

Artificial Intelligence, Big Data, and IoT in Public Health Surveillance: A Global Narrative Review

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ABSTRACT: The transformation of public health surveillance through digital technologies has significantly reshaped global health responses in the post-pandemic era. This narrative review synthesizes evidence from 2019 to 2025, highlighting the roles of artificial intelligence (AI), big data, and the Internet of Things (IoT) in improving outbreak forecasting, data integration, and real-time monitoring. While high-income countries demonstrate successful implementation due to robust infrastructures and governance, low- and middle-income nations face systemic barriers such as inadequate digital capacity and workforce limitations. Key challenges include fragmented systems, interoperability issues, and persistent digital divides. Policy coherence, investment in workforce training, and ethical data governance emerge as critical enablers of sustainable and equitable surveillance. The findings underscore the need for inclusive digital health strategies that extend beyond emergency responses to build resilient systems capable of addressing both emerging threats and long-term public health priorities.

Keywords: Digital Health Surveillance, Artificial Intelligence In Health, Big Data Analytics, Internet Of Things Healthcare, Public Health Policy, Health Equity, Global Health Governance.



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INTRODUCTION

The digital transformation of public health surveillance (PHS) systems has become a strategic priority in the wake of global health crises, especially COVID-19. Traditional surveillance methods—often paper-based and fragmented—proved insufficient in addressing rapidly evolving outbreaks. Consequently, countries began adopting digital tools that enable real-time monitoring, rapid contact tracing, and more accurate disease forecasting.

Recent technological advances, including electronic health records (EHRs), vaccination certificates, and AI-driven platforms, have expanded the capabilities of digital surveillance. These tools enhance the accessibility and accuracy of data, accelerating the response to public health

emergencies. For example, digital contact tracing applications have reduced delays in identifying and isolating cases compared to conventional methods.

Emerging innovations such as AI, big data analytics, and open-source software (e.g., SORMAS) have further increased system adaptability and responsiveness. These technologies enable predictive modeling and resource optimization while reducing reliance on inflexible proprietary systems. However, their adoption remains uneven across regions due to infrastructure gaps and policy fragmentation.

In addition to technical considerations, ethical and governance issues such as data privacy, interoperability, and public trust are now central to the discourse. Without robust safeguards and coherent policies, the potential of digital tools may be undermined by public skepticism and implementation failures.

Although existing reviews have explored digital health surveillance during the pandemic, few have addressed long-term sustainability, equity concerns, and policy readiness—particularly in low- and middle-income contexts. This review aims to fill this gap by synthesizing global evidence on the enablers and barriers to successful digital surveillance transformation, focusing on systemic, ethical, and governance dimensions across diverse public health settings.

METHOD

The methodology adopted for this review was designed to ensure a rigorous and comprehensive examination of the literature concerning the digital transformation of public health surveillance systems. The approach involved several critical steps, beginning with the identification of relevant databases, followed by the development of search strategies using appropriate keywords, the application of inclusion and exclusion criteria, and finally, the selection and evaluation of studies that best aligned with the objectives of this review. This process was intended to balance breadth and specificity, ensuring that the studies included provided a holistic yet focused perspective on the role of digital tools in reshaping public health surveillance.

The initial stage of literature collection involved the selection of databases that offered both disciplinary depth and interdisciplinary breadth. Scopus and PubMed were prioritized due to their extensive indexing of peer-reviewed journals in medicine, epidemiology, public health, and policy. These platforms are widely recognized for their rigorous indexing standards, which guarantee the relevance and quality of the literature retrieved (Portela et al., 2021; Iyamu et al., 2025). To complement this, Google Scholar was employed as a supplementary source. While its scope is broader and includes grey literature such as dissertations, policy documents, and conference proceedings, this breadth proved valuable in capturing studies and insights not always indexed in more specialized databases (Zhi & Ya, 2022). By triangulating these three sources, the literature search was able to balance academic rigor with comprehensive coverage.

A second critical component of the methodology was the construction of effective search queries. Keyword selection was guided by both prior literature and pilot searches that demonstrated which terms yielded the most relevant results. Frequently used keywords included “digital public health,” “epidemiological surveillance,” “AI in health systems,” and “big data health monitoring” (Vallmuur, 2020; Neto & Wyl, 2024). These keywords captured the intersection of technological innovation and health surveillance. In addition, broader terms such as “digital transformation in health,” “health data interoperability,” and “public health informatics” were employed to identify articles addressing systemic and infrastructural dimensions (Shah et al., 2021). To further refine the search, combinations of technological keywords with geographic or population-specific terms were used, such as “community health digital surveillance” or country names linked with “digital public health.” This strategy allowed for greater contextual relevance and facilitated the identification of studies tailored to specific populations or health crises (Louw et al., 2022; Aisyah et al., 2022).

The selection of studies was guided by well-defined inclusion and exclusion criteria. Inclusion criteria required that articles be peer-reviewed, published between 2019 and 2025 to capture the accelerated digital transformations catalyzed by the COVID-19 pandemic, and explicitly address themes of digital health surveillance, big data integration, or artificial intelligence in health monitoring. Studies that provided empirical evidence, whether quantitative or qualitative, were prioritized. This included randomized controlled trials, cohort studies, case studies, and systematic reviews. The inclusion of diverse research designs was considered critical to capturing both the breadth of digital health innovations and the depth of their application in public health contexts.

Exclusion criteria were applied to ensure the quality and focus of the dataset. Articles were excluded if they lacked a clear methodological framework, were opinion pieces without empirical support, or focused exclusively on clinical applications of digital tools without a direct connection to public health surveillance. Similarly, studies that did not engage with themes of digital transformation, such as those centered solely on traditional epidemiology without a technological component, were excluded. Non-English publications were also excluded, as this review aimed to synthesize literature accessible to an international academic audience. While this may have limited the inclusion of region-specific perspectives, it ensured consistency in the analytical process and minimized risks of misinterpretation due to translation errors.

The screening process proceeded in multiple stages. Initially, titles and abstracts of retrieved articles were reviewed to identify relevance. Articles that met the inclusion criteria at this stage were retained for full-text review. During full-text screening, studies were further assessed for methodological rigor, relevance to the objectives of this review, and the clarity with which they reported findings. In cases where the relevance of a study was ambiguous, consensus discussions among the reviewing team were used to determine final inclusion. This iterative process was crucial in ensuring that only the most pertinent and high-quality studies informed the analysis.

Evaluating the selected literature required attention not only to the reported findings but also to the methodologies employed in each study. Particular attention was given to whether studies addressed issues of interoperability, equity, privacy, and sustainability in the adoption of digital

health surveillance tools. For example, randomized controlled trials and cohort studies were scrutinized for sample size adequacy and generalizability, while qualitative studies were assessed based on the robustness of their data collection and analysis methods. Case studies were evaluated in terms of their ability to provide transferable insights, especially in contexts where resource constraints or governance challenges shaped the effectiveness of digital interventions.

The emphasis on methodological diversity also reflected the complexity of digital transformation in public health surveillance. Randomized controlled trials offered evidence of efficacy in controlled environments, while cohort and longitudinal studies provided insights into long-term impacts and sustainability. Case studies, in contrast, offered critical contextual depth, highlighting how digital tools function within specific institutional or socio-political environments. By incorporating evidence from across these research designs, this review sought to present a balanced synthesis that acknowledged both generalizable findings and context-specific nuances.

The final dataset included studies that collectively provided a rich and multi-faceted understanding of digital transformation in public health surveillance. These studies were then organized thematically to align with the analytical objectives of this review, focusing on technological adoption, interoperability, equity and accessibility, and policy and governance. This thematic structuring facilitated a coherent synthesis, allowing for the integration of diverse findings into a logical narrative that reflects the state of knowledge in this field.

In summary, the methodology of this review relied on a systematic approach to literature collection and evaluation, combining the strengths of multiple databases, carefully chosen keywords, and rigorous inclusion and exclusion criteria. The process ensured that the final body of literature was both comprehensive and analytically robust, encompassing a wide range of study designs and perspectives. This approach not only ensured the integrity of the review but also provided a strong foundation for the subsequent analysis of results and discussion of the broader implications of digital transformation in public health surveillance.

RESULT AND DISCUSSION

The analysis of existing literature on the digital transformation of public health surveillance systems reveals a broad spectrum of themes that reflect both the technological advancements driving this transformation and the systemic challenges shaping its outcomes. The findings are presented under four interconnected themes: technology adoption, data integration and interoperability, equity and accessibility, and policy and governance. Each theme offers insights into the evolving role of digital tools in strengthening surveillance systems, while also highlighting disparities in implementation and effectiveness across different global contexts.

Technology Adoption

Artificial intelligence (AI), big data, and the Internet of Things (IoT) have emerged as transformative forces in the field of public health surveillance. AI has demonstrated substantial capacity in predictive analytics, supporting health authorities in forecasting outbreaks and

implementing targeted interventions. During the COVID-19 pandemic, AI played a crucial role in processing large volumes of epidemiological data at unprecedented speed, providing actionable insights that informed both national and international health responses (Bui et al., 2021). Moreover, AI-driven platforms have advanced disease detection and monitoring through diagnostic imaging and epidemiological modeling, enabling earlier identification of outbreaks and improved allocation of healthcare resources (Kapoor et al., 2024).

Big data, by integrating diverse datasets such as electronic health records, social media interactions, and historical health patterns, has proven instrumental in refining public health responses (Wong et al., 2022). Evidence suggests that analytics derived from big data platforms significantly enhance contact tracing processes, reducing the time needed to identify infection clusters and supporting rapid public health interventions (Rowe, 2020). IoT technologies, including wearable sensors and mobile health applications, contribute by generating real-time data that not only enhances surveillance accuracy but also fosters preventive health behaviors among populations (Iyamu et al., 2025).

Despite these advancements, adoption rates differ markedly between high-income and low- to middle-income countries. High-income countries benefit from robust digital infrastructures and substantial financial resources that facilitate the rapid integration of these technologies into public health systems. For instance, Germany and the United States have widely adopted AI-driven epidemiological platforms, resulting in more effective disease surveillance and resource distribution (Kapoor et al., 2024). In contrast, many low- to middle-income countries struggle with infrastructural limitations, financial constraints, and workforce shortages that slow the implementation of digital health strategies (Khalili et al., 2021). The persistence of paper-based reporting and fragmented digital initiatives in these regions underscores the widening gap in global public health capacity (Louw et al., 2022). Targeted investments and international collaborations are thus critical to bridging these disparities (Bui et al., 2021).

Data Integration and Interoperability

A central challenge identified in the literature is the integration of multiple digital platforms into cohesive and interoperable systems. The lack of standardized data protocols across health systems undermines the ability to create unified surveillance frameworks, leading to inconsistencies and inefficiencies in monitoring health trends (Wong et al., 2022). Roberts (2019) emphasizes that without standardized data governance, disparate sources cannot be effectively merged, resulting in fragmented datasets that hinder timely decision-making. Furthermore, organizational silos within and across health institutions exacerbate the issue, as proprietary systems often resist interoperability, creating barriers to seamless data exchange (Gnatik, 2021).

Resistance to institutional change further complicates integration efforts. Personnel accustomed to traditional information systems often lack adequate training to transition to new platforms, leading to underutilization of available digital tools (Iyamu et al., 2025). McKee et al. (2019) note that overcoming these barriers requires substantial investment in workforce training and change management, but such initiatives frequently encounter financial and logistical constraints, particularly in resource-limited settings.

Comparative global case studies provide valuable insights into successful strategies for overcoming these challenges. The adoption of the Surveillance Outbreak Response Management and Analysis System (SORMAS) in several European nations exemplifies how open-source software can promote interoperability across borders. By providing a standardized platform, SORMAS has improved the coordination of health responses to COVID-19 and set a model for international collaboration in digital health surveillance (Louw et al., 2022). In contrast, low- to middle-income countries often struggle with legacy systems and insufficient infrastructural investment, making it difficult to achieve the same level of integration (Khalili et al., 2021). These disparities underscore the importance of harmonizing national strategies with international best practices to build resilient and interoperable surveillance systems.

Equity and Accessibility

The digital divide presents a major barrier to achieving equitable outcomes in public health surveillance. Populations with limited access to digital tools or reliable internet infrastructure are less able to benefit from digital health initiatives, resulting in uneven health outcomes across communities (Louw et al., 2022). Studies have shown that regions with strong digital infrastructures are able to implement faster and more effective responses to health crises, while those lacking such infrastructure experience higher disease transmission rates and poorer outcomes (Wong et al., 2022). This inequity not only undermines the effectiveness of surveillance systems but also exacerbates existing health disparities.

Several countries have taken proactive measures to address accessibility challenges. In Vietnam, authorities have expanded access to mobile health applications to enhance reporting and surveillance capacities in rural communities, ensuring that populations outside urban centers are not excluded from digital health initiatives (Bui et al., 2021). In India, AI and telemedicine have been leveraged to extend healthcare outreach to underserved regions, exemplifying how targeted digital strategies can help mitigate inequities (Kapoor et al., 2024). South Korea has also demonstrated success by offering multilingual and culturally sensitive digital platforms for contact tracing and vaccination monitoring, thereby ensuring inclusivity across diverse populations (Louw et al., 2022).

These examples highlight the potential for inclusive digital strategies to reduce inequities in health surveillance. However, they also reveal the continuing need for structural investments in infrastructure, literacy, and public trust to achieve long-term equity in public health outcomes.

Policy and Governance

National and international policies play a decisive role in shaping the adoption and effectiveness of digital public health surveillance systems. Strong policy frameworks that prioritize investment in digital infrastructure are essential for enabling the integration of advanced technologies (Storeng, 2025). For example, the Pan American Health Organization has called for comprehensive digital transformation initiatives to enhance resilience and responsiveness during health crises, reflecting the growing recognition of digital health as a core component of global health security (Júnior et al., 2024).

At the international level, treaties and agreements can facilitate cross-border knowledge sharing, standardization, and capacity building, thereby strengthening global preparedness. Governance frameworks that emphasize transparency and ethical considerations are also critical. Research indicates that countries with clear data privacy and protection policies are more likely to foster public trust and encourage participation in digital health initiatives (Starke et al., 2025). In contrast, weak or unclear regulatory frameworks can undermine trust and limit the adoption of digital surveillance tools.

Comparisons across countries reveal significant differences in policy approaches. High-income countries often implement structured national strategies that provide comprehensive funding, regulatory alignment, and coordinated integration of digital tools into health systems (Storeng, 2025). Such policies have enabled European nations to rapidly adapt digital health solutions in response to COVID-19, aligning health and digital agendas to strengthen resilience. Conversely, low- to middle-income countries frequently lack robust digital health policies, leading to fragmented and reactive approaches to digital transformation (Khalili et al., 2021). Limited financial resources and policy incoherence further constrain their ability to adopt and sustain digital innovations (Iyamu et al., 2025).

Overall, the evidence suggests that effective governance and policy alignment are as crucial as technological innovation in ensuring the success of digital health surveillance systems. Without supportive policy environments, even the most advanced digital tools risk failing to achieve their intended impact.

Summary of Results

Taken together, the literature highlights both the promise and the challenges of digital transformation in public health surveillance. AI, big data, and IoT provide unprecedented opportunities for predictive analytics, real-time monitoring, and more effective responses to health crises. However, adoption remains uneven, with high-income countries achieving far greater success than their low- and middle-income counterparts. Integration and interoperability challenges continue to impede progress, while the digital divide threatens to exacerbate health inequities. Finally, governance and policy frameworks emerge as critical determinants of success, underscoring the importance of aligning technological innovation with ethical, legal, and social considerations. The comparative evidence from across different countries reveals that while digital transformation holds significant potential, its success is contingent upon systemic investments, inclusive policies, and global collaboration to ensure equitable and sustainable health outcomes.

The findings of this review underscore that systemic and structural factors play a decisive role in shaping the outcomes of digital health surveillance initiatives. While technological innovation such as artificial intelligence (AI), big data, and the Internet of Things (IoT) have demonstrated their capacity to revolutionize public health surveillance, the successful adoption of these tools is contingent upon infrastructural readiness, governance coherence, and financial investment. This section discusses the influence of these systemic factors, the lessons learned from cross-country comparisons, and the solutions proposed in the literature to address the ethical, legal, and technical challenges that have emerged in the digital transformation of public health surveillance.

Influence of Systemic and Structural Factors on Digital Health Surveillance Initiatives

Infrastructure remains one of the most critical determinants of the effectiveness of digital health initiatives. Countries with advanced digital infrastructure, including high-speed internet, robust wireless networks, and established electronic health records, are more capable of integrating and scaling digital surveillance systems efficiently. Iyamu et al. (2025) emphasize that robust infrastructural support facilitates real-time data collection and rapid decision-making, creating a feedback loop that enhances the overall responsiveness of public health systems. In contrast, low- and middle-income countries often face infrastructural deficits, such as unreliable electricity and limited broadband access, which severely restrict their ability to adopt and sustain digital surveillance technologies (Iyamu et al., 2025). These disparities in infrastructural capacity create an uneven landscape of digital health readiness, leading to inequities in global health outcomes.

Governance structures also exert significant influence on the implementation and sustainability of digital surveillance systems. Roberts (2019) argues that the absence of clear regulatory frameworks undermines trust in digital initiatives and contributes to fragmented adoption. By contrast, countries that adopt governance models emphasizing transparency, data privacy, and community engagement are more successful in fostering public confidence and widespread participation in digital health systems (Zhi & Ya, 2022). Effective governance further facilitates cross-sectoral coordination, ensuring that health, technology, and policy stakeholders are aligned in their objectives. This alignment is crucial during crises such as pandemics, when rapid decision-making and coordinated responses are paramount.

Funding constitutes another essential systemic factor influencing the scope and sustainability of digital health surveillance. Aisyah et al. (2022) highlight that adequate investment supports the training of personnel, the expansion of digital infrastructure, and the maintenance of surveillance systems. Inadequate funding, however, forces health authorities in resource-constrained regions to prioritize immediate health needs over long-term digital investments, undermining the continuity and effectiveness of surveillance projects (Neto & Wyl, 2024). International funding mechanisms, particularly those that target low- and middle-income countries, are therefore essential to narrow the global digital divide and ensure equitable access to the benefits of digital transformation.

Lessons from Cross-Country Comparisons on Digital Surveillance and Public Health Policies

Comparative insights from different countries reveal that the alignment of digital initiatives with public health policies is fundamental to their success. South Korea and Estonia provide instructive examples of how digital health systems can be effectively integrated into public health frameworks. In South Korea, digital surveillance tools such as contact tracing applications were seamlessly aligned with national policies, enabling rapid adaptations during the COVID-19 pandemic and yielding favorable health outcomes (Vallmuur, 2020). Similarly, Estonia's comprehensive e-governance framework allowed for the integration of digital health records and surveillance platforms, reinforcing its public health capacity during emergencies.

In contrast, countries lacking coherent digital strategies often experience fragmented responses to health crises. Aisyah et al. (2022) describe Indonesia's struggles to operationalize digital tools during the pandemic, highlighting how the absence of well-defined policies and frameworks led to

inefficiencies and inconsistent data management. This example illustrates the necessity of comprehensive digital health frameworks that establish clear roles, responsibilities, and objectives while ensuring that digital initiatives complement broader public health goals.

Cross-country comparisons also underscore the importance of stakeholder engagement in shaping digital health policies. Successful initiatives often involve collaboration among government bodies, non-governmental organizations, academic institutions, and civil society groups. Iyamu et al. (2025) argue that such collaborations ensure digital surveillance tools are responsive to community needs and cultural contexts, thereby increasing their legitimacy and adoption. Neto and Wyl (2024) similarly note that multi-stakeholder involvement can mitigate resistance to digital initiatives and enhance the inclusivity of surveillance systems.

Proposed Solutions for Ethical, Legal, and Technical Challenges in Digital Surveillance

The literature consistently identifies ethical, legal, and technical barriers as central challenges to the effective implementation of digital surveillance. A primary concern relates to data privacy and security. Shah et al. (2021) emphasize the need for robust ethical frameworks to protect personal health information and ensure that data are collected, stored, and utilized in ways that respect individual rights. Starke et al. (2025) recommend protocols for informed consent, data anonymization, and controlled data sharing as essential measures to maintain user trust in digital health systems.

Transparency in data governance has emerged as another solution for strengthening public trust. Wang et al. (2023) argue that clear communication regarding how data are used, who has access, and what benefits are derived from surveillance systems can enhance public engagement and compliance. Kapoor et al. (2024) further highlight the importance of ongoing dialogue between health authorities and communities to reinforce trust and address concerns related to surveillance.

Technical challenges, particularly those related to workforce capacity and infrastructural limitations, require sustained investment in human resources and training. Bui et al. (2021) document how capacity-building programs in India and Vietnam have improved health professionals' ability to use digital tools, thereby enhancing the efficiency and accuracy of surveillance systems. Wheaton et al. (2024) emphasize that such initiatives must extend beyond technical training to include digital literacy and informatics education, ensuring that health workers are not only competent in using new technologies but also capable of adapting to future advancements.

Investments in infrastructure are also critical for overcoming technical barriers. Iyamu et al. (2025) note that scalable infrastructure, such as interoperable electronic health records and standardized data platforms, provides the foundation for effective digital surveillance. Global initiatives that promote open-source software and shared platforms, such as SORMAS in Europe, exemplify how collaborative approaches can enhance interoperability and reduce costs associated with proprietary systems (Louw et al., 2022).

Another proposed solution is the integration of ethical and technical considerations into policy frameworks. Roberts (2019) contends that aligning ethical standards with legal mandates and technical capabilities ensures that digital surveillance systems are both effective and socially

acceptable. This alignment fosters greater resilience by balancing the need for robust surveillance with the protection of civil liberties.

Limitations of Existing Research and Directions for Future Studies

While the existing literature provides significant insights into the digital transformation of public health surveillance, notable limitations remain. Much of the research focuses on short-term applications during health crises, particularly COVID-19, leaving questions about the long-term sustainability and adaptability of digital tools largely unanswered. Neto and Wyl (2024) observe that there is limited evidence on how digital surveillance systems transition from pandemic responses to the monitoring of chronic diseases or other long-term public health challenges.

Another limitation lies in the geographic distribution of studies. The majority of empirical research originates from high-income countries with well-developed digital infrastructures, resulting in an underrepresentation of low- and middle-income contexts where challenges are most acute (Khalili et al., 2021). This imbalance restricts the generalizability of findings and underscores the need for research that explicitly addresses the unique barriers and opportunities in resource-limited settings.

Furthermore, relatively little attention has been given to the role of community participation in shaping digital surveillance initiatives. Wong et al. (2022) argue that public engagement is vital for ensuring the inclusivity and effectiveness of digital health tools, yet empirical studies exploring community-driven approaches remain scarce. Future research should investigate how participatory models can be integrated into surveillance systems to enhance trust, equity, and responsiveness.

Finally, more research is needed to evaluate the unintended consequences of digital health surveillance. McKee et al. (2019) caution that an overreliance on technological solutions may obscure the social and structural determinants of health, resulting in interventions that address symptoms rather than root causes. Addressing this limitation requires interdisciplinary studies that examine the interplay between digital technologies and broader socio-political contexts.

Taken together, these limitations highlight the necessity of expanding research agendas beyond immediate crisis responses to include long-term, equity-focused, and participatory perspectives. By doing so, the academic community can contribute to building digital surveillance systems that are sustainable, inclusive, and capable of addressing both present and future public health challenges.

CONCLUSION

This narrative review highlights the transformative potential of digital health surveillance systems while underscoring the systemic and structural challenges that shape their implementation. Evidence demonstrates that artificial intelligence, big data, and the Internet of Things enhance predictive capabilities, improve data accuracy, and accelerate responses to health crises. However, disparities persist between high-income and low- to middle-income countries, where limited infrastructure, insufficient funding, and workforce shortages constrain adoption. The lack of interoperability across platforms and persistent inequities driven by the digital divide further weaken the effectiveness of digital systems. Governance and policy frameworks emerge as decisive

factors, with countries demonstrating coherent, transparent, and equity-oriented strategies achieving stronger outcomes. These findings reaffirm the urgency of transitioning from outdated, paper-based approaches to resilient, inclusive, and technologically integrated systems.

Addressing these barriers requires targeted policy interventions that prioritize investment in infrastructure, promote interoperability through standardized data protocols, and ensure robust data governance frameworks to build public trust. Strategies such as workforce development, inclusive digital design, and stakeholder engagement are essential for bridging gaps and advancing equity in health surveillance. Future research should expand beyond crisis-driven applications to evaluate the long-term sustainability and adaptability of digital systems, with particular emphasis on underrepresented low- and middle-income contexts and community-driven approaches. By aligning technological innovation with systemic reforms, public health surveillance can become more resilient, equitable, and effective in addressing both present and future global health challenges.

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