "5,*", where affiliation 5 is Beijing Ditan Hospital, Capital Medical University, Beijing, China. Correction to text and Figure 4: On page 117 and throughout Figure 4 (page 118), the statistical term and its abbreviation should be corrected from "hazard ratios (*HR*)" to "odds ratios (*OR*)"; this applies to the main text, all y-axis labels, and the figure footnote.

doi: 10.46234/ccdcw2026.085

Vol. 7 No. 43

In the article entitled *Genomic Characterization of Human Adenovirus Type 21 Strains — 7 PLADs, China, 2023-2024* [2025, 7(43): 1357–1363. doi: 10.46234/ccdcw2025.228], three corrections should be made. Correction to Figure 2: In panel A (penton base protein), the "-" at position 353 should be changed to "D", and the "A" at position 363 should be changed to "-". In panel B (pIIIa protein), the "A" at positions 524-527 should all be changed to "-". Correction to text: On page 1631, "362EE363" should be changed to "362ET363". On page 1357, "116" should be changed to "117".

doi: 10.46234/ccdcw2026.086

Youth Editorial Board

Indexed by Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), PubMed Central (PMC), Scopus, Chinese Scientific and Technical Papers and Citations, and Chinese Science Citation Database (CSCD)

The inauguration of *China CDC Weekly* is in part supported by Project for Enhancing International Impact of China STM Journals Category D (PIIJ2-D-04-(2018)) of China Association for Science and Technology (CAST).

CHINA CDC WEEKLY

CCDC weekly

Vol. 8 No. 17 Apr. 24, 2026

中国疾病预防控制中心周报(英文)

Responsible Authority
National Disease Control and Prevention Administration

Sponsor
Chinese Center for Disease Control and Prevention &
Chinese Academy of Preventive Medicine

Editor-in-Chief
Jianwei Wang

Editing and Publishing
China CDC Weekly Editorial Office
No.155 Changbai Road, Changping District, Beijing, China
Tel: 86-10-63150501, 63150701
Email: weekly@chinacdc.cn

Printing: Beijing Kexin Printing Co., Ltd

Complimentary Access

CSSN
ISSN 2096-7071 (Print)
ISSN 2097-3101 (Online)
CN 10-1629/R1