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A novel semi-quantitative methodology for national poliovirus reintroduction and outbreak risk assessment

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ABSTRACT

Background: Under the *International Health Regulations (2005)*, World Health Organization Member States need to verify certification of polio–free status annually. In 2018, Australia sought to reassess and comprehensively characterise the risk posed by wild-type and vaccine-derived poliovirus introductions to national health security. However formal guidelines for national polio risk assessment were not publicly available.

Methods: Four risk elements were identified and weighted using an expert-informed modified Delphi method: reintroduction hazard; population susceptibility; detection capability; and response capability. Australian data and qualitative evidence were analysed, documented and scored against risk element indicators to characterise polio risk as a semi–quantitative estimate and qualitative risk category statement.

Results: The semi-quantitative risk characterisation calculated likelihood and impact scores of 0.43 and 0.13, respectively (possible range: 0.02–4.5). The assessment concluded that the risk of poliovirus reintroduction, resultant outbreaks of poliovirus infection, and sustained transmission occurring in Australia is very low.

Conclusions: Until poliovirus is eradicated, it remains in countries' strategic health security interest to maintain optimal investment in polio prevention, preparedness, surveillance and response capability to manage their level of risk. We present a structured, transparent and reproducible methodology for national or sub-national polio risk characterisation that generates evidence for targeted investment to maintain polio-free status.

1. Introduction

Poliovirus circulation persists in some of the most underdeveloped and insecure regions of the globe [1,2]. In 2014, the World Health Organization (WHO) declared the international spread of poliovirus a Public Health Emergency of International Concern (PHEIC) [3]. Australia, along with other countries in the WHO Western Pacific region (WPR), was certified as free of circulating indigenous wild-type poliovirus (WPV) in 2000 [4,5]. Therefore, a WPV or circulating vaccine-derived poliovirus (cVDPV) detection in Australia would constitute a significant acute public health event subject to mandatory national and international reporting requirements. Under the *International Health Regulations (IHR 2005),* the WHO WPR Certification Committee for the Eradication of Poliomyelitis (RCC) requests regional Member States to submit annual progress reports to verify certification of national polio-free status. Countries perceived to be at lower risk in the region, including Australia, are recommended to conduct and include annual risk assessments [6]. In 2016, Australia identified the need to reassess and comprehensively characterise the risk posed by WPV and vaccine-derived polioviruses (VDPVs) to national health security, in light of increasing concern about cVDPV outbreaks globally in the preceding two decades [7,8]. In May 2018, an outbreak of cVDPV-1 in Australia's nearest geographical neighbour, Papua New Guinea [9], highlighted the changing regional risk profile. This event emphasised the importance of conducting regular assessments, but also raised questions about the best-practice approach to comprehensive polio risk characterisation at national or sub-national level. A background literature review revealed that although methodologies used by WHO for regional risk assessment have been described [10], formal

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Abbreviations

AFP	Acute flaccid paralysis
AIR	Australian Immunisation Register
ANU	Australian National University
cVDPV	Circulating vaccine-derived poliovirus
IHR	International Health Regulations
GIS	Geographic Information System
HDI	Human Development Index
JEE	Joint External Evaluation
JMP	Joint Monitoring Programme
NAC	Australian National Authority for Containment of poliovirus
NCC	National Certification Committee for the Eradication of Poliomyelitis
NIP	National Immunisation Program
NNDSS	National Notifiable Disease Surveillance System
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PEP	Australian Polio Expert Panel
PEF	Poliovirus Essential Facilities
PIM	Poliovirus Infectious Materials
RCC	Regional Certification Committee for the Eradication of Poliomyelitis
RCE	Risk characterisation estimate
UNDP	United National Development Programme
UNICEF	United Nations Children's Fund
VDPV	vaccine-derived poliovirus
WASH	Water, sanitation and hygiene
WHO	World Health Organization
WPR	WHO Western Pacific Region
WPV	Wild-type poliovirus

internationally accepted guidelines for national polio risk assessment were not publicly available.

2. Methods

Informed by regional polio risk assessment methodologies [10] and WHO guidelines for rapid risk assessment [11], a structured, mixed-methods approach was developed to capture the key components that influence poliovirus reintroduction, outbreak and sustained transmission risk, and to quantify their likelihood and impact. Here we provide a brief overview; however, the complete methodology is publicly available on the Australian Government Department of Health's polio risk webpage [12].

An overarching risk question was formulated for Australia (Box 1). Four risk elements were defined to facilitate evaluation of the likelihood and impact components, respectively. Each risk element incorporated several sub-components into the risk characterisation (Table 1). For the likelihood component, the elements were reintroduction hazard (*H*) and population susceptibility (*S*). A likelihood score was derived from the sum of weighted hazard and susceptibility assessment scores. For the impact component, the elements were detection capability (*D*), and response capability (*R*). An impact score was derived from the sum of weighted detection and response capability scores. To develop risk element weightings, Australia's poliomyelitis expert advisory committees – the Polio Expert Panel (PEP) and the National Certification Committee for the Eradication of Poliomyelitis (NCC) – participated in two surveys utilising a modified Delphi method to derive weightings (*w*). The weightings represented an estimate of the relative importance of each risk element, i.e. its proportional contribution (%) to poliovirus reintroduction and outbreak risk under Australian conditions (Table 1).

To address the sub-components of each risk element (Table 1), eight focused risk questions were developed, for which a total of 25 risk indicators were identified. For each risk indicator, data and documentary evidence for the preceding five years were collated, analysed, and brief summaries documented against each sub-component. To calculate risk element scores, information collated for each sub-component was combined and scored against a predefined risk element scoring template containing descriptive categories ranging from *very satisfactory* (1) to *very inadequate* (5). An estimate of the reliability, quality and completeness of information available (at the time of assessment) to evaluate each risk element was also incorporated. Termed a confidence coefficient (*c*), this ranged from *very high* (0.2) to *very low* (1); and was also scored against a predefined scoring template.

2.1. Risk characterisation estimate (RCE)

The principal assessment result was a semi-quantitative risk characterisation estimate (RCE), which comprised the plotted intersection of the respective likelihood and impact scores in a risk matrix. Corresponding with the risk matrix, thresholds representing predefined, descriptive polio risk categories allowed translation of the RCE into a qualitative, categorical risk statement ranging from *very low risk* to *very high risk* (Fig. 1). The formula for calculating the RCE is provided (Table 2).

2.2. Reintroduction hazard assessment

This assessment evaluated the likelihood of poliovirus importation, and poliovirus reintroduction attributable to a failure of laboratory containment policies, practices or import regulations. Highest risk subpopulations for WPV and VDPV importation (circulating or ambiguous vaccine-derived viruses) were identified (Australian residents included). Risk stratification criteria were defined and applied to generate a list of priority countries categorised by polio risk, followed by analyses of international traveller arrival trends from those countries, including unauthorised arrivals. Poliovirus importation risk reduction policies (e.g. requirements for international certificates of vaccination), including health requirements for humanitarian resettlement from polio high-risk countries were also summarised.

Information pertaining to national Poliovirus Essential Facilities (PEFs), and associated verification procedures, including national surveys and inventories of laboratories holding WPV and potentially poliovirus infectious materials (PIM) were summarised. Relevant laboratory quality assurance processes, import regulations for exotic

Box 1
Overarching risk question formulated for the Australian national polio risk assessment

What is the risk of wild-type (WPV) or vaccine-derived poliovirus (cVDPV, iVDPV or aVDPV) reintroduction, AND resultant outbreaks of poliovirus infection, AND sustained transmission occurring in Australia in the next five years (2019–2023)?

Table 1
Risk elements, sub-components and weightings used for characterisation of Australia's poliovirus reintroduction, outbreak and sustained transmission risk.

Risk assessment component	Risk element	Sub-components	Expert-informed weightings (w1–w4)
Likelihood	Reintroduction hazard (H)	• Poliovirus importation threats (infectious travellers) • Laboratory containment policies, practices and import regulations	0.15 (*w1*)
	Population susceptibility (S)	• Population immunity profile, including vulnerable subpopulations • National immunisation program (NIP) performance and delivery • Population access to water, sanitation and hygiene (WASH) services	0.5 (*w2*)
Impact	Detection capability (D)	• Poliovirus surveillance system quality and performance (clinical, enterovirus and environmental components) • Nationally notifiable status and supporting surveillance infrastructure • Track record of imported case and environmental detection event management and outcomes	0.3 (*w3*)
	Response capability (R)	• Healthcare infrastructure, system and IHR core capacities • Polio outbreak response preparedness • Socio-political stability	0.05 (*w4*)

infectious agents and established standards for microbiological safety and containment were also documented. Furthermore, Australia's progress against the WHO Global Action Plan to minimise poliovirus-facility associated risk (*GAPIII*) [13], as overseen by the Australian National Authority for Containment (NAC) of poliovirus was also considered.

2.3. Population susceptibility assessment

This assessment evaluated Australia's population immunity profile against poliovirus, and the performance and delivery of the National Immunisation Program (NIP). Data from the Australian Immunisation Register (AIR) were analysed to present national childhood polio immunisation coverage rates (as per WHO/UNICEF standards), as well as annualised coverage rates for one, two and five-year old children by Indigenous status and sub-national jurisdiction. The structure and function of the NIP, including catch-up immunisation policies and programs targeting vulnerable subpopulations (e.g. residents of the Torres Strait islands and recent migrants from polio risk countries) were documented.

Using geographic information system (GIS) software, aggregated data on migrant settlement from polio risk countries were overlaid with polio immunisation coverage data for the corresponding period, to generate a series of sub-national choropleth polio susceptibility risk

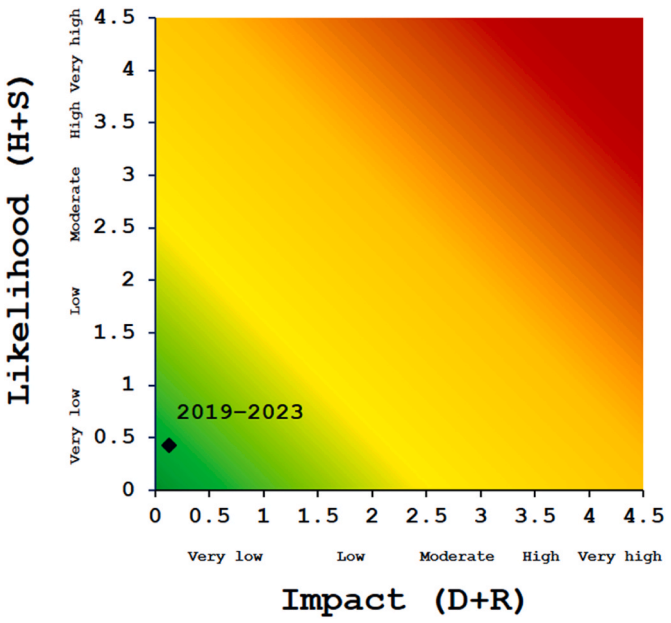

Fig. 1. Plotted poliovirus reintroduction and outbreak risk characterisation estimate for Australia, as at January 2019.

Table 2
Variables used to calculate the polio risk characterisation estimate (RCE).

Risk characterisation estimate (RCE) = *Likelihood* score x *Impact* score, where

- *Likelihood* score = (*w1* x *H* x *c1*) + (*w2* x *S* x *c2*)
- *Impact* score = (*w3* x *D* x *c3*) + (*w4* x *R* x *c4*)

Symbol	Variable description	Scoring intervals
H	Reintroduction hazard risk element	1 – very satisfactory
S	Population susceptibility risk element	2 – satisfactory
D	Detection capability risk element	3 – acceptable
R	Response capability risk element	4 – inadequate 5 – very inadequate
c	Confidence coefficient score: incorporates an estimate of confidence in the reliability, quality and completeness of information available to score each risk element at the time of assessment	0.2 – very high 0.4 – high 0.6 – moderate 0.8 – low 1.0 – very low
w	Weighting factor: represents an estimate of a risk element's relative importance (expressed as a proportional contribution) to the RCE	Sum of four weighting factors equal 1 (100%)

maps. The maps served to identify at sub-national level (statistical populations generally between 20,000 and 130,000 residents), any potential high-risk localities where recent migrant arrivals from polio risk countries were settling in communities with comparatively lower (<85%) polio childhood immunisation coverage rates.

Results of the most recent national poliovirus serosurvey (2012) were reviewed and summarised. This estimated the proportion seropositive for each poliovirus type (1–3) for the population as a whole and by age group, to align with differing vaccination schedules between 1955 and 2012 [14].

The quality and coverage of Australia's water, sanitation and hygiene (WASH) infrastructure and essential sanitary service provision were also considered. National WASH data were accessed from the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene [15] and from an online database managed by the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) [16]. Information collated from industry reports and academic publications were used to describe WASH access and sanitary service provision to vulnerable subpopulations, including rural and

remote Aboriginal and Torres Strait Islander communities [17–20].

2.4. Detection capability assessment

This assessment summarised a previous review of the key components, structure, function and quality of the Australian poliovirus surveillance system [21]. Description of the clinical surveillance component included an analysis of non-polio acute flaccid paralysis (AFP) detection rates, and described recent performance against other WHO-recommended poliovirus surveillance performance indicators at national and sub-national level. Description of the supplementary surveillance component included enterovirus surveillance within Australia's national enterovirus reference laboratory network, as well as Australia's poliovirus environmental surveillance program and findings at selected sentinel sites around the country.

The national surveillance case definition for poliovirus infection [22], legislative requirements for national notification, and data capture processes and systems using Australia's National Notifiable Disease Surveillance System (NNDSS) were also described. The management and outcomes of Australia's most recent imported WPV case (2007) [23] and ambiguous VDPV (aVDPV) environmental detection events (2017) [2] were summarised as evidence of system effectiveness.

2.5. Response capability assessment

This assessment evaluated the findings of a 2017 WHO Joint External Evaluation (JEE) of Australia's healthcare infrastructure, system and IHR core capacities [24]. The purpose, structure, key components and review history of Australia's updated Poliovirus Infection Outbreak Response Plan (2019) [25] were considered, as were the processes and resources available to conduct rapid risk assessment and provide prompt advice on response plan activation and control strategies. The terms of reference of Australia's two complementary expert advisory committees on poliomyelitis (PEP and NCC) were considered, as well as the frequency of stakeholder engagement (e.g. meetings and exercises) to review national surveillance performance data indicators and maintain polio outbreak response readiness. Finally, the assessment considered Australia's rankings in the 2018 Global Peace Index [1] and UNDP human development index (HDI) [26] as a proxy for identifying any underlying public health, social, geopolitical, economic or environmental risk factors that could contribute to a sustained polio transmission risk, or undermine the effectiveness of an outbreak response in Australia.

2.6. Risk assessment scoring

Data and documentary evidence were compiled and analysed in the latter half of 2018. Scoring against the predefined risk characterisation templates was completed in January 2019 by a team from the Australian Government Department of Health and the Australian National University (ANU). The study was approved by the ANU Science and Medical Delegated Ethics Review Committee (Protocol number: 2018/735).

3. Results

The semi-quantitative RCE for Australia calculated likelihood and impact scores of 0.43 and 0.13, respectively (possible range: 0.02–4.5) (Table 3). The results were plotted on a risk matrix, which corresponded with a qualitative risk category statement of very low risk (Fig. 1). Therefore, the risk assessment team concluded, that as at January 2019:

- There is a very low probability of outbreaks of poliovirus infection, in the unlikely event that reintroduction and exposure occurs during the specified assessment timeframe (2019–2023).
- Outbreaks of poliovirus infection are highly likely to be prevented or rapidly detected, contained, and eliminated due to an effective combination of reintroduction risk reduction policies, very high immunisation coverage rates, a comprehensive national polio surveillance system, and an advanced national response capability, including a comprehensive polio outbreak response plan and access to expert laboratory and epidemiological resources.
- Australia has highly developed healthcare and WASH infrastructures accessible to the vast majority of the population, which contributes to the very low probability of a significant polio disease burden at the population level, with a corresponding limited national impact in terms of the public health, social, economic, reputational and political consequences.
- The Australian national health system's core capacity, including capability and investment in polio prevention, preparedness, surveillance, outbreak response, risk communication and stakeholder awareness is considered very high at the time of assessment.

Table 3
Risk characterisation estimate calculated for Australia, as at January 2019.

Risk element	Expert weighting	Risk element scores (range: 1–5)	Confidence coefficient score (range: 0.2–1)	Weighted score
Reintroduction hazard (H)	0.15	1	0.2	0.03
Population susceptibility (S)	0.5	2	0.4	0.4
Total likelihood score:				**0.43**
Detection capability (D)	0.3	2	0.2	0.12
Response capability (R)	0.05	1	0.2	0.01
Total impact score:				**0.13**

4. Discussion

The debilitating consequences of poliomyelitis are well described [27], with an estimated 400,000 polio survivors in Australia alone [28]. While at the population level, the burden of disease due to a localised, promptly contained outbreak in a previously poliovirus-free country may be comparatively limited, the social and economic impact (including outbreak response costs, and associated enhanced surveillance to verify that containment and elimination has been successful) may remain substantial. It is also possible that public or political concern may disproportionately exceed the true population-level health risk. This will require coordinated, consistent risk communication from public health stakeholders (supported by a transparent, risk-based body of evidence) to effectively mitigate the associated impact.

All polio-free WHO Member states are required to regularly verify certification of national polio-free status. However, the absence of published international guidelines for conducting national polio risk assessment means that countries likely use varying approaches considered most relevant to their national context, or within the scope of available national resources and expertise. This complicates comparability of national polio risk assessment results, against a backdrop of dynamic global polio risks. In addition, a paucity of evidence to highlight existing data and information gaps may constrain appropriate investment in risk mitigation strategies, e.g. by strengthening routine childhood immunisation program performance, or targeted polio preparedness and outbreak response planning.

A comprehensive evaluation of Australia's polio risk was last conducted in 2012 [29]; however, the assessment scope did not extend to importation threats associated with VDPVs. Secondly, the evaluation's transparency and reproducibility were limited by the absence of a structured methodology detailing how information drawn from the documentary evidence evaluation and data analyses were integrated to reach a conclusion of low risk. These limitations highlighted the need to

develop a structured, documented approach to facilitate the completion of transparent and reproducible national or sub-national assessments, which can be readily repeated to enable objective trend analyses in response to the dynamic regional and global polio risk landscape.

This study developed and applied a novel, semi-quantitative assessment methodology using Australian data and documentary evidence. For any given country, an answer to the overarching risk question posed may seem intuitive to the national and international polio expert community, or to those familiar with a country's healthcare infrastructure, systems and policies. However, the value of a comprehensive risk assessment lies in the evidence-based conclusions that may be drawn from a structured, reproducible and transparent compilation and evaluation of documentary evidence and data analyses. The plotting of risk profile results as a RCE allows transparent depiction and monitoring of temporal trends, which may serve to demonstrate the effectiveness of existing policies or systems over time or conversely, highlight areas of highest risk requiring targeted investment to support system strengthening. The results of a comprehensive assessment may therefore provide confidence in a country's capacity to manage its poliovirus reintroduction and outbreak risk, whilst highlighting those areas in need of focused resources or investment to maintain polio-free status.

The methodology was principally developed for the Australian context to inform policymaker decision making, support risk communication, risk-based prioritisation for allocation of limited public health resources, and to meet reporting requirements of the WPR RCC. However, the risk element, confidence coefficient and qualitative polio risk statement scoring templates were also purposefully designed to cover the full possible range of poliovirus reintroduction and outbreak risk factor manifestation, thereby accounting for countries' varying health system core capacities across the globe. The methodology may therefore prove useful for other countries to evaluate and manage their own poliovirus risk and could be further adapted to be most relevant to the regional, national or sub-national context, public health resources and quality of information available for assessment.

The methodology and findings of the Australian risk assessment are subject to a number of assumptions and limitations. Principally, the RCE and associated conclusion of very low risk is based on the assumption that all epidemiological variables (risk elements) that influence poliovirus reintroduction and outbreak risk remain static during the specified assessment timeframe. However, Australia's polio risk may shift substantially at any time and for various reasons including, e.g. reduced global investment in the polio eradication drive, regional conflict or economic crises degrading health system core capacities, declining population immunity due to vaccine hesitancy, or increased poliovirus circulation in communities from which Australia receives a large number of traveller arrivals. These considerations reinforce the importance of regularly repeating polio risk assessments, particularly if a significant change in one or more epidemiological variables occurs. The results are therefore not intended for use as a rigid polio risk forecasting tool, but rather describe what occurred in the five-year timeframe immediately preceding the 2019 assessment, as a baseline for comparison to future assessments (e.g. annual rapid assessments, or more comprehensive risk characterisation completed every five years). Indeed, in the intervening period since the comprehensive assessment was completed in January 2019, two major unforeseen international events have significantly altered the global polio eradication landscape. The first being the COVID-19 pandemic, with resultant impacts on childhood immunisation programs, communicable diseases surveillance and public health resources more broadly, particularly in lower- and middle-income countries. These effects resulted in a nearly ninefold increase in reported poliomyelitis cases in 2020, compared to 2019 [30–32]. The second event being geopolitical upheaval in Afghanistan. In 2021, events in Afghanistan prompted significant internal population displacement and the rapid repatriation of large numbers of Afghan residents to various countries including Australia, as well as raising concerns about polio eradication efforts in the region [33–35]. Both these events demonstrate the importance of incorporating updated information into regular, rapid annual assessments to maintain the currency of the risk characterisation pertaining to poliovirus reintroduction risk.

Secondly, the assessment results are substantially influenced by the level of confidence in the quality and completeness of information and data used to evaluate the respective risk elements. The perceived quality of evidence used to inform the risk element scoring may be subject to bias, depending on the composition and frame of reference of the team tasked with conducting the scoring. Equally, the risk element scoring intervals were purposefully designed not to be overly rigid, but rather intended as guidelines to allow context-appropriate interpretation. Hence, the risk assessment team should assign risk element scores based on the qualitative description that most accurately resembles conclusions that may be drawn from the information assessed, noting that different combinations of criteria may occur together. However, this design feature means that some subjectivity in the scoring process remains. The weighting of risk elements through expert opinion is equally subjective. Nevertheless, an expert elicitation process may be considered the most accurate and valid estimation of the relative importance of the respective risk elements that is feasible without dedicated further research, and is a method frequently employed in qualitative risk assessment [11]. An additional limitation pertains to calculation of the RCE, specifically the question of whether there is an assumption of independence of the various risk elements, when in fact they are inter-dependent. Finally, to minimise perceived bias in the risk characterisation results, the composition of the risk assessment team requires careful consideration. This will depend on the national context, available resources and expertise and the intended end-users of the findings generated through the assessment. We recommend that risk assessment teams incorporate expertise in the fields of epidemiology, virology, laboratory biosafety, immunisation and health systems from national government health departments and independent academic or research institutions.

5. Conclusion

We present a structured, transparent and reproducible methodology for regular national or sub-national polio risk characterisation. Use of this framework generates evidence for targeted investment to maintain polio-free status and may also prove useful for other countries to evaluate their polio risk. Application of this methodology using Australian data and information concluded that, as at January 2019, the risk of WPV or cVDPV reintroduction, resultant outbreaks of poliovirus infection, and sustained transmission occurring in Australia is very low. Until poliovirus is eradicated, it remains in all countries' strategic health security interest to maintain optimal investment in polio prevention, preparedness, surveillance and outbreak response capability to manage their level of risk.

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CRediT authorship contribution statement

Hendrik S. Camphor: Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Visualization, Project administration. **Christina Bareja:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Anna Glynn-Robinson:** Conceptualization, Methodology, Writing – review & editing. **Benjamin G. Polkinghorne:** Conceptualization, Methodology, Writing – review & editing, Supervision. **David N. Durrheim:** Conceptualization, Methodology, Validation, Writing – review & editing.

Declaration of competing interest

None declared.

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References

[1] Institute for Economics & Peace. Global Peace index 2018: measuring Peace in a complex world. http://visionofhumanity.org/reports/. [Accessed 14 January 2019].
[2] Jorba J, Diop OM, Iber J, Henderson E, Zhao K, Sutter RW, et al. Update on vaccine-derived polioviruses - Worldwide, January 2017-June 2018. MMWR (Morb Mortal Wkly Rep) 2018;67(42):1189–94.
[3] World Health Organization. WHO statement on the meeting of the International Health Regulations Emergency Committee concerning the international spread of wild poliovirus. https://www.who.int/mediacentre/news/statements/2014/polio-20140505/en/. [Accessed 15 August 2019].
[4] World Health Organization. Major milestone reached in global polio eradication: Western Pacific Region is certified polio-free. Comm Dis Intell 2000;24:10.
[5] Adams A, Boualam L, Diorditsa S, Gregory C, Jee Y, Mendoza-Aldana J, et al. Maintaining polio-free certification in the world health organization Western pacific region for over a decade. J Infect Dis 2014;210(suppl_1):S259–67.
[6] World Health Organization. Polio endgame in the Western pacific region. 2013-2018, http://iris.wpro.who.int/handle/10665.1/10814. [Accessed 2 January 2019].
[7] Dowdle W, Kew O. Vaccine-derived polioviruses: is it time to stop using the Word "rare". J Infect Dis 2006;194(5):539–41.
[8] Wright PF, Modlin JF. The demise and rebirth of polio—a modern phoenix? J Infect Dis 2008;197:335–6.
[9] World Health Organization. Circulating vaccine-derived poliovirus type 1 and outbreak response in Papua New Guinea. Wkly Epidemiol Rec 2019 2018;94(6):65–7.
[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.
[11] World Health Organization. Rapid risk assessment of acute public health events. 2012. http://www.who.int/csr/resources/publications/HSE_GAR_ARO_2012_1/en/. [Accessed 26 June 2018].
[12] Australian Government Department of Health. Polio surveillance: status of polio in Australia. 2020. https://www1.health.gov.au/internet/main/publishing.nsf/Content/ohp-poliomyelitis.htm. [Accessed 16 October 2020].
[13] World Health Organization. Global action plan to minimize poliovirus facility-associated risk after type-specific eradication of wild polioviruses and sequential cessation of oral polio vaccine use (GAPIII). 2015. http://apps.who.int/iris/handle/10665/208872. [Accessed 8 January 2019]. Accessed.
[14] Hendry A, Dey A, Quinn H, Hueston L, Dwyer D, McIntyre P. National centre for immunisation research and surveillance (NCIRS): 2012 - 2013 national poliovirus serosurvey report. 2018. Unpublished report.
[15] United Nations Children's Fund (UNICEF). WASH data – Australia. https://washdata.org/data/household. [Accessed 23 November 2019].
[16] WASHWatch.org. World WASH data. All WASH data for every country in the world. https://data.humdata.org/dataset/world-wash-data. [Accessed 23 November 2019].
[17] Bailie R, Stevens M, McDonald E, Brewster D, Guthridge S. Exploring cross-sectional associations between common childhood illness, housing and social conditions in remote Australian Aboriginal communities. BMC Publ Health 2010;10(1):147.
[18] Australian Government Productivity Commission. Overcoming indigenous disadvantage: key indicators. https://www.pc.gov.au/research/ongoing/overcoming-indigenous-disadvantage/2016. [Accessed 11 January 2019].
[19] Lansbury N, Shanon C, Jagals P. It's a fallacy that all Australians have access to clean water, sanitation and hygiene. The Conversation; 2016. http://theconversation.com/its-a-fallacy-that-all-australians-have-access-to-clean-water-sanitation-and-hygiene-61436. [Accessed 11 January 2019].
[20] Hall N, Barbosa MC, Currie D, Dean AJ, Head B, Hill PS, et al. Water, sanitation and hygiene in remote Indigenous Australian communities: a scan of priorities. Global Change Institute discussion paper: Water for equity and wellbeing series; 2017. http://gci.uq.edu.au/un-sustainable-development-goals-water-sanitation-and-hygiene. [Accessed 23 November 2019].
[21] Paterson B, Durrheim DN. Review of Australia's polio surveillance. Comm Dis Intell 2013;37(2):149–55.
[22] Australian Government Department of Health. Australian national notifiable diseases case definitions: poliovirus infection. http://www.health.gov.au/internet/main/publishing.nsf/content/cda-surveil-nndss-casedefs-cd_polio.htm. [Accessed 15 January 2019].
[23] Stewardson AJ, Roberts JA, Beckett CL, Prime HT, Poh-Sien L, Thorley BR, et al. Imported case of poliomyelitis, Melbourne, Australia. Emerg Infect Dis 2009 2007;15(1):63.
[24] World Health Organization. Joint external evaluation of IHR core capacities of Australia. https://www.who.int/ihr/publications/WHO-WHE-CPI-REP-2018.8/en/. [Accessed 14 January 2019].
[25] Australian Government Department of Health. Poliomyelitis outbreak response plan for Australia. http://www.health.gov.au/internet/main/publishing.nsf/Content/polio-plan.htm. [Accessed 14 January 2019].
[26] United Nations Development Programme (UNDP). Human development indicators: Australia. http://hdr.undp.org/en/countries/profiles/AUS. [Accessed 10 January 2019].
[27] Heymann DL. Control of communicable diseases Manual. twentieth ed. Washington, DC: American Public Health Association; 2015.
[28] Polio Australia. Polio epidemics and survivor numbers. https://www.polioaustralia.org.au/australian-polio-survivors/. [Accessed 4 July 2018].
[29] Martin N, Paterson BJ, Durrheim DN. Australia's polio risk. Comm Dis Intell 2014;38(2):E107–13.
[30] Kalkowska DA, Voorman A, Pallansch MA, Wassilak SG, Cochi SL, Badizadegan K, et al. The impact of disruptions caused by the COVID-19 pandemic on global polio eradication. Vaccine 2021. https://doi.org/10.1016/j.vaccine.2021.04.026. Apr 27;S0264-410X(21)00473-4.
[31] World Health Organization. Countries reaffirm commitment to ending polio at launch of new eradication strategy. https://www.who.int/news/item/10-06-2021-countries-reaffirm-commitment-to-ending-polio-at-launch-of-new-eradication-strategy. [Accessed 10 October 2021].
[32] Din M, Ali H, Khan M, Waris A, Ullah S, Kashif M, et al. Impact of COVID-19 on polio vaccination in Pakistan: a concise overview. Rev Med Virol 2021;31(4):e2190.
[33] Ahmadi A, Essar MY, Lin X, Adebisi YA, Lucero-Prisno III DE. Polio in Afghanistan: the current situation amid COVID-19. Am J Trop Med Hyg 2020;103(4):1367–9.
[34] Roberts L. Taliban's rise puts polio eradication in danger. Science 2021;373(6555):605–6. https://www.science.org/content/article/us-departure-afghanistan-imperils-global-quest-eradicate-polio.
[35] Bhutta ZA. The incoming Afghan government must allow immunizations. Nature 2021;597(7878):595. https://www.nature.com/articles/d41586-021-02557-9.