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(REVIEW ARTICLE)

The Role of Pediatric Immunization in Combating Antimicrobial Resistance: A Global Review (with an India Focus)

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Abstract

Antimicrobial resistance (AMR) threatens child health by increasing the risk of treatment failure, prolonged illness, complications, and mortality. Vaccines are a powerful but under-used AMR intervention: they prevent bacterial infections directly, avert viral illnesses that are often inappropriately treated with antibiotics, reduce transmission (including of resistant strains), and lower healthcare exposure where resistant organisms circulate. This review synthesizes the biological mechanisms linking immunisation to AMR reduction, evidence by vaccine (pneumococcal conjugate vaccine [PCV], *Haemophilus influenzae* type b [Hib], typhoid conjugate vaccine [TCV], influenza, rotavirus, measles, pertussis, varicella), and population-level outcomes (antibiotic consumption, resistant disease, otitis media, hospitalization). We integrate global policy (WHO Global Action Plan on AMR; Immunization Agenda 2030) with an India-specific lens (National Action Plan on AMR, ICMR AMR surveillance, Universal Immunisation Programme introductions of PCV/TCV). We propose metrics to track vaccine AMR impact, implementation strategies that align immunisation with antimicrobial stewardship, and a forward agenda for research (next gen vaccines for priority AMR pathogens, maternal infant strategies, and digital data integration).

Keywords: Pediatric Immunisation; Antimicrobial Resistance; PCV; Hib; TCV; Influenza; Rotavirus; India; ICMR; Antimicrobial Stewardship; Vaccine-Preventable Diseases

1. Introduction

AMR is among the leading global health threats, with millions of deaths associated with resistant bacterial infections each year [1–3]. Children are disproportionately affected due to high infection incidence, empirical antibiotic use, and exposure in community and hospital settings. Vaccination is one of the few interventions that simultaneously reduces infection incidence, antibiotic demand, and transmission of resistant organisms, thereby lowering selection pressure and slowing AMR emergence [4–7]. Global strategies (WHO Global Action Plan on AMR, Immunization Agenda 2030) explicitly call out vaccination as a core AMR pillar [5,8,9]. In India, where infectious burden and antibiotic consumption are high, the Universal Immunisation Programme (UIP) and National Action Plan on AMR (NAP-AMR) position vaccines as central to stewardship goals [10–12].

2. Mechanisms: how vaccines reduce AMR

2.1. Biological and epidemiological pathways

- **Direct prevention of bacterial disease** (e.g., PCV prevents invasive pneumococcal disease): fewer infections → fewer antibiotic courses → less selection for resistance [4,6,13].

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- **Herd protection**: reduced carriage/transmission of both susceptible and resistant strains (e.g., conjugate vaccines reduce nasopharyngeal carriage) [14–16].
- **Averting viral illnesses** frequently mismanaged with antibiotics (influenza, measles, rotavirus): fewer inappropriate antibiotic prescriptions and fewer secondary bacterial infections [7,17–19].
- **Lower healthcare exposure**: fewer clinic/ED visits and admissions reduce risk of acquiring resistant organisms (e.g., ESBL, MRSA) [20].
- **Serotype replacement moderated by broader-valent vaccines**: higher-valent PCVs maintain net AMR benefit even if some non-vaccine serotypes expand [21].
- **Synergy with stewardship**: vaccination reduces baseline disease pressure, allowing narrower empiric regimens and shorter courses [22].

3. Evidence by Vaccine (Core Pediatric Schedule)

3.1. Pneumococcal conjugate vaccine (PCV10/13/15/20)

3.1.1. Outcomes

Sharp declines in invasive pneumococcal disease (IPD), pneumonia, acute otitis media (AOM), all-cause antibiotic prescribing, and penicillin/cephalosporin-resistant IPD [13–16,21,23].

3.1.2. Mechanisms

Reduced carriage of vaccine serotypes (many historically resistant) → herd effects in unvaccinated groups [14,15].

3.1.3. AMR link

Multi-country analyses show substantial declines in resistant IPD after PCV introduction; overall antibiotic use in children falls due to fewer AOM/pneumonia episodes [13,16,21,23].

3.2. Haemophilus influenzae type b (Hib)

3.2.1. Outcomes

Marked reduction in Hib meningitis/pneumonia and associated antibiotics [24,25].

3.2.2. AMR link

Lower disease burden reduces β-lactam exposure; surveillance shows declines in Hib disease where resistance had been emerging [24–26].

3.3. Typhoid conjugate vaccine (TCV)

3.3.1. Outcomes

Significant reduction of typhoid fever in endemic settings and declines in multidrug-resistant and fluoroquinolone-nonsusceptible *Salmonella Typhi* [27–29].

3.3.2. India relevance

TCV introduction supports control of extensively drug-resistant (XDR) typhoid threats across South Asia [10,27–30].

3.4 Influenza vaccine

3.3.3. Outcomes

Fewer febrile respiratory illnesses and fewer secondary bacterial complications translate into lower antibiotic prescriptions (often inappropriate for viral disease) [17,31].

3.3.4. AMR link

Even modest increases in influenza coverage can reduce large volumes of unnecessary antibiotics at population level [17,31].

3.4. Rotavirus vaccine

3.4.1. Outcomes

Large reductions in severe diarrhoea and hospitalization; studies show **reduced antibiotic use for gastroenteritis** in vaccinated settings [18,32].

3.4.2. AMR link

Curtailing antibiotic overuse in viral diarrhoea directly reduces selection pressure in the gut microbiome [18,32].

3.5. Measles vaccine

3.5.1. Outcomes

Averts measles and **post-measles bacterial infections**; decreases antibiotic exposure associated with complications (otitis media, pneumonia) [19,33].

3.5.2. AMR link

Prevention of measles outbreaks reduces surge-driven, often unnecessary antibiotic use [19,33].

3.6. Pertussis and varicella vaccines

3.6.1. Outcomes

Lower pertussis and varicella incidence, fewer secondary bacterial infections (e.g., varicella-associated impetigo) → less antibiotic use [34–36].

3.6.2. Take-home

Across multiple vaccines, the consistent pattern is **fewer infections → fewer antibiotic courses → less resistance**.

4. Population-Level Outcomes: Antibiotic Use and Resistance

4.1.1. Antibiotic consumption

After PCV and Hib introductions, several countries observed **10–30% reductions** in pediatric outpatient antibiotic prescribing, especially for AOM and RTIs [16,21,23,37].

4.1.2. Resistant disease

Decreases in penicillin-resistant IPD (PCV), MDR Typhi (TCV), and β-lactam-nonsusceptible Hib are documented in surveillance reports [13,24,27–29].

4.1.3. Healthcare utilization

Lower hospitalizations reduce nosocomial AMR exposures (e.g., ESBL-Enterobacterales) [20].

4.1.4. Equity

Gains are greatest where baseline disease burden and antibiotic exposure are high (LMICs) [7,18,27,32].

5. India: Burden, Policy, and Program Integration

5.1. Burden and surveillance

India faces a high incidence of pediatric bacterial and viral infections with rising resistance among priority pathogens (*S. pneumoniae, H. influenzae, S. Typhi, E. coli, K. pneumoniae*) [10–12,38,39]. The ICMR AMR Surveillance Network and the Integrated Health Information Platform (IHIP) provide expanding data on resistance patterns and vaccine-preventable disease trends [11,12,38].

5.2. Policy framework

5.2.1. National Action Plan on AMR (NAP-AMR)

Recognizes immunisation as a core prevention strategy aligned with One Health [10].

5.2.2. Universal Immunisation Programme (UIP)

Nationwide incorporation of Hib, PCV, rotavirus, measles–rubella, and TCV (progressively scaled). These reduce illness episodes that typically drive antibiotic demand [40–43].

5.2.3. Implementation priorities

Strengthen district-level coverage, catch-up for missed doses, integrate vaccine/antibiotic data streams, and expand TCV in high-risk geographies.

5.3 Early signals of impact

- Post-PCV data show downward trends in severe pneumococcal disease; rotavirus vaccine scale-up associates with fewer diarrhea admissions (and antibiotics) [41–43].
- TCV pilots and phased rollouts in Indian states report fewer typhoid cases and facility visits, with implications for MDR Typhi control [28–30,41].

6. Integration with Antimicrobial Stewardship (AMS)

- **Clinic/ED algorithms** combining vaccine status with RTI/AOM pathways reduce unnecessary antibiotic initiation (e.g., "vaccine up-to-date + mild viral URTI → no antibiotics + review in 48–72 h") [22,37].
- **Hospital stewardship** ties discharge antibiotic duration to vaccine-mediated risk profiles; e.g., post-PCV AOM protocols shift to watchful waiting more often [23,37].
- **Peri-outbreak response**: Rapid vaccination (measles, influenza) + AMS messaging → less panic prescribing during outbreaks [19,31].
- **Digital health**: Link EIR/IIS with e-prescribing so that vaccination episodes, missed doses, and antibiotic fills can be co-analyzed for quality improvement [44–46].

7. Economics and Value for Money

Vaccines avoid direct treatment costs and AMR externalities (longer stays, second-line drugs). PCV, Hib, rotavirus, and TCV repeatedly demonstrate cost-effectiveness when AMR costs are included. Modeling suggests that strong vaccine portfolios could avert billions of dollars in AMR-related costs over decades in high-burden settings [6,29,32,47,48].

8. Implementation challenges

- Coverage gaps (missed zero-dose and under-immunised communities) reduce AMR benefits [8,9].
- Serotype/pathogen replacement requires ongoing surveillance and higher-valent or updated vaccines [21].
- Supply/financing constraints may delay introductions (e.g., TCV) where AMR benefit is large [28,29].
- Data fragmentation between immunisation and pharmacy/AMS datasets hinders attribution of AMR gains [44–46].
- Hesitancy and communication issues can spike inappropriate antibiotic demand during outbreaks [31,33].

9. Measuring the Vaccine–AMR Effect: Practical Metrics

9.1. Program metrics

Coverage (by dose and district), timeliness, zero-dose rate.

9.2. Clinical metrics

AOM/RTI visits per 1,000 children; diarrhea admissions; influenza-like illness.

9.3. Antibiotic metrics

Outpatient antibiotic prescriptions/1,000 child-months; "antibiotics for viral diagnoses"; hospital DOT (days of therapy) for broad-spectrum agents.

9.4. AMR metrics

IPD due to penicillin-nonsusceptible *S. pneumoniae*; MDR Typhi incidence; Hib β-lactam nonsusceptibility; ESBL colonization among pediatric admissions.

9.5. Integrated dashboards

Combine EIR/IIS + e-pharmacy + lab AMR surveillance; report quarterly at district/state/national levels [11,12,44–46].

10. Policy Recommendations (Global and India)

- **Make vaccines a formal AMR indicator.** Track vaccine coverage and AMR-relevant outcomes in AMR national plans and WHO Joint External Evaluations [5,8,9].
- **Accelerate introductions and catch-up** for **PCV, Hib, rotavirus, TCV, influenza** in high-burden districts; prioritize urban slums and remote blocks (India) [40–43].
- **Link immunisation with AMS**: embed vaccine prompts in prescribing systems; audit "antibiotics for viral diagnoses"; publish vaccine-AMS scorecards [22,37,44].
- **Strengthen surveillance**: fund ICMR/state labs for pediatric AMR panels; couple with serotype/strain typing (PCV) and *S. Typhi* resistance genomics [11,12,21,28].
- **Invest in communication**: explain the **vaccine–AMR** link to clinicians and parents; during outbreaks, combine vaccination drives with targeted AMS messages [31,33].
- **Plan for next-gen vaccines** targeting AMR-priority bacteria (e.g., *E. coli*, *K. pneumoniae*); support maternal immunisation to protect early infancy [49–51].
- **Use digital health**: national dashboards that overlay **coverage, antibiotic use, and AMR** with geo-analytics to focus outreach [44–46].

Table 1 Pediatric Vaccines and Their AMR Pathways/Effects

Vaccine	Primary Pathogen/Illness	Main AMR Pathways	Illustrative Outcomes
PCV (10/13/15/20)	*S. pneumoniae* (IPD, pneumonia, AOM)	↓ infections; ↓ carriage of resistant serotypes; herd effects	↓ penicillin/cephalosporin-resistant IPD; ↓ AOM and antibiotics [13–16,21,23]
Hib	Hib meningitis/pneumonia	↓ disease and β-lactam exposure	↓ Hib disease; fewer antibiotics [24–26]
TCV	*Salmonella Typhi*	↓ MDR/XDR Typhi circulation	↓ typhoid incidence; ↓ resistant Typhi [27–30]
Influenza	Viral RTIs	↓ inappropriate antibiotics; ↓ secondary bacterial infections	↓ community antibiotic use [17,31]
Rotavirus	Viral diarrhea	↓ antibiotics for gastroenteritis	↓ antibiotic courses in children [18,32]
Measles	Measles and post-measles bacterial infections	↓ secondary infections → ↓ antibiotics	↓ antibiotic exposure during outbreaks [19,33]
Pertussis/Varicella	Pertussis; varicella ± secondary skin infections	↓ disease → ↓ antibiotics	↓ antibiotic demand [34–36]

Table 2 Strategies to Maximise Vaccine Impact on AMR (Global + India)

Level	Strategy	Operational Elements	Expected AMR Benefit
National (Global)	Make vaccines explicit AMR indicators	Include coverage + AMR outcomes in NAP-AMR M and E	Alignment, accountability [5,8,9]
India (MoHFW/ICMR)	Scale PCV, TCV; strengthen Hib/rotavirus/MR	District microplans; catch-up; high-risk geographies	↓ antibiotic consumption; ↓ MDR Typhi; ↓ resistant IPD [10–12,40–43]
Systems	Integrate EIR/IIS with e-prescribing and lab AMR	HL7-FHIR interfaces; quarterly dashboards	Trackable vaccine–AMR signal [44–46]
Clinical (AMS)	Vaccine-aware antibiotic algorithms	"No antibiotics for viral diagnoses"; AOM watchful waiting	↓ inappropriate outpatient antibiotics [22,23,37]
Outbreaks	Rapid vaccination + AMS comms	Influenza/measles campaigns; hotline scripts	↓ panic prescribing [19,31,33]
R and D	Next-gen AMR-priority vaccines	Public–private partnerships, maternal/infant focus	Future reduction in resistant pathogens [49–51]

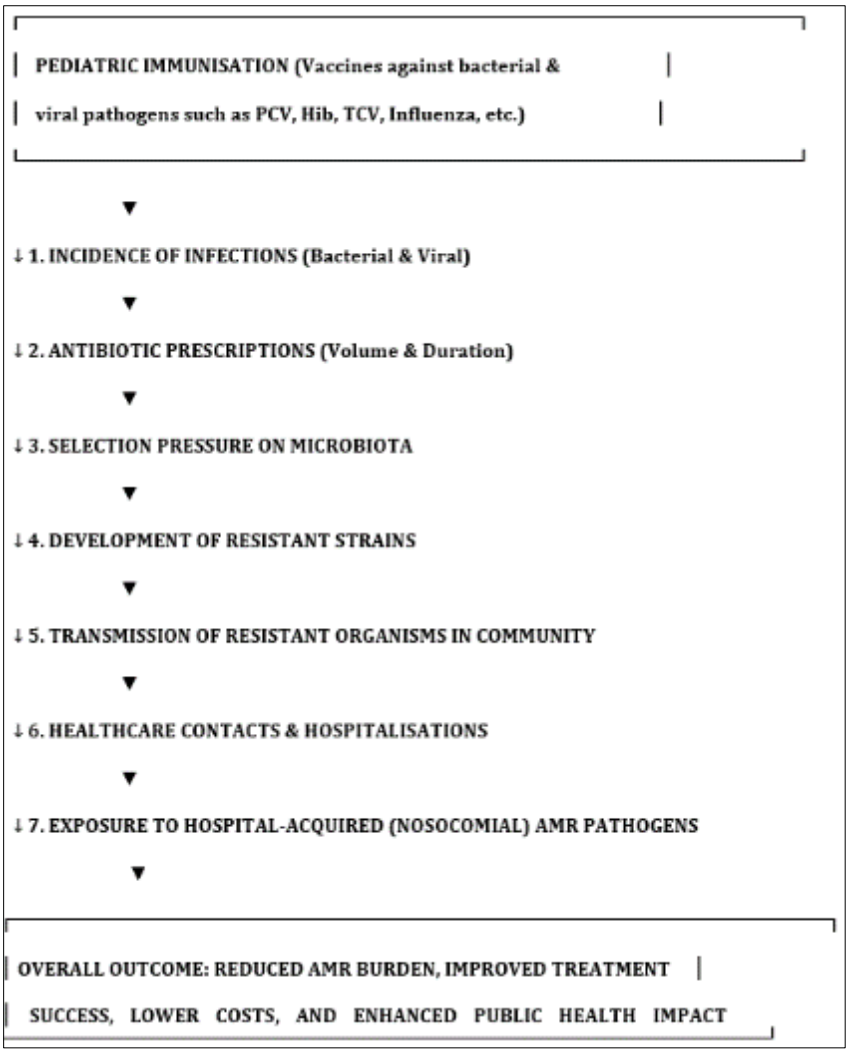

Figure 1 Mechanistic Pathways Linking Pediatric Vaccination and AMR (ASCII, B/W)

Future Directions

- Next-gen vaccines for AMR priority pathogens (E. coli, K. pneumoniae, S. aureus), optimized adjuvants, and maternal immunisation to protect neonates [49–51].
- Geno-surveillance integration: pair vaccine impact with pathogen genomics to watch serotype/strain shifts and resistance evolution [21,28,49].
- Digital convergence: unify immunisation, prescribing, and lab AMR data; create district-level dashboards to target gaps and measure AMR benefit in near-real time [44–46].
- Behavioral science: design parent/clinician nudges linking "vaccines save antibiotics" to practical decisions (e.g., AOM watchful waiting) [22,37].
- Equity: prioritise zero-dose and remote communities to capture the largest AMR gains [8,9].

11. Conclusion

Pediatric immunisation is a front-line AMR intervention. By preventing infections, curbing antibiotic demand, limiting transmission of resistant strains, and reducing healthcare exposure, vaccines deliver measurable AMR benefits. Globally and particularly in India maximising PCV, Hib, TCV, rotavirus, measles, and influenza coverage, integrating immunisation with AMS, and linking data systems for joint vaccine–AMR monitoring can substantially reduce resistant infections and antibiotic use. As next-generation vaccines and digital infrastructure mature, vaccination should be recognised and funded as a core pillar of AMR control.

Compliance with ethical standards

Disclosure of conflict of interest

No Conflict of Interest

References

[1] World Health Organization. Global Antimicrobial Resistance and Use Surveillance Report. Geneva: WHO; 2023.

[2] Murray CJL, Ikuta KS, Sharara F, et al. Global burden of bacterial antimicrobial resistance in 2019. Lancet. 2022;399(10325):629–655.

[3] Centers for Disease Control and Prevention. Antibiotic Resistance Threats Report. Atlanta: CDC; 2023.

[4] Levin BR, Antia R, Blower S, et al. A theoretical framework for vaccines as tools to combat antimicrobial resistance. Clin Microbiol Rev. 2017;30(4):937–976.

[5] World Health Organization. Global Action Plan on Antimicrobial Resistance. Geneva: WHO; 2015.

[6] Organisation for Economic Co-operation and Development. Stemming the Superbug Tide: Just a Few Dollars More. Paris: OECD; 2018.

[7] Gavi, the Vaccine Alliance. Vaccines as Tools to Fight Antimicrobial Resistance: Evidence Synthesis. Geneva: Gavi; 2022.

[8] World Health Organization. Immunization Agenda 2030: A Global Strategy to Leave No One Behind. Geneva: WHO; 2021.

[9] UNICEF. Immunization Roadmap 2030. New York: UNICEF; 2022.

[10] Ministry of Health and Family Welfare, Government of India. National Action Plan on Antimicrobial Resistance. New Delhi: MoHFW; 2017 (updated editions).

[11] Indian Council of Medical Research (ICMR). Antimicrobial Resistance Surveillance Network Annual Report. New Delhi: ICMR; 2023.

[12] National Centre for Disease Control (NCDC) and ICMR. National AMR Surveillance and Research Network – Methods and Indicators. New Delhi: NCDC/ICMR; 2022–2024.

[13] O'Brien KL, Wolfson LJ, Watt JP, et al. Impact of pneumococcal conjugate vaccine on antibiotic-resistant pneumococcal disease. N Engl J Med. 2009;360(3):244–256.

[14] Moore MR, Link-Gelles R, Schaffner W, et al. Herd immunity and serotype shifts after pneumococcal conjugate vaccine introduction. J Infect Dis. 2015;211(6):881–891.

[15] Brueggemann AB, Pichon B, Panagiotou S, et al. Changes in pneumococcal carriage and resistance after vaccine introduction. Clin Infect Dis. 2019;69(10):1831–1841.

[16] Madhi SA, et al. Pneumococcal conjugate vaccine and reductions in otitis media and antibiotic use. Pediatrics. 2012;129(3):e561–e568.

[17] Doherty M, Buchy P, Standaert B, et al. Influenza vaccination and antibiotic use: modelling and empirical evidence. Vaccine. 2016;34(50):6529–6536.

[18] Pitzer VE, et al. Rotavirus vaccination and antibiotic prescribing for diarrhoea. J Pediatric Infect Dis Soc. 2020;9(5):540–549.

[19] Moss WJ. Measles control and reduction of secondary bacterial infections. Infect Dis Clin North Am. 2011;25(1):179–193.

[20] Tacconelli E, Carrara E, Savoldi A, et al. Reducing nosocomial exposure through prevention strategies. Lancet Infect Dis. 2018;18(2):e306–e375.

[21] Hausdorff WP, Dagan R, Klugman KP. Serotype replacement and higher-valent pneumococcal vaccines: implications for antimicrobial resistance. Vaccine. 2020;38(32):4932–4944.

[22] Hersh AL, Fleming-Dutra KE, Shapiro DJ, et al. Outpatient antibiotic stewardship in pediatrics. Pediatrics. 2018;142(2):e20181165.

[23] Fireman B, Black SB, Shinefield HR, et al. Pneumococcal conjugate vaccine and antibiotic prescribing trends for acute otitis media. Pediatrics. 2019;144(1):e20190510.

[24] Watt JP, Wolfson LJ, O'Brien KL, et al. Global decline in Haemophilus influenzae type b disease after vaccination. Lancet. 2009;374(9696):903–911.

[25] Collins S, et al. Hib vaccine impact on resistance patterns. J Antimicrob Chemother. 2014;69(1):121–127.

[26] Centers for Disease Control and Prevention. Hib Surveillance – Post-Vaccine Era Summaries. Atlanta: CDC; 2022.

[27] Qadri F, et al. Effectiveness of typhoid conjugate vaccine in South Asia. Lancet Glob Health. 2021;9(8):e1047–e1055.

[28] Britto C, Dyson ZA, Duchene S, et al. Extensively drug-resistant typhoid and the role of conjugate vaccine. Clin Infect Dis. 2020;71(10):e185–e192.

[29] Antillón M, Bilcke J, Pitzer VE. Typhoid conjugate vaccine cost-effectiveness and AMR implications. Lancet Infect Dis. 2017;17(7):729–739.

[30] Indian Council of Medical Research (ICMR). Typhoid vaccination and antimicrobial use reduction in India: Policy Brief. New Delhi: ICMR; 2023.

[31] Smith DRM, et al. Influenza vaccination and antibiotic prescribing in primary care. BMJ Open. 2021;11(7):e046883.

[32] Aliabadi N, Tate JE, Haynes AK, et al. Declines in antibiotic use after rotavirus vaccine introduction. Clin Infect Dis. 2019;69(11):2059–2066.

[33] Perry RT, et al. Measles vaccination and secondary bacterial complications. J Infect Dis. 2012;205(Suppl 1):S28–S33.

[34] Cherry JD. Pertussis vaccine impact on clinical disease and antibiotic use. Pediatr Infect Dis J. 2012;31(3):S47–S50.

[35] Marin M, et al. Varicella vaccination: complications and antibiotic use. Clin Infect Dis. 2016;62(3):S60–S66.

[36] Lever A, et al. Bacterial skin infections secondary to varicella: prevention by vaccination. J Infect. 2010;60(4):311–318.

[37] Fleming-Dutra KE, et al. Inappropriate outpatient antibiotic prescribing in children. JAMA. 2016;315(17):1864–1873.

[38] Chatterjee P, et al. Burden of antibiotic use in India. J Antimicrob Chemother. 2020;75(10):3051–3061.

[39] Balasubramanian S, et al. Pediatric infectious diseases and antimicrobial resistance in India. Indian Pediatr. 2021;58(11):1021–1030.

[40] Ministry of Health and Family Welfare (MoHFW). Universal Immunisation Programme – PCV Scale-up Policy Notes. New Delhi: MoHFW; 2022.

[41] Ministry of Health and Family Welfare (MoHFW). Typhoid Conjugate Vaccine (TCV) Pilot and Rollout Updates. New Delhi: MoHFW; 2023.

[42] Universal Immunisation Programme (UIP). Rotavirus and Measles-Rubella Coverage Reports. New Delhi: MoHFW; 2019–2024.

[43] World Health Organization – India. Immunization Programme Monitoring Updates. New Delhi: WHO India; 2025.

[44] Centers for Disease Control and Prevention and HL7. Immunization Information Systems and FHIR Guidance. Atlanta: CDC; 2023.

[45] District Health Information Software (DHIS2) Tracker. Immunization and AMR Indicator Integration Guidance. Oslo: DHIS2; 2024.

[46] Pan American Health Organization and World Health Organization. Linking Immunisation and AMR Data Systems: Technical Brief. Washington DC: PAHO/WHO; 2023.

[47] Klugman KP, Black S. Impact of vaccines on antimicrobial resistance and economics. Vaccine. 2018;36(44):6606–6612.

[48] Laxminarayan R, et al. Economic burden of AMR and prevention scenarios. Health Policy Plan. 2021;36(8):1249–1257.

[49] World Health Organization. WHO Priority Pathogens List – Bacterial AMR Update. Geneva: WHO; 2024.

[50] Micoli F, Adamo R, Costantino P, et al. Glycoconjugate and protein vaccines against AMR pathogens. NPJ Vaccines. 2021;6(1):112.

[51] Madhi SA, et al. Maternal immunisation strategies and infant protection. Lancet. 2020;396(10255):688–700.