

Infectious Disease Management in Pediatric Emergency Departments in Low- and Middle-Income Countries: A Review of Diagnostic Tools, Treatment Protocols, and Preventive Measures

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Abstract

Pediatric Emergency Departments (PEDs) in low- and middle-income countries (LMICs) face significant challenges in managing infectious diseases due to limited resources, poor infrastructure, and socioeconomic barriers. This review explores the burden of infectious diseases in pediatric populations, the diagnostic tools available, treatment protocols, and preventive measures implemented in LMIC PEDs. We emphasize the need for an integrated approach to improve health outcomes, focusing on enhancing healthcare infrastructure, training healthcare workers, and promoting public health awareness. Key recommendations and future directions are discussed to address the critical gaps and challenges in managing pediatric infectious diseases in these settings.

Keywords

pediatric emergency departments, low- and middle-income countries, infectious diseases, pediatric populations, diagnosis, prevention, treatment

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Introduction

Background on Pediatric Emergency Care in Low-Resource Settings

Pediatric Emergency is a domain of healthcare concerned with providing urgent interventions to medical emergencies across all pediatric age groups.¹ The knowledge of prompt interventions in a pediatric emergency setting helps to reduce mortality across all pediatric age groups.¹ In low- and middle-income countries (LMICs), defined as nations with a gross national income per capita between \$1046 and \$12535, providing emergency care presents unique challenges.² These challenges are primarily due to deficits in both human and physical resources essential for diagnostic and therapeutic actions.² Administering emergency care in low-income communities presents distinct problems that must be

addressed to deliver adequate and timely care to children in need.³ Pediatric emergency care requires a comprehensive multidisciplinary approach, necessitating the collaboration of various healthcare professionals to

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ensure optimal intervention.⁴ Adequate numbers of pediatric specialists, including pediatric emergency specialists, pediatric cardiologists, pediatric nephrologists, neonatologists, pulmonologists, pediatric surgeons, and pediatric nurses, are essential for correct diagnosis and management. The lack of emergency medicine specialization programs in most LMICs poses a significant challenge that must be addressed.⁵ There are multiple socioeconomic factors affecting access and quality of care in pediatric emergency centers. Higher income levels are often associated with better access to healthcare services due to the ability to afford health insurance coverage and out-of-pocket expenses.⁶ Higher levels of education are associated with better health outcomes because people with higher education are frequently better able to navigate the healthcare system, understand medical advice, and engage in preventive health activities.⁷ Individuals with a stable job and access to employer-sponsored health insurance are more likely to have consistent access to medical treatment than those who are unemployed.⁸ Inadequate healthcare services may lack access to specialist treatment, diagnostic testing, or preventive screenings, resulting in unmet healthcare needs and inequities in health outcomes.⁸ The cost of healthcare affects people's health-seeking behavior as they may not visit healthcare facilities due to perceived high costs, especially for advanced therapeutic and diagnostic interventions.⁹

Methodology

To conduct this review, we searched PubMed, Embase, the Cochrane Library, Scopus, and Web of Science. Our search strategy combined keywords related to "pediatric emergency care," "infectious diseases," "low- and middle-income countries," and relevant terms for "diagnostic tools," "treatment protocols," and "preventive measures." The search was confined to articles published between inception of the database and June 2023. The search string used was: ("pediatric emergency care" OR "child emergency department") AND ("infectious diseases" OR "TB" OR "pneumonia" OR "malaria") AND ("low-income countries" OR "middle-income countries") AND ("diagnostic tools" OR "treatment protocols" OR "preventive measures").

Studies were included if they focused on pediatric emergency care within LMICs and discussed diagnostic tools, treatment protocols, or preventive measures for infectious diseases. We considered peer-reviewed articles, including original research, reviews, and guidelines published in English. Conversely, we excluded studies that did not specifically address infectious diseases or pediatric emergency care in LMICs. Additionally,

articles not meeting the peer-reviewed criteria, such as opinion pieces and editorials, were excluded from the review. The selection process involved two independent reviewers who screened the titles and abstracts of identified studies to assess their relevance. Those meeting the initial criteria were subjected to a full-text review. During this phase, the studies were evaluated against the established inclusion and exclusion criteria. Any discrepancies between the reviewers were resolved through discussion or consultation with a third reviewer to ensure accuracy and consistency in the selection process.

The extracted data were synthesized qualitatively to identify common themes, patterns, and trends. A narrative synthesis was employed to summarize the findings related to diagnostic tools, treatment protocols, and preventive measures.

Burden and Management of Infectious Diseases in Pediatric Populations

Infectious diseases continue to pose a significant burden on pediatric populations globally. Children are often more vulnerable to infections due to their underdeveloped immune systems, making them more susceptible to contracting and experiencing severe symptoms of various illnesses.¹⁰ Factors such as inadequate healthcare infrastructure, poor sanitation, and limited access to essential resources like clean water and vaccines exacerbate the prevalence and severity of diseases such as malaria, pneumonia, diarrheal diseases, and tuberculosis among others.¹¹ Globally, infectious illnesses such as pneumonia, diarrhea, and malaria continue to be the top causes of mortality for children accounting for 44.1% mortality between 1990 and 2019.¹² Pneumonia, diarrhea and malaria were responsible for approximately 30% of global deaths among children under the age of 5 in 2019.¹³ Roughly half of these deaths, totaling 2.4 million, occurred during the newborn period within the first 28 days of life.¹³ In 2019, the sub-Saharan African (SSA) region documented an average under-5 mortality rate of 76 deaths per 1000 live births, translating to approximately 1 child out of every 13 dying before reaching the age of 5 years.¹⁴

Efforts to reduce the burden of infectious diseases in pediatric populations must focus on improving healthcare infrastructure, increasing access to vaccines, and promoting public health awareness and education.¹⁵ Challenges such as vaccine hesitancy and drug-resistant strains of bacteria and viruses require a collaborative approach between healthcare providers, public health specialists, policymakers, and communities to decrease the burden of infectious diseases among children.¹⁶ Effective and timely diagnosis and management of pediatric populations are critical because of their unique

developmental stages, physiological variances, and the rapid deterioration of their conditions.¹⁷ Hence, caregivers, parents, and healthcare professionals must be proficient in promptly identifying and addressing child emergencies.¹⁸ Although approximately 10% to 20% of unwell children may require hospital referral, delays in recognition, late arrival, resource shortages, and disease severity render the initial 24 hours of hospitalization the most precarious period, with one-third of patient deaths occurring during this time.¹⁹ Resource-limited settings where the capacity to address life-threatening conditions is confined to basic healthcare resources present a unique challenge to the establishment and maintenance of critical care services.²⁰

Epidemiology of Infectious Diseases in LMIC PEDs

The shortage of resources, poor management, and lack of hygienic practices in LMICs lead to the spread of pediatric infectious diseases. Long-standing challenges include the lack of preventive interventions due to the absence of feasible control measures, as there is a disinterest among biomedical companies in developing vaccines and medications for diseases predominantly found in LMICs.¹¹ Measles, for example, continues to kill 600 000 children a year despite the availability of an effective vaccine. Invasive bacterial diseases such as pneumonia, meningitis, and sepsis are major causes of mortality among children in LMICs, with pneumonia remaining the leading infectious cause of death among children under five in developing countries.²¹ Pneumonia in children has been associated with areas that have a high TB prevalence, with risk factors including young age, malnutrition, immunosuppression, and air pollution, all prevalent in LMICs.²²

There is inequity between LMICs and high-income countries in the global burden of infectious diseases among children. LMICs account for 98% of the disease burden among children, yet they are represented in only 22% of trials.²³ In 2015, Sub-Saharan Africa contributed 50% of under-five deaths worldwide, and South Asia contributed 31%.²⁴ Despite a global decline in under-five mortality by half over the past two decades, this progress has not been shared equally. A study by McAllister et al reported pneumonia as the leading cause of death among children under five globally, with an estimated 800 000 deaths and a substantial burden in LMICs.²⁵ These diseases significantly contribute to illness and long-term health complications in children, creating a substantial strain on healthcare systems already battling resource limitations. While mortality rates are essential for understanding global health and

comparing countries, they do not provide a complete picture of how many people are sick or how well the healthcare system is functioning. Similarly, morbidity indicators, which track the spread of diseases, are underused because of limited data, ineffective reporting, and gaps in data storage and analysis.²⁶ The impact of infectious diseases on healthcare systems in LMICs emphasizes the critical importance of targeted interventions and sustainable healthcare infrastructure development to alleviate their burden on vulnerable populations.

Diagnostic Tools

There is a paucity of high-quality diagnostic tools in LMICs because accurate and advanced diagnostic tools are generally expensive to acquire and require extensive cost and specialized knowledge to maintain. Additionally, the lack of regulation around testing standards makes cheaper but less accurate products dominate the healthcare system, causing some providers to shun their use altogether and rely on clinical judgment instead. To this end, the World Health Organization (WHO) publishes guidelines on syndromic management of common diseases, wherein patients are treated for the most likely pathogens to cause their specific presentation. Although this can be effective in many cases, overtreatment results, which ends up costing more resources and contributes to antimicrobial resistance. For this reason, inexpensive modalities such as point-of-care tests (POCTs) are heavily relied upon in the developing world.²⁷ Regarding TB specifically, sputum microscopy and chest radiographs are commonly available tools used for diagnosis.²⁸ Another test, induced sputum, is effective for diagnosing pertussis, pneumocystis pneumonia, and tuberculosis, providing a higher yield than nasopharyngeal aspirate.²²

Infectious diseases among children involve pathogens such as *E. coli* and *Campylobacter coli*, among others. In these cases, metaproteomic analyses could be used as an effective diagnostic tool to analyze different pathotypes and serotypes.²⁹ Oxygen saturation rates lower than 90% to 92% among pneumonia pediatric cases have been associated with an increased risk of mortality. Consequently, hypoxia serves as an essential prognostic indicator in pediatric pneumonia cases. However, many LMICs do not have access to regular use of pulse oximetry, and the availability of oxygen is limited.²² There is limited availability of mycobacterium tuberculosis PCR tests, such as Xpert or Xpert Ultra, in LMICs for diagnosing pediatric TB, which results in diagnoses being largely based on symptom identification.²² A study analyzing the management of TB in Cambodia revealed gaps in diagnostic accuracy due to a lack of good-quality chest X-ray machines, limited access to rapid molecular diagnostic

Table 1. Key Infectious Diseases and Diagnostic Tools in LMIC Pediatric Emergency Departments.

Disease	Diagnostic tool	Accuracy	Affordability	Accessibility
Pneumonia	Chest radiograph, pulse oximetry	Moderate	High/Low	Moderate/Limited
Malaria	Rapid diagnostic tests (RDTs)	High	Moderate	Variable
Diarrheal diseases	Stool analysis	Moderate	Moderate	Moderate
Tuberculosis	Sputum microscopy, Xpert PCR	High	High/Moderate	Limited

systems, poor-quality microscopes, and a low supply of X-ray films.³⁰ This increases the proportion of untreated childhood tuberculosis, which results in adverse outcomes if not treated promptly.

As one would expect, accuracy, affordability, and accessibility vary greatly between different diagnostic modalities as shown in Table 1 and play an important role in hospital availability and clinician use in the developing world. Accurate and timely diagnosis of infectious diseases in children is crucial for effective treatment and improved health outcomes. However, in LMICs, achieving this can be challenging. Challenges associated with bringing high-quality diagnostics to the developing world include harsh environmental conditions, differences in local epidemiology, and lack of proper regulation. One of the biggest challenges of implementing diagnostic tools for infectious diseases in the pediatric population in LMICs is cost. Many parents in these areas have reported that tuberculosis sputum tests and other services within hospitals require out-of-pocket expenditure. In other situations, when TB services were provided free of charge, parents reported they did not have money to travel to receive the services.³⁰ Development of diagnostic tests takes about 5 to 10 years and requires investments of up to \$10 million. In developed countries, this is largely funded by the private sector; however, in LMICs, there is little private sector interest because of the perceived lack of return on investment.²⁷ Additionally, the quality of laboratory services improves patient care, as using laboratory results to guide clinical management can produce positive outcomes. This requires timely communication between the labs and healthcare providers, but LMICs often lack the resources, supplies, and trained personnel for this coordination. As a result, physicians' lack of confidence in laboratory results due to these issues results in additional disregard for laboratory services.²⁷

Treatment Protocols

Review of Evidence-Based Guidelines and Recommendations

The landscape of pediatric emergency care in various countries, including India, Pakistan, and Mozambique, is characterized by a diverse spectrum of conditions and

challenges. In India, national guidelines emphasize the necessity of secondary care facilities being staffed by pediatricians, equipped with basic laboratory testing and imaging capabilities, and access to intravenous medications for pediatric patients. These guidelines underscore a commitment to specialized care for children and are crucial for maintaining quality standards in pediatric healthcare delivery.^{4,31-33} In Pakistan, the multifaceted nature of pediatric emergency care is highlighted with a focus on understanding the burden of injuries and infectious diseases among pediatric patients presenting to emergency departments and wards. The establishment of surveillance systems like the Pakistan National Emergency Department Surveillance (Pak-NEDS) is pivotal for comprehending this landscape.^{33,34} While national guidelines are not explicitly quoted, the study underscores the importance of evidence-based guidelines to guide pediatric emergency care practices, particularly in resource-constrained settings. The study also emphasizes the need for a well-defined pediatric ambulance service and funding support for research and surveillance initiatives.

Similarly, in Mozambique, aligning interventions with national guidelines is imperative to address healthcare challenges. Despite limitations in data accessibility, the study emphasizes the need for robust data systems in accordance with national guidelines to inform effective strategies. The study's findings on mortality rates, hospitalization patterns, and prevalent diagnoses underscore the relevance of evidence-based interventions aligned with national guidelines. By adhering to these guidelines, healthcare providers can better address the unique challenges of pediatric emergency care in Mozambique, ultimately enhancing outcomes for pediatric patients. Overall, evidence-based guidelines play a crucial role in guiding pediatric emergency care practices in various countries, ensuring the provision of specialized care, and improving outcomes for pediatric patients.^{4,33}

Discussion on Barriers to Effective Treatment Implementation in LMIC Settings

Access to emergency care in LMICs is characterized by a disparity among pediatric patients. Funding priorities tend to focus more on primary care, neglecting the implementation of emergency care systems crucial for

Table 2. Challenges and Barriers in Implementing Treatment Protocols in LMIC PEDs.

Challenge	Description
Limited resources	Insufficient medical supplies and equipment for effective treatment
Lack of trained professionals	Shortage of healthcare workers specialized in pediatric emergency care
Data quality issues	Poor data collection and management affecting treatment planning
Funding priorities	More focus on primary care, neglecting emergency care systems
Logistical challenges	Inefficient ambulance services and chaotic ED workflows causing treatment delays

addressing time-sensitive conditions. Additionally, data quality and standardization issues pose challenges, hindering accurate epidemiological research and impeding the identification of effective interventions. However, emergency medical service (EMS) systems are considered valuable data sources that could drive quality improvement efforts and help reduce disparities in healthcare access, particularly for vulnerable populations such as neonates, adolescents, rural communities, and socioeconomically disadvantaged groups.^{1,20}

In Mozambique, barriers such as flawed data registration systems, limited access to historical data, and lack of extensive research lead to an inability to generate guidelines, create tailored interventions, and develop epidemiological data that support national emergency care.³³ This increases the importance of optimizing data registration to inform resource allocation and intervention planning, necessitating comprehensive healthcare infrastructure improvements by enhancing transportation systems and bolstering health education initiatives. In Pakistan, barriers including limited resources, the shortage of dedicated pediatric emergency facilities, and a lack of trained healthcare professionals lead to suboptimal and delayed care of pediatric patients, increasing the burden of infectious diseases management as mentioned in Table 2. Pakistan also suffers from data collection and surveillance issues, limiting its progress toward national guidelines and targeted intervention development.³¹ Logistical challenges such as inefficient ambulance services and chaotic ED workflows during emergencies contribute to delays in accessing care and hinder effective treatment implementation.

Preventive Measures

Overview of Preventive Measures Including Vaccination Programs, Hygiene Practices, and Infection Control Strategies

Optimizing pediatric emergency care in LMICs necessitates a multifaceted approach encompassing preventive measures, including vaccination programs, hygiene practices, and infection control strategies. These measures are pivotal in mitigating the high mortality rates prevalent in

pediatric emergency departments (PEDs), particularly among neonates.^{4,31-33} Vaccination programs play a paramount role in curtailing the burden of infectious diseases. Efforts to increase vaccination coverage, as seen in India, have been instrumental in combating diseases such as pneumonia and diarrhea, leading causes of mortality among children under five. Similarly, in Mozambique, vaccination initiatives align with global endeavors to safeguard child health, contributing to a healthier populace.^{4,32,33} Hygiene practices, including access to clean water and proper sanitation, serve as essential preventive measures, particularly in LMICs where communicable diseases pose significant health challenges. Improved hygiene can significantly reduce the burden of diseases like diarrhea, contributing to better child health outcomes. Implementing stringent hygiene practices within communities acts as a bulwark against the spread of pathogens, fortifying defenses against communicable diseases in settings like Mozambique.¹⁶

Infection control strategies, particularly within healthcare settings, are indispensable for preventing the spread of diseases and reducing healthcare-associated infections. Robust infection control measures instituted in hospitals and healthcare facilities, as advocated in Pakistan, help safeguard vulnerable pediatric patients from acquiring infections during their treatment.³¹ Such strategies are crucial in nurturing a safe environment for patients and healthcare providers alike, thereby improving overall healthcare outcomes. Synthesizing these preventive measures into a cohesive framework can forge resilient defenses against disease burdens, nurturing healthier populations and fostering sustainable development in pediatric healthcare.^{31,32} Enhancing preventive measures and ensuring their effective implementation could significantly reduce the burden of pediatric emergencies in LMICs, improving child health outcomes.

Identification of Gaps and Challenges in Preventive Interventions

The analysis of preventive interventions for pediatric health in LMICs reveals several critical gaps and challenges.^{4,31-33} Despite efforts to reduce pediatric morbidity and mortality, millions of children in these countries

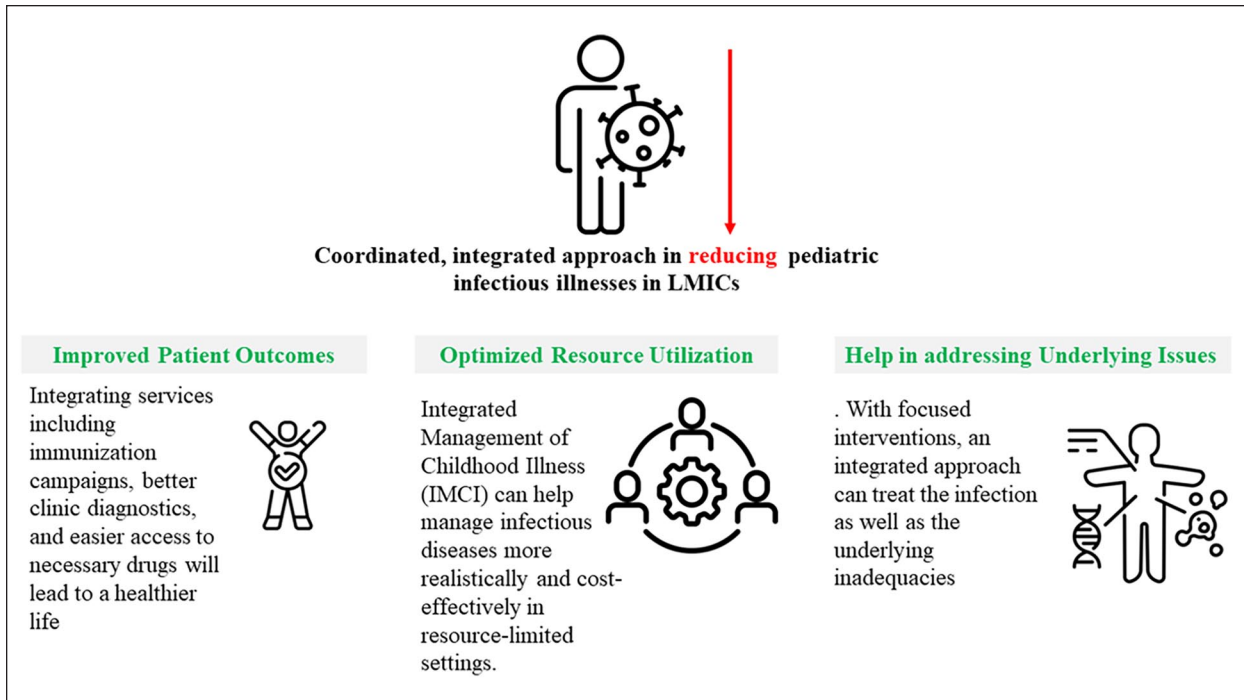


Figure 1. The benefits of applying coordinated, integrated approach in the management of infectious diseases in LMICs.

continue to die from preventable causes such as preterm birth, pneumonia, diarrheal diseases, birth asphyxia, trauma, and infectious diseases. One key challenge identified is the lack of tailored preventive interventions addressing the specific needs of vulnerable populations, including neonates, adolescents, rural dwellers, and socioeconomically disadvantaged families. While EMS play a crucial role in connecting children with acute health needs to higher levels of care, there remains a gap in preventive strategies that could mitigate the need for emergency interventions. Disparities in access to care persist, particularly affecting rural and poor populations, necessitating targeted interventions to improve access to essential health services in underserved areas. Integrating preventive interventions into existing EMS systems and public health initiatives is vital to address underlying factors contributing to pediatric morbidity and mortality in LMICs.³²

Integration of Diagnostic Tools, Treatment Protocols, and Preventive Measures

Importance of an Integrated Approach to Infectious Disease Management

Although the progress toward achieving the fourth Millennium Development Goal in reducing the mortality rate in children younger than 5 years since 1990 has been

notable, with the annual number of under-five deaths falling to 4.9 (4.6-5.4) million in 2022 as reported by the United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME), millions of children still died before their fifth birthday.³⁵ This serves as an important reminder that there are still risks to the health and survival of newborns and children worldwide, especially among the most vulnerable populations of LMICs. Approximately half of the 4.9 million lives lost before the age of five belonged to infants, but 2.1 million other children and youth between the ages of 5 and 24 also lost their lives. Sub-Saharan Africa and Southern Asia accounted for the majority of these fatalities.³⁵ Ending unnecessary mortality of children and teens is a long-term task that requires targeted, integrated approaches. Managing pediatric infectious illnesses in LMICs necessitates a coordinated, integrated approach where resources are typically insufficient, and healthcare systems confront multiple obstacles.³⁶ The main benefits of using this approach in managing pediatric illnesses in LMICs are shown in Figure 1.³⁷

Strategies for Integrating Diagnostic, Treatment, and Preventive Interventions in LMIC PEDs

Several strategies have been developed to effectively integrate diagnostic, therapeutic, and preventive interventions in pediatrics in LMICs:

1. **Approaches Aimed at Healthcare Providers:** This includes educational meetings, nutrition training for health workers, educational outreach, and practice facilitation. These have shown positive effects on outcomes with moderate- or high-certainty evidence. Tailored interventions (practice-changing interventions chosen after a review of the barriers that need to be overcome) targeted at healthcare workers have been proposed to improve health outcomes in LMICs.³⁶
2. **Approaches Aimed at Healthcare Professionals for Specific Problems:** This includes the use of birth kits, teaching healthcare professionals to be more patient-centered during clinical consultations, and reducing the prescription of antibiotics, all of which have been found to improve patient outcomes.³⁶
3. **Approaches Aimed at Healthcare Recipients (Community-Based):** This includes mass media interventions to increase vaccine uptake. More health literacy and adherence to medical interventions have been demonstrated through community-based health education programs and vaccination uptake reminders.³⁶

The World Health Organization (WHO) developed the Integrated Management of Childhood Illness (IMCI) plan in the mid-1990s, working with UNICEF and numerous other organizations, individuals, and institutions. These recommendations stress the sensible, economical, and efficient use of medications and diagnostic equipment. They are based on an evidence-based syndromic approach to case management. The systematic assessment of common symptoms and clinical indicators, along with the development of well-formulated guidelines and appropriate training for healthcare staff, could facilitate the implementation of logical and efficient interventions. Using this method can assist in identifying the clinical problem, determining its severity, and putting the necessary treatment plans into action, whether this is to refer the child right away, manage at home, or manage within the resources at hand.³⁸ The IMCI strategy comprises three components:

- **Training Component:** Clinical care education for healthcare personnel using the IMCI guidelines.
- **Systems Component:** Investing in the administration and organization of healthcare systems, particularly procurement related to the provision of IMCI.
- **Community Health Component:** Conducting home visits and community health promotion to

promote good child-rearing practices, proper nutrition, and access to resources for sick children.³⁸

Consistency and efficacy can be increased by creating and implementing standardized protocols for diagnosis, treatment, and prevention in various healthcare settings. The widespread implementation of essential IMCI components is necessary to meet the Sustainable Development Goal of 3.2, which calls for lowering child mortality to at least 25 deaths per 1000 live births by 2030, particularly in nations where the burden of avoidable childhood death is substantial.³⁹

An example of the implementation of the ICCM approach was reported in seven studies included in a systematic review conducted by Oliphant et al. It was reported that ICCM increased the health-seeking behavior from healthcare professionals delivering the service, with uncertainty regarding its effect on the mortality rate and appropriate treatment coverage.⁴⁰

Health System Strengthening

Discussion on the Role of Health System Strengthening in Improving Infectious Disease Management in LMIC PEDs

Strengthening health systems in LMICs by improving infrastructure, training health workers, and enhancing access to health services is crucial for the effective delivery of interventions. Health systems are essential to the health and welfare of children and adolescents. However, for ultimate change, social systems must work in conjunction with these health systems to provide this age group with services appropriate for their stage of life in terms of promotion, prevention, and treatment.⁴¹

Increasing the resilience of the health system is the most basic strategy for preventing and controlling infectious diseases. The WHO has modularized health systems into six main “building blocks” or components.⁴² First, the foundation for the other blocks is provided by governance and leadership as well as health information systems. Key components for risk management against infectious diseases are defined as the leadership of local and federal governments, intergovernmental collaboration, legislation concerning infectious diseases, and information sharing.⁴³ Second, a robust health system that is ready for the prevention and management of infectious diseases depends on flexible, easily accessible financing. Global investment in health system improvement and sector-wide initiatives is on the rise; in 2020, it reached USD 5.5 billion, or 9.95% of total spending.⁴⁴ However, an alarming note is that 79% of

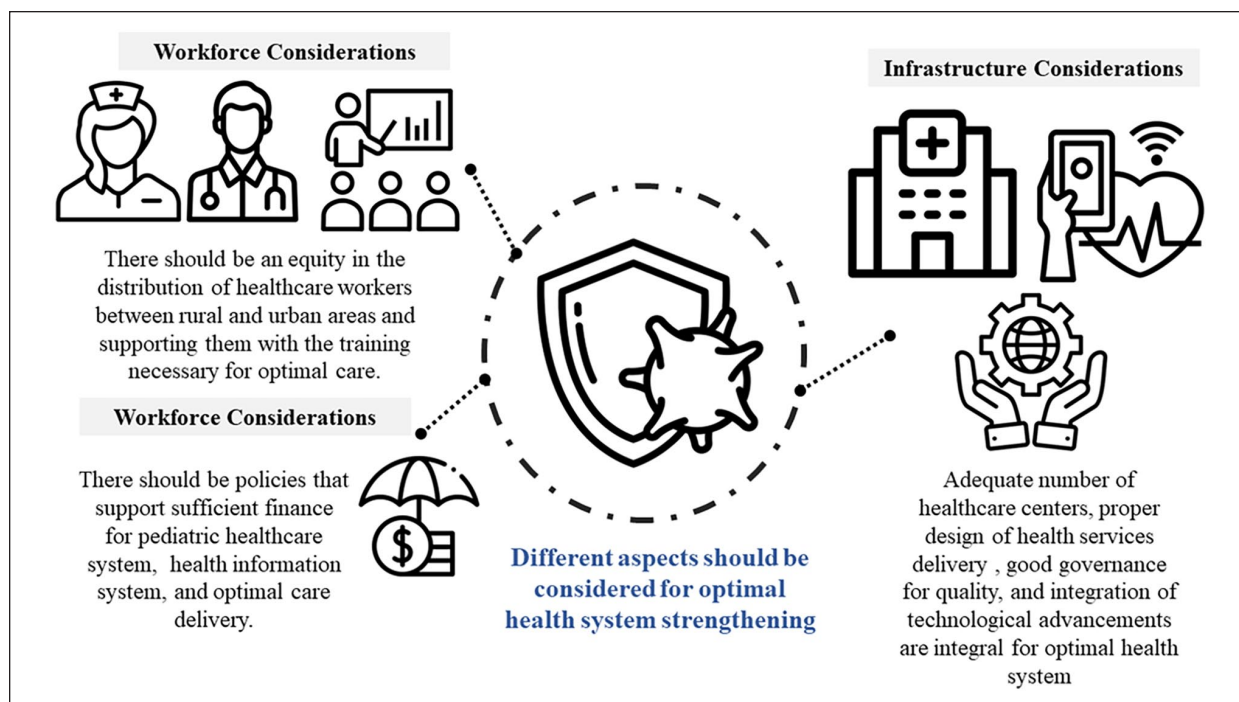


Figure 2. Different considerations in strengthening health system in LMICs.

global spending on healthcare is in high-income countries, despite containing only 16% of the world's population, which requires immediate consideration.⁴⁵ Thirdly, the COVID-19 pandemic has highlighted the need for a strengthened health workforce in creating a capable healthcare system. Lastly, as the direct results of a health system, people's perceptions and experiences with access to health products, technology, and service delivery are crucial, necessitating the improvement of human-centric healthcare delivery.⁴² In addition, primary health care (PHC) is considered to be "the engine for Universal Health Coverage (UHC),"⁴⁶ which is necessary to guarantee a robust health system because of its efficacy in decreasing the mortality rate from infectious diseases and enhancing health outcomes.⁴⁷

Three degrees of improvement are possible for health systems: macro, which refers to the entire system; meso, which refers to a region, area, or community; and micro, which refers to a clinic, provider, or individual user. The majority of efforts have been made at the micro level to enhance system quality in LMICs, but many of these tactics have produced unsatisfactory results.⁴¹ Structural approaches (ie, macro-level and meso-level) hold greater promise for creating high-quality health systems because they are complicated adaptive structures that demand precise objectives, sufficient resources, and enforced restrictions against inferior care. Macro-level strategies target the social, political, economic, and

organizational frameworks that form the health system, whereas meso-level strategies target the subnational levels of regions, districts, and networks of medical facilities or communities.^{41,48} Four such strategies were proposed by the Lancet Global Health Commission on high-quality health systems: governance for quality, clinical education changes, service delivery redesign to maximize quality, and greater public involvement. Such structural changes will greatly enhance health system quality and reduce the spread of pediatric infectious diseases.⁴⁹ Figure 2 illustrates these strategies.

Conclusion

Successful management of infectious diseases in LMICs requires proper funding from national and international organizations to increase the availability of targeted diagnostics, interventions, and preventive measures. Moreover, there should be specialized training programs aimed at increasing the efficiency of healthcare workers in managing pediatric cases promptly. Supporting policies and educational programs to increase the awareness of pediatric families on how to deal with and report medical emergencies to healthcare providers, especially in areas with underserved healthcare facilities, are crucial. Promoting data collection and surveillance systems is critical in developing national guidelines and targeted interventions. Furthermore, research studies on the collected data will

guide policymakers and funding agencies regarding the challenges that should be controlled.

Recommendations

1. **Increase Funding and Resources:** Allocate more funds to pediatric emergency care in LMICs to ensure adequate resources and infrastructure.
2. **Enhance Training Programs:** Develop and implement specialized training programs for healthcare workers in pediatric emergency medicine.
3. **Strengthen Data Collection:** Improve data collection and management systems to support evidence-based decision-making.
4. **Promote Preventive Measures:** Increase efforts in vaccination campaigns, hygiene education, and infection control practices.
5. **Implement Integrated Approaches:** Foster integrated diagnostic, treatment, and preventive strategies to improve patient outcomes.

Future Directions

1. **Research and Development:** Invest in research to develop cost-effective diagnostic tools and treatment protocols tailored to the needs of LMICs.
2. **Policy Development:** Formulate and enforce policies that support sustainable healthcare infrastructure and equitable access to care.
3. **Community Engagement:** Engage communities in public health initiatives to increase awareness and participation in preventive measures.
4. **International Collaboration:** Encourage international collaborations to share knowledge, resources, and best practices in pediatric emergency care.
5. **Technological Innovation:** Explore innovative technologies, such as telemedicine, to extend the reach of healthcare services in remote and underserved areas.

Limitations

1. **Resource Constraints:** The lack of resources in LMICs limits the implementation of advanced diagnostic and treatment protocols.
2. **Data Gaps:** Incomplete or inaccurate data hampers the ability to develop effective interventions and policies.
3. **Training Deficiencies:** Insufficient training programs for healthcare workers affect the quality of care in pediatric emergency departments.

4. **Cultural Barriers:** Cultural beliefs and practices may hinder the acceptance and implementation of preventive measures.
5. **Infrastructure Challenges:** Poor infrastructure in LMICs complicates the delivery of emergency healthcare services.

Abbreviations

- **LMICs:** Low- and Middle-Income Countries
- **PEDs:** Pediatric Emergency Departments
- **TB:** Tuberculosis
- **RDTs:** Rapid Diagnostic Tests
- **POCTs:** Point-of-Care Tests
- **IMCI:** Integrated Management of Childhood Illness
- **ICCM:** Integrated Community Case Management
- **UN IGME:** United Nations Inter-Agency Group for Child Mortality Estimation
- **UHC:** Universal Health Coverage
- **PHC:** Primary Health Care
- **EMS:** Emergency Medical Service

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Contributions

Mohammed Alsabri (MA), considered the first author and corresponding author, proposed the project, contributed to the conception, formulation, and drafting of the article, and reviewed and revised the manuscript. AS, NA, I.V.I, M.A.S, N.A.T, A.H.A, AK, and L.L.G participated in writing and revising the final manuscript. AS designed the figures and created the tables. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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References

- Olatunji G, Kokori E, Aderinto N, Eltayeb Muhammad Ibrahim D, Alhadheri A, Alsabri MAH. Pediatric emergency care in low-resource settings. *Curr Emerg Hosp Med Rep*. 2024;12(2):82-87. doi:10.1007/s40138-024-00291-w
- Peabody JW, Taguiwalo MM, Robalino DA, Frenk J. Improving the quality of care in developing countries. In: Jamison DT, Breman JG, Measham AR, et al., eds. *Disease Control Priorities in Developing Countries*. 2nd ed. Washington (DC): The International Bank for Reconstruction and Development / The World Bank; 2006. Chapter 70.
- Burke TF, Hines R, Ahn R, et al. Emergency and urgent care capacity in a resource-limited setting: an assessment of health facilities in western Kenya. *BMJ Open*. 2014;4(9):e006132-e006132. doi:10.1136/bmjopen-2014-006132
- Ismail H, Chowdhary H, Taira BR, et al. Paediatric emergency care at an academic referral hospital in Mozambique. *African J Emerg Med Rev africaine la Med d'urgence*. 2021;11(4):410-415. doi:10.1016/j.afjem.2021.07.003
- Calvillo E, Reynolds T, Hirshon JM, et al. Emergency care in sub-Saharan Africa: results of a consensus conference. *Afr J Emerg Med*. 2013;3(1):42-48. doi:10.1016/j.afjem.2013.01.001
- Uchendu O, Ilesanmi O, Olumide A. Factors influencing the choice of health care providing facility among workers in a local government secretariat in south western Nigeria. *Ann Ib Postgrad Med*. 2013;11(2):87-95.
- Institute of Medicine (US) Committee on Health Literacy, Nielsen-Bohman L, Panzer A, Kindig D. What Is Health Literacy? Published online 2004. Accessed July 19, 2024. <https://www.ncbi.nlm.nih.gov/books/NBK216035/>
- Factors That Affect Health-Care Utilization - Health-Care Utilization as a Proxy in Disability Determination - NCBI Bookshelf. Accessed July 19, 2024. <https://www.ncbi.nlm.nih.gov/books/NBK500097/>
- Azuogu BN, Eze NC, Azuogu VC, Onah CK, Ossai EN, Agu AP. Appraisal of healthcare-seeking behavior and prevalence of workplace injury among artisans in automobile site in Abakaliki, Southeast Nigeria. *Niger Med J*. 2018;59(5):45-49. doi:10.4103/nmj.NMJ_110_18
- Singh G, Tucker EW, Rohlwink UK. Infection in the developing brain: the role of unique systemic immune vulnerabilities. *Front Neurol*. 2021;12:805643. doi:10.3389/fneur.2021.805643
- Jafari HS. Major infectious diseases of children in developing countries: challenges and opportunities of today and the future. *Semin Pediatr Infect Dis*. 2004;15(3):121-123. doi:10.1053/j.spid.2004.08.002
- GBD 2019 Child and Adolescent Communicable Disease Collaborators. The unfinished agenda of communicable diseases among children and adolescents before the COVID-19 pandemic, 1990-2019: a systematic analysis of the Global Burden of Disease Study 2019. *Lancet*. 2023;402(10398):313-335. Epub 2023 Jun 29. Erratum in: *Lancet*. 2023 Oct 28;402(10412):1528. doi:10.1016/S0140-6736(23)02368-1. PMID: 37393924; PMCID: PMC10375221 doi:10.1016/S0140-6736(23)00860-7
- Child mortality (under 5 years). Accessed July 19, 2024. <https://www.who.int/news-room/fact-sheets/detail/levels-and-trends-in-child-under-5-mortality-in-2020>
- Nwagbara UI, Osuala EC, Chireshe R, et al. Mapping evidence on factors contributing to maternal and child mortality in sub-Saharan Africa: a scoping review protocol. *PLoS One*. 2022;17(8):e0272335-e0272335. doi:10.1371/journal.pone.0272335
- Geweniger A, Abbas KM. Childhood vaccination coverage and equity impact in Ethiopia by socioeconomic, geographic, maternal, and child characteristics. *Vaccine*. 2020;38(20):3627-3638. doi:10.1016/j.vaccine.2020.03.040
- He Z, Bishwajit G, Zou D, Yaya S, Cheng Z, Zhou Y. Burden of common childhood diseases in relation to improved water, sanitation, and hygiene (WASH) among Nigerian children. *Int J Environ Res Public Health*. 2018;15(6):1241. doi:10.3390/ijerph15061241
- Remick K, Gausche-Hill M, Joseph MM, Brown K, Snow SK, Wright JL; AMERICAN ACADEMY OF PEDIATRICS Committee on Pediatric Emergency Medicine and Section on Surgery, AMERICAN COLLEGE of EMERGENCY PHYSICIANS Pediatric Emergency Medicine Committee, EMERGENCY NURSES ASSOCIATION Pediatric Committee. Pediatric readiness in the emergency department. *Pediatrics*. 2018;142(5):5-6.
- Honcoop A, McCulloh RJ, Kerns E, et al. An assessment of information needs and workflows for emergency service providers and caregivers of children with medical complexity. *BMC Health Serv Res*. 2023;23(1):453. doi:10.1186/s12913-023-09366-y
- WHO. Updated guideline: paediatric emergency triage, assessment and treatment: care of critically-ill children. *World Heal Organ*. Published online 2016:7.
- Turner EL, Nielsen KR, Jamal SM, von Saint André-von Arnim A, Musa NL. A review of pediatric critical care in resource-limited settings: a look at past, present, and future directions. *Front Pediatr*. 2016;4:5. doi:10.3389/fped.2016.00005
- Mwananyanda L, Thea DM, Chipeta J, et al. The etiology of pneumonia in Zambian children: findings from the pneumonia etiology research for child health (PERCH) study. *Pediatr Infect Dis J*. 2021;40(9S):S40-S49. doi:10.1097/INF.0000000000002652
- Marangu D, Zar HJ. Childhood pneumonia in low-and-middle-income countries: an update. *Paediatr Respir Rev*. 2019;32:3-9. doi:10.1016/j.prrv.2019.06.001
- Joseph PD, Caldwell PH, Barnes EH, Craig JC. Disease burden-research match? Registered trials in child health from low- and middle-income and high-income countries. *J Paediatr Child Health*. 2017;53(7):667-674. doi:10.1111/jpc.13537
- Keating EM, Haq H, Rees CA, et al. Global disparities between pediatric publications and disease burden from 2006 to 2015. *Glob Pediatr Health*. 2019;6:2333794X19831298-2333794X19831298. doi:10.1177/2333794X19831298
- McAllister DA, Liu L, Shi T, et al. Global, regional, and national estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015:

- a systematic analysis. *Lancet Glob Health*. 2019;7(1):e47-e57. doi:10.1016/S2214-109X(18)30408-X
26. Agrawal S, Kumar M, Chakole S. Nurturing the next generation: health challenges in infants and children across Asia and Africa. *Cureus*. 2023;15(7):e42573-e42573. doi:10.7759/cureus.42573
 27. Peeling RW, Mabey D. Point-of-care tests for diagnosing infections in the developing world. *Clin Microbiol Infect*. 2010;16(8):1062-1069. doi:10.1111/j.1469-0691.2010.03279.x
 28. Ballif M, Renner L, Claude Dusingize J, et al.; International Epidemiologic Databases to Evaluate AIDS (IeDEA), International Epidemiologic Databases to Evaluate AIDS IeDEA. Tuberculosis in pediatric antiretroviral therapy programs in low- and middle-income countries: diagnosis and screening practices. *J Pediatric Infect Dis Soc*. 2015;4(1):30-38.
 29. Keddy KH, Saha S, Okeke IN, Kalule JB, Qamar FN, Kariuki S. Combating childhood infections in LMICs: evaluating the contribution of Big Data Big data, biomarkers and proteomics: informing childhood diarrhoeal disease management in low- and middle-income countries. *EBioMedicine*. 2021;73:103668. doi:10.1016/j.ebiom.2021.103668
 30. An Y, Teo AKJ, Huot CY, et al. Barriers to childhood tuberculosis case detection and management in Cambodia: the perspectives of healthcare providers and caregivers. *BMC Infect Dis*. 2023;23(1):80. doi:10.1186/s12879-023-08044-y
 31. Das JK, Siddiqui F, Padhani ZA, et al. Health behaviors and care seeking practices for childhood diarrhea and pneumonia in a rural district of Pakistan: a qualitative study. *PLoS One*. 2023;18(5):e0285868-e0285868. doi:10.1371/journal.pone.0285868
 32. Newberry JA, Rao SJ, Matheson L, et al. Paediatric use of emergency medical services in India: a retrospective cohort study of one million children. *J Glob Health*. 2022;12:04080. doi:10.7189/jogh.12.04080
 33. Brugnolaro V, Fovino LN, Calgaro S, et al. Pediatric emergency care in a low-income country: characteristics and outcomes of presentations to a tertiary-care emergency department in Mozambique. *PLoS One*. 2020;15(11):e0241209-e0241209. doi:10.1371/journal.pone.0241209
 34. Mir M, Bachani AM, Khawaja H, et al. The Pakistan national emergency department surveillance study (Pak-NEDS): introducing a pilot surveillance. *BMC Emerg Med*. 2015;15(Suppl 2):1-11.
 35. Levels and trends in child mortality - UNICEF DATA. Accessed July 19, 2024. <https://data.unicef.org/resources/levels-and-trends-in-child-mortality-2024/>
 36. Pantoja T, Opiyo N, Lewin S, et al. Implementation strategies for health systems in low-income countries: an overview of systematic reviews. *Cochrane Database Syst Rev*. 2017;9(9):CD011086. doi:10.1002/14651858
 37. Benguigui Y, Stein F. Integrated management of childhood illness: an emphasis on the management of infectious diseases. *Semin Pediatr Infect Dis*. 2006;17(2):80-98. doi:10.1053/j.spid.2006.04.006
 38. Gera T, Shah D, Garner P, Richardson M, Sachdev HS. Integrated management of childhood illness (IMCI) strategy for children under five. *Cochrane Database Syst Rev*. 2016;2016(6):CD010123-CD010123. doi:10.1002/14651858.CD010123.pub2
 39. Integrated management of childhood illness. Accessed July 19, 2024. <https://www.who.int/teams/maternal-newborn-child-adolescent-health-and-ageing/child-health/integrated-management-of-childhood-illness>
 40. Oliphant NP, Manda S, Daniels K, et al. Integrated community case management of childhood illness in low- and middle-income countries. *Cochrane Database Syst Rev*. 2021;2(2):CD012882-CD012882. doi:10.1002/14651858.CD012882.pub2
 41. Kruk ME, Lewis TP, Arsenault C, et al. Improving health and social systems for all children in LMICs: structural innovations to deliver high-quality services. *Lancet*. 2022;399(10337):1830-1844. doi:10.1016/S0140-6736(21)02532-0
 42. Indicators AHO. Monitoring the building blocks of health systems. Geneva, Switz WHO Doc Prod Serv. Published online 2010
 43. Sakamoto H, Rahman M, Nomura S, et al. Japan health system review. *Health Syst Transit*. 2018;8(1):33-34.
 44. Zhang X-X, Jin Y-Z, Lu YH, et al. Infectious disease control: from health security strengthening to health systems improvement at global level. *Glob Health Res Policy*. 2023;8(1):38. doi:10.1186/s41256-023-00319-w
 45. Health financing. Accessed July 19, 2024. <https://www.healthdata.org/research-analysis/health-policy-planning/health-financing>
 46. Organization WH. Primary health care on the road to universal health coverage: 2019 monitoring report: executive summary. Published online 2019.
 47. Gilardino RE, Valanzasca P, Rifkin SB. Has Latin America achieved universal health coverage yet? Lessons from four countries. *Arch Public Health*. 2022;80(1):38. doi:10.1186/s13690-022-00793-7
 48. Kruk ME, Gage AD, Arsenault C, et al. High-quality health systems in the sustainable development goals era: time for a revolution. *Lancet Glob Health*. 2018;6(11):e1196-e1252. doi:10.1016/S2214-109X(18)30386-3
 49. Topp SM. The Lancet global health commission on high quality health systems—where's the complexity? *Lancet Glob Health*. 2017;5(6):e571.