

Methods and Applications

Risk Assessments for Type 1 Wild Poliovirus and Type 2 Vaccine-Derived Poliovirus Importation and Transmission — China, 2023

Wei Kang^{1,2}; Chunxiang Fan^{1,2}; Yifan Song^{1,2}; Zhaonan Zhang^{1,2}; Xiaoqi Wang^{1,2}; Miao Wang^{1,2}; Jing Ma³; Mulei Chen³; Yuzhen Yang^{1,2}; Yi Wen^{1,2}; Lei Cao^{1,2}; Lance Rodewald^{1,2}; Fuzhen Wang^{1,2}; Zundong Yin^{1,2}; Ning Wen^{1,2}; Hong Yang^{1,2,#}

ABSTRACT

Introduction: All countries face the potential threat of imported polioviruses, including both wild type and circulating vaccine-derived polioviruses. In response, we conducted a province-level assessment in China to evaluate the risk of importation and transmission of type 1 wild poliovirus (WPV1) and type 2 vaccine-derived poliovirus (VDPV2).

Methods: Distinct risk assessment tools for WPV1 and VDPV2 were employed, incorporating three primary indicators — population immunity, poliovirus surveillance, and importation risk. WPV1 was assessed using 13 secondary indicators, whereas VDPV2 utilized 21 secondary indicators. Assessments used comprehensive provincial data from the preceding five years. Scores (S-values) were derived from the secondary indicators' criteria and ratings, and used to classify the provincial-level administrative divisions (PLADs) into three risk categories: high, medium, and low. The top 10% of PLADs were designated as high-risk, with the remaining provinces equally distributed into medium- and low-risk categories.

Results: In 2023, Xizang, Qinghai, and Xinjiang PLADs faced the highest risk of WPV1 importation and transmission; Xizang, Shaanxi, and Hainan PLADs were at the greatest risk for VDPV2 importation and transmission.

Conclusions: Risk assessment for VDPV2 importation and transmission has identified a distinct set of high-risk provinces compared to those identified by WPV1 risk assessment. Preventive and proactive response measures tailored to the specific risks should be implemented to maintain China's polio-free status.

type 1 remains not eradicated. In 2022, there were 30 reported cases of type 1 wild poliovirus (WPV1) globally (1), decreasing to 12 cases in 2023, all of which were first found in Pakistan and Afghanistan (2). Over the past two years, there have been three WPV1 genetic clusters identified across three transmission chains — two within Pakistan and Afghanistan, and one in Africa, which was imported from Pakistan in 2022 but saw transmission halted before the year's end (3). The movement of polioviruses across geographical boundaries places under-vaccinated populations at risk worldwide. Given its adjacency to Pakistan and Afghanistan, China faces an increased threat of WPV1 importation and propagation. Consequently, China performs annual WPV importation and transmission risk assessments at the provincial level to evaluate and mitigate this risk. These assessments help pinpoint provincial-level administrative divisions (PLADs) at the highest risk, allowing for targeted risk reduction strategies.

Global detections of circulating type 2 vaccine-derived poliovirus (cVDPV2) reached their peak in 2020 with 1,905 cases. Subsequently, there was a decline in detections: 1,517 cases in 2021 and 1,132 cases in 2022. Polioviruses were isolated from various sources including acute flaccid paralysis (AFP) cases, asymptomatic individuals (among case contacts, healthy children, and community-based samples), and environmental (wastewater) sources (4). Notably, in 2022, cVDPV2 was detected in countries where polio had been previously eradicated and maintained high vaccination coverage using inactivated poliovirus vaccine (IPV) for many years. Reports of polio cases surfaced from both the United States and Israel (5–6), while contemporaneous detections of type 2 vaccine-derived poliovirus (VDPV2) in wastewater were reported in Israel, the United Kingdom, and Canada (7). These isolates were genetically linked, indicating

Of the three types of wild poliovirus (WPV), only

transnational circulation of the virus.

Given the evolving prevalence of polioviruses, notably the recent global rise of cVDPV2s, in 2023, we incorporated a VDPV2 risk assessment into the annual polio risk evaluation for the first time. Here, we present the findings of WPV1 and VDPV2 importation and transmission risks in China for the year 2023.

METHODS

The WPV1 risk assessment tool implemented in China, originally developed by Zhang Ying et al. in 2013 (8), is detailed in Table 1. This tool was subsequently enhanced to assess the risks associated with VDPV2 importation and transmission, utilizing a modified Delphi technique (9). During this process, two rounds of questionnaire-driven consultations were conducted with 20 experts in polio, AFP surveillance, enterovirus research, and vaccine-preventable diseases. These experts evaluated various indicators, selecting those that most effectively represented the risks of VDPV2 importation and transmission, as shown in Table 2. The weighting values assigned to each significant indicator reflect its relative importance. In Tables 1 and 2, the experts rated the weightings for each leading indicator, where each expert distributed weights across three primary indicators up to a possible total of 10 (8–9).

The two tools, WPV1 and VDPV2 risk, utilize three primary indicators: population immunity, surveillance system quality, and importation risk. Population immunity refers to the community-level resistance against WPV1 or VDPV2 poliovirus. The surveillance system quality is assessed by evaluating the performance of AFP and environmental surveillance systems. Importation risk evaluates the susceptibility to virus importation and subsequent transmission. The VDPV2 tool differs from the WPV1 tool by incorporating additional indicators: IPV coverage, implementation of IPV supplementary vaccination activities, and the presence of direct travel connections between any PLAD in China and a country experiencing cVDPV2 transmission.

The sum of weighted scores (S) was calculated as $S = w_A \times f(A) + w_B \times f(B) + w_C \times f(C)$, where w represents the weight of the secondary indicators and f represents the scores of the secondary indicators. The S scores were ranked from high to low and categorized into high, medium and low-risk groups. The 10% of PLADs with the highest scores were considered high risk, and the

remaining PLADs were divided into half with medium risk and half at low risk.

This study sourced data on vaccine coverage from the China Immunization Information System (CIIS), AFP data from the Acute Flaccid Paralysis Surveillance Information Report Management System (AFPSIRMS), and measles incidence data from the National Notifiable Disease Reporting System (NNDRS). Demographic data were obtained from the China Statistical Yearbook, covering the period from 2018 to 2022. These data were organized, computed, and analyzed descriptively using Microsoft Excel (version 2019, Microsoft, Redmond, USA).

RESULTS

Table 3 presents the risk scores for WPV1 and VDPV2 at the provincial level. For WPV1, S-values ranged from 0 to 34. Scores above 27 denote a high risk, scores between 13 and 27 indicate a medium risk, and scores below 13 represent a low risk. For VDPV2, S-values varied from 17 to 77, with scores above 60 signaling a high risk, scores between 40 and 60 suggesting a medium risk, and scores below 40 signifying a low risk.

For WPV1 risk assessment, the PLADs categorized as high-risk included Xizang, Qinghai, and Xinjiang. Those identified as medium-risk were Chongqing, Ningxia, Jilin, Hubei, Tianjin, Heilongjiang, Anhui, Jiangxi, Guangdong, Gansu, Liaoning, Shanxi, and Guizhou. PLADs such as Beijing, Inner Mongolia, Jiangsu, Zhejiang, Fujian, Shandong, Hainan, Shaanxi, Hunan, Shanghai, Henan, Hebei, Sichuan, Guangxi, and Yunnan were considered low-risk.

For the risk of VDPV2, Xizang, Hainan, and Shaanxi were identified as high-risk PLADs; Chongqing, Tianjin, Qinghai, Shanxi, Xinjiang, Beijing, Guizhou, Hebei, Inner Mongolia, Hubei, Hunan, Anhui, Guangdong, Gansu, and Henan were classified as medium-risk; and Heilongjiang, Fujian, Shandong, Ningxia, Liaoning, Jiangxi, Jilin, Jiangsu, Yunnan, Zhejiang, Shanghai, Guangxi, and Sichuan were considered low-risk PLADs. Detailed scores for provincial second-level indicators are presented in Supplementary Tables S1 and S2 (available at <https://weekly.chinacdc.cn/>).

DISCUSSION

Our study on polio risk assessment employed two

TABLE 1. WPV1 importation and transmission risk assessment tool.

Primary and secondary indicators	Criterion	Scores	Weight
A. Population immunity			
A1. Average PV3 coverage from 2020 to 2022 (%)	>95, 90–95, <90	0, 1, 2	Five
A2. DTaP1 coverage trends from 2020 to 2022 (%)	<10, 10–20, >20	0, 1, 2	Five
A3. Proportion of AFP cases aged ≥6 months with zero doses of PV in the past five years (%)	<2, 2–5, >5	0, 1, 2	Five
A4. Proportion of AFP cases aged ≥6 months with 1–2 doses of PV in the past five years (%)	<5, 5–10, >10	0, 1, 2	Five
A5. Proportion of AFP cases aged ≥6 months with unknown PV vaccination history in the past five years (%)	<5, 5–10, >10	0, 1, 2	Five
A6. Average incidence of measles among 1–14-year-olds from 2020 to 2022 (/100,000)	<5, 5–10, >10	0, 1, 2	Five
B. AFP surveillance system			
B1. NPAFP reported rate in children <15 years from 2020 to 2022 (/100,000)	≥1, <1	0, 1	Three
B2. Proportion of AFP cases with two adequate stool samples obtained in 14 days from 2020 to 2022 (%)	≥80, <80	0, 1	Three
B3. Proportion of reported high-risk AFP cases from 2020 to 2022 (%)	<2, 2–5, >5	0, 1, 2	Three
B4. Whether clustered high-risk AFP cases were reported during 2020 to 2022	No, Yes	0, 1	Three
B5. Average NPEV isolation rate during 2020 to 2022 (%)	>5, 3–5, <3	0, 1, 2	Three
C. Importation risk			
C1. Whether bordering a WPV1 endemic area	No, Yes	0, 1	Six
C2. Previous history of polio outbreaks (including import transmission)	No, Yes	0, 1	Six

Note: The routine immunization schedule for the polio vaccine in China involves IPV administration at 2 and 3 months, and bOPV at 4 months and 4 years. 'Weight' refers to the relative importance of various primary indicators in the risk assessment tool.

Abbreviation: WPV1=type 1 wild poliovirus; AFP=acute flaccid paralysis; PV=polio vaccine; NPAFP=non-polio AFP; NPEV=non-polio enterovirus; bOPV=bivalent oral poliovirus vaccine; PV3=three doses of the polio vaccine; DTaP1=first dose in the series for diphtheria, tetanus, and pertussis vaccination.

independent tools, utilizing provincial-level input data, to ascertain PLADs most vulnerable to the importation and transmission of WPV1 and VDPV2 polioviruses. The findings indicate that Xizang, Qinghai, and Xinjiang are the PLADs most susceptible to WPV1, while Xizang, Shaanxi, and Hainan face the highest risk for VDPV2. Despite the absence of imported polioviruses during 2022–2023, the potential for poliovirus importation from neighboring and distant countries remains a significant concern, posing a continued risk of transmission within China should an importation occur.

The World Health Organization (WHO) recommends that all polio-free countries perform routine annual risk assessments to facilitate the implementation of preventive measures in high-risk areas (10). Such assessments provide a scientific framework for governments to make informed programmatic decisions. Our study utilized both qualitative and quantitative methods to evaluate the poliovirus risk. Research in Pakistan and Afghanistan employed mathematical models to examine transmission dynamics, revealing that these countries form an epidemiological block characterized by sustained transmission among under-vaccinated

populations (11–12). In a similar vein, Australian researchers developed a semi-quantitative risk assessment tool that incorporates two primary indicators: likelihood factors (reintroduction hazard and population susceptibility) and impact factors (detection and response capabilities), which were weighted and integrated (13).

Although certain PLADs were identified as higher-risk areas, the overall risk of WPV1 or VDPV2 importation and transmission in China for 2023 remains relatively low. This is attributed to China's consistent achievement of a high polio vaccine coverage rate and the maintenance of high-quality AFP surveillance (14–15). Moreover, the WHO Western Pacific Region has classified China as a low-polio-risk country.

China's WPV polio risk assessment was last reported in 2019 (16). The recent WPV1 risk assessment results align with those from the past several years, identifying the same three PLADs as high-risk. We recommend that these high-risk PLADs assess their risk factors to refine targeted preventive measures and reduce the risk of importation and transmission.

This study utilized a novel tool designed to assess the risk of importation and transmission of type 2

TABLE 2. VDPV2 importation and transmission risk assessment tool.

Primary and secondary indicators	Criteria	Scores	Weight
A. Population immunity			
A1. Proportion of AFP cases aged ≥ 6 months with 0 doses of PV or unknown immunization history in the past five years (%)	$<2, 2-5, >5$	0, 1, 2	Five
A2. Proportion of AFP cases aged ≥ 6 months with 1–2 doses of PV in the past five years (%)	$<5, 5-10, >10$	0, 1, 2	Five
A3. Proportion of AFP cases aged ≥ 6 months with ≥ 3 doses of PV in the past five years (%)	$>95, 90-95, <90$	0, 1, 2	Five
A4. Average incidence of measles among 1–14-year-olds from 2020 to 2022 (/100,000)	$\leq 2, >2$	0, 1	Five
A5. Proportion of children born between 2016.3.1–2019.10.1 with only one dose of IPV (%)	$<10, 10-20, >20$	0, 1, 2	Five
A6. Proportion of children born between 2016.3.1–2019.10.1 with 0 doses of IPV (%)	$<5, 5-10, >10$	0, 1, 2	Five
A7. Coverage of ≥ 2 doses of IPV in children <5 years (%)	$>95, 90-95, <90$	0, 1, 2	Five
B. Poliovirus surveillance system			
B1. Reported NPAFP rate in children <15 years in the past five years (/100,000)	$\geq 1, <1$	0, 1	Three
B2. Proportion of AFP cases with two adequate stool samples in 14 days in the past five years (%)	$\geq 80, <80$	0, 1	Three
B3. Proportion of PLADs that meet B1 and B2 indicators at each first administrative level (%)	$\geq 80, <80$	0, 1	Three
B4. Proportion of reported high-risk AFP cases in the past five years (%)	$<2, 2-5, >5$	0, 1, 2	Three
B5. The absolute value of NPAFP reported rate trends in the past five years (%)	$\leq 10, >10$	0, 1	Three
B6. Average isolation rate of NPEV (%)	$>5, 2-5, <2$	0, 1, 2	Three
B7. Proportion of AFP cases that followed-up within 60 days (%)	$>90, 80-90, <80$	0, 1, 2	Three
B8. Rate of provincial lab result virus isolation results available in 14 days (%)	$>90, 80-90, <80$	0, 1, 2	Three
B9. Whether environmental surveillance is conducted	No, Yes	3, 0	Three
C. Importation risk			
C1. Whether bordering a VDPV2 endemic area	No, Yes	0, 10	Two
C2. Whether there are direct travel links with a VDPV2-infected country	No, Yes	0, 0.5 $\times$ countries	Two
C3. Whether there was a type 2 poliovirus-related importation outbreak in the past five years	No, Yes	0, 1	Two
C4. Whether there were VDPV import outbreaks in the past five years (excluding iVDPVs)	$<2, 2-5, >5$	0, 3, 6	Two
C5. Whether supplementary immunization or catch-up vaccination was conducted	No, Yes	1, 0	Two

Abbreviation: AFP=acute flaccid paralysis; PV=polio vaccine; VDPV=vaccine-derived poliovirus; iVDPV=immunodeficiency-associated vaccine-derived poliovirus; PLAD=provincial-level administrative division; NPAFP=non-polio AFP; NPEV=non-polio enterovirus.

poliovirus (9). This tool represents an extension of the established WPV risk assessment tool and marks the first deployment of the new VDPV2 risk assessment tool in China. Our findings indicate that numerous PLADs identified as medium to high risk possess correspondingly low levels of population immunity. The study derived dose-number-based IPV coverage rates from individual vaccination records, revealing that IPV coverage among children under 5 years has not reached 90% in some regions. Furthermore, 24 PLADs had more than 20% of age-eligible children receiving one IPV dose, 6 PLADs exceeded 10% of age-eligible children without any IPV doses, and 26 PLADs had less than 90% of children under 5 years receiving two or more IPV doses (Supplementary Table 2). The results suggest that during the

implementation of the updated polio vaccination strategy — shifting from 1 dose of IPV and 3 doses of bOPV (bivalent oral poliovirus vaccine) to 2 doses of IPV and 2 doses of bOPV (17) — many children born during the transition received only one or no IPV doses without any supplementary immunization. This concerning trend was notable in Hainan and Shaanxi, where the WPV1 risk was low, yet VDPV2 risk was high (Table 3). In these areas, many children received inadequate IPV doses, insufficient for robust type 2 PV protection as antibody levels against VDPV2 might be relatively low. The efficacy of two IPV doses is superior to a single dose (18). Despite high overall vaccination rates in these PLADs, the inclusion of bOPV and tOPV doses might mask the transmission risk of VDPV2 unless indicators A5, A6, and A7 are

TABLE 3. Weighted scores for WPV1 and VDPV2 importation and transmission risk in China, 2023.

WPV1 risk assessment results			VDPV2 risk assessment results		
PLADs	Weighted scores	Risk classification	PLADs	Weighted scores	Risk classification
Xizang	34	High	Xizang	77	High
Qinghai	29	High	Hainan	64	High
Xinjiang	28	High	Shaanxi	62	High
Chongqing	27	Medium	Chongqing	56	Medium
Ningxia	26	Medium	Tianjin	55	Medium
Jilin	23	Medium	Qinghai	54	Medium
Hubei	20	Medium	Shanxi	53	Medium
Tianjin	19	Medium	Xinjiang	51	Medium
Heilongjiang	19	Medium	Beijing	50	Medium
Anhui	19	Medium	Guizhou	50	Medium
Jiangxi	16	Medium	Hebei	47	Medium
Guangdong	16	Medium	Inner Mongolia	47	Medium
Gansu	16	Medium	Hubei	47	Medium
Liaoning	14	Medium	Hunan	46	Medium
Shanxi	13	Medium	Anhui	43	Medium
Guizhou	13	Medium	Guangdong	42	Medium
Beijing	11	Low	Gansu	42	Medium
Inner Mongolia	11	Low	Henan	40	Medium
Jiangsu	11	Low	Heilongjiang	39	Low
Zhejiang	11	Low	Fujian	38	Low
Fujian	11	Low	Shandong	38	Low
Shandong	11	Low	Ningxia	38	Low
Hainan	11	Low	Liaoning	36	Low
Shaanxi	11	Low	Jiangxi	36	Low
Hunan	8	Low	Jilin	35	Low
Shanghai	6	Low	Jiangsu	32	Low
Henan	6	Low	Yunnan	30	Low
Hebei	5	Low	Zhejiang	28	Low
Sichuan	5	Low	Shanghai	27	Low
Guangxi	0	Low	Guangxi	21	Low
Yunnan	0	Low	Sichuan	17	Low

Abbreviation: WPV1=type 1 wild poliovirus; PLADs=provincial-level administrative divisions.

considered within the VDPV2 risk assessment. PLADs at high risk should urgently implement catch-up IPV vaccinations to enhance population immunity against type 2 PV. IPV supplementary immunization and catch-up campaigns are actively being carried out in several PLADs, including the border regions of Yunnan and Xinjiang.

The sensitivity and timeliness of AFP surveillance are paramount. Our assessment of the WPV1 risk revealed that the NPAFP reporting rate fell below the

target of 1/100,000 in five PLADs, indicating a need to enhance active case monitoring and reporting in the pediatric, infectious diseases, and neurology departments of hospitals. Additionally, the isolation rate of NPEV from 2020 to 2022 was below 3% across 17 PLADs, underscoring a potential reduction in AFP surveillance sensitivity. This decline could reflect improved sanitary conditions locally. In terms of environmental surveillance, 14 PLADs maintained ongoing wastewater monitoring in 2022, and by 2023,

three more PLADs had initiated this practice. Environmental surveillance is critical for monitoring poliovirus distribution in the population via detection in wastewater, as polioviruses primarily spread through fecal contamination. Given that China's immunization strategy commences with the IPV, which prevents paralysis but not infection, supplementing AFP surveillance with environmental monitoring is crucial to ensure effective poliovirus detection.

This study evaluated the potential for virus importation following the conclusion of the COVID-19 pandemic. Our analysis included key factors such as ongoing poliovirus (PV) circulation in neighboring countries. Unlike the risk assessment for WPV1, the tool for VDPV2 incorporated additional quantifiable indicators. These indicators include direct air transport connections with countries experiencing VDPV2 outbreaks and the implementation of supplementary or catch-up vaccination programs to mitigate importation risks. For instance, despite their robust population immunity and active surveillance for AFP, jurisdictions like Beijing and Guangdong face higher importation risks due to globalization and frequent international exchanges. Accordingly, these areas should enhance their capabilities to detect polioviruses and prevent transmission.

This study was subject to several limitations. First, the data were collected from various PLADs, where the quality of AFP surveillance and polio immunization programs may differ significantly. Second, the accuracy, completeness, and quality of data for each indicator influenced the final risk assessment results, potentially leading to an underestimation of risk due to incomplete case data or insufficient field investigations. Additionally, the usage of dynamic data for each secondary indicator may have contributed to instability in the findings throughout the study period. It is important to note that the risk results presented are relative risks and should be used primarily for guidance and reference. Lastly, the selection of indicators by experts introduces a degree of subjectivity.

This study revealed that in the 2023 WPV1 importation and transmission risk assessment for China, Xizang, Qinghai, and Xinjiang were identified as the regions with the highest risk. Similarly, the VDPV2 risk assessment indicated that Xizang, Shaanxi, and Hainan bear the greatest risk of VDPV2 importation and dissemination. Such risk assessments are crucial for pinpointing areas where public health programs require enhancement. Despite the absence of local poliovirus transmission in China, it is advisable

for these high-risk PLADs to augment their poliovirus vaccination rates, particularly the 2-dose IPV, to maintain robust population immunity. Furthermore, enhancements in the timeliness, sensitivity, and detection capabilities of the AFP surveillance system are recommended. PLADs with medium or low risk should also adopt preventative strategies tailored to their specific risk profiles to bolster and preserve a polio-free status across the nation.

Conflicts of interest: No conflicts of interest.

Acknowledgements: The Provincial Centers for Disease Control and Prevention in China.

Funding: Supported by the Evaluation of 2 Polio Vaccine Strategy Switches in China (JY22-3-10).

doi: [10.46234/ccdcw2024.225](https://doi.org/10.46234/ccdcw2024.225)

Corresponding author: Hong Yang, yanghong@chinacdc.cn.

¹ National Key Laboratory of Intelligent Tracking and Forecasting for Infectious Diseases, Chinese Center for Disease Control and Prevention, Beijing, China; ² National Immunization Program, Chinese Center for Disease Control and Prevention, Beijing, China; ³ Education and Training of Chinese Center for Disease Control and Prevention, Beijing, China.

Submitted: January 20, 2024; Accepted: October 01, 2024

REFERENCES

1. Lee SE, Greene SA, Burns CC, Tallis G, Wassilak SGF, Bolu O, et al. Progress toward poliomyelitis eradication - Worldwide, January 2021-March 2023. *MMWR Morb Mortal Wkly Rep* 2023;72(19):517-22. <https://doi.org/10.15585/mmwr.mm7219a3>.
2. Global Polio Eradication Initiative. Wild poliovirus list. <https://polioeradication.org/wild-poliovirus-count/>. [2023-12-19].
3. World Health Organization. Statement of the thirty-fifth polio IHR emergency committee. 2023. <https://www.who.int/news/item/12-05-2023-statement-of-the-thirty-fifth-polio-ihr-emergency-committee>. [2023-5-12].
4. Global Polio Eradication Initiative. Global circulating vaccine-derived poliovirus (cVDPV). <https://polioeradication.org/circulating-vaccine-derived-poliovirus-count> [2024-1-9].
5. Link-Gelles R, Lutterloh E, Ruppert PS, Backenson PB, St. George K, Rosenberg ES, et al. Public health response to a case of paralytic poliomyelitis in an unvaccinated person and detection of poliovirus in wastewater-New York, June-August 2022. *Am J Transplant* 2022;22(10):2470-4. <http://dx.doi.org/10.1111/ajt.16677>.
6. Zuckerman NS, Bucris E, Morad-Eliyahu H, Weiss L, Vasserman R, et al. Environmental surveillance of a circulating vaccine-derived poliovirus type 2 outbreak in Israel between 2022 and 2023: a genomic epidemiology study. *Lancet Microbe*. [2024-9-13]. [https://doi.org/10.1016/S2666-5247\(24\)00116-2](https://doi.org/10.1016/S2666-5247(24)00116-2)
7. World Health Organization. Detection of circulating vaccine derived polio virus 2 (cVDPV2) in environmental samples- the United Kingdom of Great Britain and Northern Ireland and the United States of America. 2022. <https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON408>. [2022-9-14].
8. Zhang Y, Luo HM, Wen N, Cui FQ, Wang HB. A study of risk assessment tool on wild poliovirus importation and transmission. *Chin J Vaccin Immun* 2013;19(1):17-9,80. <http://qikan.cqvip.com/Qikan/Article/Detail?id=45099556>. (In Chinese).
9. Kang W, Wen N, Wen Y, Yang YZ, Zhang P, Yang H. Construction of

- a risk assessment tool for importation and transmission of type 2 poliovirus in China using a modified Delphi method. *Chin J Vaccin Immun* 2023;29(4):377 – 82. <https://doi.org/10.19914/j.CJVI.2023064>.
10. Lowther SA, Roesel S, O'Connor P, Landaverde M, Oblapenko G, Deshevoi S, et al. World Health Organization regional assessments of the risks of poliovirus outbreaks. *Risk Anal* 2013;33(4):664 – 79. <https://doi.org/10.1111/risa.12032>.
 11. Kalkowska DA, Duintjer Tebbens RJ, Thompson KM. Environmental surveillance system characteristics and impacts on confidence about no undetected serotype 1 wild poliovirus circulation. *Risk Anal* 2019;39(2):414 – 25. <https://doi.org/10.1111/risa.13193>.
 12. Duintjer Tebbens RJ, Pallansch MA, Cochi SL, Ehrhardt DT, Farag NH, Hadler SC, et al. Modeling poliovirus transmission in pakistan and afghanistan to inform vaccination strategies in undervaccinated subpopulations. *Risk Anal* 2018;38(8):1701 – 17. <https://doi.org/10.1111/risa.12962>.
 13. Campbor HS, Bareja C, Glynn-Robinson A, Polkinghorne BG, Durrheim DN. A novel semi-quantitative methodology for national poliovirus reintroduction and outbreak risk assessment. *Travel Med Infect Dis* 2021;44:102181. <https://doi.org/10.1016/j.tmaid.2021.102181>.
 14. Ye JK, Cao L, Yu WZ, Song YF, Yin ZD. Reported routine immunization coverage with National Immunization Program vaccines in China, 2020-2021. *Chin J Vaccin Immun* 2022;28(5):576 – 80. <https://doi.org/10.19914/j.CJVI.2022110>.
 15. Yang H, Fan CX, Zhu SL, Wang FZ, Li YQ, Tang L, et al. Surveillance for acute flaccid paralysis among children less than 15 years of age in China, 2017-2019. *Chin J Vaccin Immun* 2021;27(2):152 – 6,172. <https://doi.org/10.19914/j.CJVI.2021018>.
 16. Yang H, Fan CX, Cao L, Ma C, Hao LX, Yin ZD, et al. Risk assessment for wild poliovirus importation and transmission at subnational levels of China in 2019. *Chin J Vaccin Immun* 2020;26(3):261 – 4,286. <https://d.wanfangdata.com.cn/periodical/zgjhmy202003005>. (In Chinese).
 17. Chinese Preventive Medicine Association. Expert consensus on informed consent for vaccination (Part One). *Pract Prev Med* 2021;28(4):385 – 411. <https://doi.org/10.3969/j.issn.1006-3110.2021.04.001>.
 18. World Health Organization. Polio vaccines: WHO position paper – June 2022. *Wkly Epidemiol Record* 2022;97(25):277 – 300. <https://www.who.int/publications/i/item/WHO-WER9725-277-300#:~:text=Polio%20vaccines:%20WHO%20position%20paper%20%E2%80%93%20June%202022.%20Weekly%20Epidemiological>.

SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Detailed WPV1 risk scores for each secondary indicator in all PLADs of China.

PLADs	A. Population immunity							B. AFP surveillance system						C. Importation risk		
	A1	A2	A3	A4	A5	A6	Sub-total	B1	B2	B3	B4	B5	Sub-total	C1	C2	Sub-total
Beijing	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Tianjin	0	2	0	0	0	0	2	1	1	0	0	1	3	0	0	0
Hebei	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Shanxi	0	2	0	0	0	0	2	0	0	0	0	1	1	0	0	0
Inner Mongolia	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Liaoning	0	1	0	0	0	0	1	0	1	0	1	1	3	0	0	0
Jilin	2	2	0	0	0	0	4	1	0	0	0	0	1	0	0	0
Heilongjiang	0	2	0	0	0	0	2	1	0	0	0	2	3	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
Jiangsu	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Zhejiang	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Anhui	0	2	0	0	0	0	2	0	0	0	1	2	3	0	0	0
Fujian	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Jiangxi	1	1	0	0	0	0	2	0	0	0	0	2	2	0	0	0
Shandong	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Henan	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0
Hubei	1	2	0	0	1	0	4	0	0	0	0	0	0	0	0	0
Hunan	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	0
Guangdong	0	2	0	0	0	0	2	0	0	0	0	2	2	0	0	0
Guangxi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hainan	0	1	0	0	0	0	1	0	1	0	0	1	2	0	0	0
Chongqing	0	2	0	0	1	0	3	1	1	0	0	2	4	0	0	0
Sichuan	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Guizhou	0	1	0	0	1	0	2	0	0	0	0	1	1	0	0	0
Yunnan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xizang	0	1	2	0	2	0	5	0	0	1	0	2	3	0	0	0
Shaanxi	0	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0
Gansu	0	2	0	0	0	0	2	0	0	0	0	2	2	0	0	0
Qinghai	2	2	0	0	0	0	4	1	0	0	0	2	3	0	0	0
Ningxia	2	2	0	0	0	0	4	0	1	0	0	1	2	0	0	0
Xinjiang	0	1	0	0	1	0	2	0	0	0	0	2	2	1	1	2

Abbreviation: WPV1=type 1 wild poliovirus; AFP=acute flaccid paralysis; PLAD=provincial-level administrative division.

SUPPLEMENTARY TABLE S2. Detailed VDPV2 risk scores for each secondary indicator in all PLADs of China.

PLADs	A. Population immunity								B. Polio virus surveillance system										C. Importation risk					
	A1	A2	A3	A4	A5	A6	A7	Sub-total	B1	B2	B3	B4	B5	B6	B7	B8	B9	Sub-total	C1	C2	C3	C4	C5	Sub-total
Beijing	0	0	0	0	1	1	2	4	0	0	1	0	0	2	0	0	3	6	0	6	0	0	0	6
Tianjin	0	0	0	0	2	0	2	4	1	1	0	0	1	1	2	2	3	11	0	0	0	0	1	1
Hebei	0	0	0	0	2	2	2	6	0	0	1	0	1	0	0	0	3	5	0	0	0	0	1	1
Shanxi	0	0	0	0	2	2	2	6	0	0	0	0	1	1	1	1	3	7	0	0	0	0	1	1
Inner Mongolia	0	0	0	0	2	2	2	6	0	0	1	0	0	2	1	1	0	5	0	0	0	0	1	1
Liaoning	0	0	0	0	2	1	2	5	0	1	0	0	1	1	0	0	0	3	0	0	0	0	1	1
Jilin	0	0	0	0	2	0	2	4	1	0	0	0	1	0	0	0	3	5	0	0	0	0	0	0
Heilongjiang	0	0	0	0	2	1	2	5	1	0	0	0	1	2	0	0	0	4	0	0	0	0	1	1
Shanghai	0	0	0	0	0	0	1	1	0	0	1	0	1	2	0	0	0	4	0	5	0	0	0	5
Jiangsu	0	0	0	0	2	0	2	4	0	0	1	0	1	2	0	0	0	4	0	0	0	0	0	0
Zhejiang	0	0	0	0	1	0	1	2	0	0	1	0	1	1	0	0	3	6	0	0	0	0	0	0
Anhui	0	0	0	0	2	0	2	4	0	0	1	0	1	2	0	0	3	7	0	0	0	0	1	1
Fujian	0	0	0	0	2	0	2	4	0	0	1	0	1	1	1	1	0	5	0	0.5	0	0	1	1.5
Jiangxi	0	0	0	0	2	1	2	5	0	0	1	0	1	1	0	0	0	3	0	0	0	0	1	1
Shandong	0	0	0	0	2	0	2	4	0	0	1	0	1	1	1	1	0	5	0	0.5	0	0	1	1.5
Henan	0	0	0	0	2	0	2	4	0	0	1	0	1	1	0	0	3	6	0	0	0	0	1	1
Hubei	0	0	0	0	2	0	2	4	0	0	0	0	1	0	2	2	3	8	0	0.5	0	0	1	1.5
Hunan	0	0	0	0	2	1	2	5	0	0	0	0	1	0	1	1	3	6	0	0.5	0	0	1	1.5
Guangdong	0	0	1	0	1	0	1	3	0	0	1	0	0	1	1	1	0	4	0	6.5	0	0	1	7.5
Guangxi	0	0	0	0	2	0	1	3	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0
Hainan	0	0	2	0	2	1	2	7	0	1	0	0	0	1	2	2	3	9	0	0	0	0	1	1
Chongqing	0	0	0	0	2	0	2	4	1	1	0	0	1	1	2	2	3	11	0	0.5	0	0	1	1.5
Sichuan	0	0	0	0	0	0	2	2	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	2
Guizhou	0	0	1	0	2	1	2	6	0	0	0	0	0	1	1	1	3	6	0	0	0	0	1	1
Yunnan	0	0	0	0	2	1	2	5	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1
Xizang	2	0	2	0	1	2	2	9	0	1	0	1	0	1	2	2	3	10	0	0	0	0	1	1
Shaanxi	0	0	0	0	2	2	2	6	0	0	0	0	1	2	2	2	3	10	0	0	0	0	1	1
Gansu	0	0	0	0	2	1	2	5	0	0	0	0	1	2	1	1	0	5	0	0	0	0	1	1
Qinghai	0	0	0	0	2	2	2	6	1	1	0	0	1	1	2	2	0	8	0	0	0	0	0	0
Ningxia	0	0	0	0	2	0	2	4	1	0	0	0	1	1	0	0	3	6	0	0	0	0	0	0
Xinjiang	0	0	0	0	0	1	1	2	0	0	1	0	1	2	1	1	0	6	10	1.5	0	0	0	11.5

Abbreviation: VDPV2=type 2 vaccine-derived poliovirus; PLADs=provincial-level administrative divisions.