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OPINIONS/PERSPECTIVES/POINT OF VIEW

Decentralized by Design, Centralized by Necessity: The Blockchain-Surveillance Dilemma

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DOI: https://doi.org/10.30953/bhty.v9.525

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Keywords: Blockchain, data governance, disease surveillance, interoperability, permissioned blockchain

Abstract

Disease surveillance systems face delays in data collection, validation, and reporting at various levels, which undermines early detection and rapid response. Blockchain technology, as a transparent and immutable architecture, can accelerate the flow of epidemiological data and increase trust among actors, but the transition from idea to practical tool requires an analysis of requirements and limitations. This article examines the key challenges of applying blockchain in disease surveillance in two axes: first, governance challenges, data sovereignty, and the inherent conflict of decentralized architecture with epidemiological requirements and privacy laws; second, technical, infrastructural, and operational challenges such as digital identity, interoperability, communication limitations, economic model, and security vulnerabilities. Therefore, the conclusion shows that blockchain can only contribute to transparency and traceability in the form of permissioned/consortium networks with verified identity, and its true effectiveness depends on feasibility studies, piloting, and intelligent combination with data exchange standards and international cooperation.

Key takeaways

- Blockchain can potentially improve transparency, traceability, and trust in surveillance systems.
- Real effectiveness requires feasibility studies, pilots, and detailed evaluations.
- The future of patient care lies in a combination of digital technologies, data exchange standards, and international collaboration.

Submitted: July 20, 2026, Accepted: August 3, 2026, Published: September 7, 2026

Pandemics, such as COVID-19, and their widespread damage remind us again and again of the importance of early detection and rapid response as the cornerstones of epidemic containment, and the necessity of an efficient surveillance system. One of the principal obstacles in this path is the delay in collecting, validating, and reporting data on recent cases of the disease at different levels of the health system.

The current structure of the surveillance system involves collecting data from various health centers that use disparate information systems. Intermediate organizations then filter this data according to their disparate rules before it ultimately reaches the national and global levels. This hierarchy, combined with weak coordination and communication, severely reduces the "timeliness" of data and hinders early intervention.[1] Therefore, it makes sense to search for new architectures that can make the flow of data transparent and faster while maintaining accuracy and confidentiality. Blockchain technology is one option that has attracted the attention of health policymakers in recent years. However, moving from an attractive idea to a practical tool in disease surveillance requires careful analysis of requirements, limitations, and design tailored to the realities of the health system.

Blockchain could theoretically revolutionize the flow of epidemiological data by providing an immutable and transparent platform where each transaction is added to a continuous chain after being collectively verified. Imagine that instead of a new case report taking weeks to travel from hospital to province to center, the initial physician record, with a valid digital signature and laboratory verification, would be recorded as an encrypted event on a shared platform and immediately available to the relevant authorities. Such transparency could increase trust among different actors and speed up case registration.[2] But the key question is, whether it is possible to implement such a network in practice?

Optimistically, implementing decentralized blockchain-based surveillance systems can greatly enhance our ability to

detect disease outbreaks early by enabling the timely gathering and analysis of data from various healthcare facilities in a unified network with shared rules and regulations at both the country and global levels. These systems can collect data simultaneously from multiple sources and analyze it in real-time using advanced algorithms, enabling rapid new case registration and the identification of potential hotspots. Within a blockchain network, registered cases are rapidly approved based on laboratory test results and subsequently broadcast to all nodes within the network. This facilitates prompt analysis, enabling the identification of increases in new case numbers and the early detection of disease outbreaks. Furthermore, decentralized blockchain-based surveillance systems can be deployed using healthcare professionals' internet-connected mobile phones, enabling the registration of new cases that are broadcast to all nodes globally, with other nodes verifying the new cases across international borders.[3]

The deployment of these systems faces serious challenges in terms of governance and data sovereignty: the contradiction between the public decentralized design and epidemiological and security requirements, the weakness of the integrated digital identity, the lack of interoperability with health systems, communication limitations, conflicts with privacy laws, the lack of a transparent economic model, operational and behavioral barriers for physicians, and security vulnerabilities.[4] In the following section, these challenges are expanded on two main axes:

Governance, Legal Challenges, and Epidemiological Contradiction

The most important obstacle is the inherent contradiction between decentralized architecture and national health sovereignty. In many conceptual designs, doctors can register cases with mobile phones and validate them cross-border through decentralized consensus; however, infectious disease data are extremely sensitive, and governments will never allow their patients' raw data to be validated on nodes outside the control of national sovereignty. From an epidemiological perspective, case confirmation is based on standard case definitions and laboratory confirmation from a national reference, not decentralized voting by doctors in other countries. This design flaw stems from the fact that the proposed architecture resembles a public blockchain, while the desired network should be a consortium/permissioned blockchain with authenticated identities. Furthermore, rules such as the "right to be forgotten" in the General Data Protection Regulation (GDPR)/Fast Health Interoperability Resources (FHIR) clearly conflict with the inherent immutability of blockchain, and the economic model for covering transaction costs and node incentives remains unclear.[2]

Technical, Infrastructure, and Operational Challenges

At the technical level, the lack of a unified digital identity infrastructure for the qualification of doctors and patients undermines the integrity of the network. In addition, the lack of compatibility of laboratory systems due to the absence of data exchange standards such as HL7/FHIR is a serious obstacle to interoperability. Internet connectivity limitations, especially in rural or low-income areas, make real-time access impossible. In addition, operational and behavioral barriers, such as delays in physicians registering cases, slow the system's response time. From a security perspective, attacks such as Sybil (51% of attacks) and metadata leaks pose serious threats to data confidentiality and integrity. Ultimately, the choice between running on personal mobile phones or powerful servers, depending on the network architecture, greatly affects the final cost and becomes a design challenge.

Conclusion

Blockchain technology has the potential to help improve transparency, traceability, and trust in surveillance systems under certain circumstances. However, its real effectiveness requires feasibility studies, pilot projects, and detailed economic and technical evaluations. The future of patient care likely lies not in a single technology but in a clever combination of digital technologies, data exchange standards, and international collaboration. In such a framework, blockchain can be considered as one of the potential components of the global healthcare ecosystem and can help to strengthen the preparedness of health systems against future epidemics.

Funding

The author received no financial support for the research, authorship, or publication of this article.

Financial and Non-Financial Relationships and Activities

The author declares no financial or non-financial relationships or activities that could be perceived as influencing the work reported in this article.

Data Availability Statement (DAS), Data Sharing, Reproducibility, and Data Repositories

No new data were generated or analyzed in this article. Therefore, data sharing and data repository requirements are not applicable.

Application of AI-Generated Text or Related Technology

Generative AI or AI-assisted technologies were used solely for language editing, including suggestions for grammar, wording, and readability. The author reviewed and approved all such suggestions and takes full responsibility for the final content of the manuscript. No AI-generated content was used to develop the scientific arguments, analysis, or conclusions of the article.

Contributions

The author was solely responsible for the conceptualization, literature review, analysis, writing, revision, and final approval of the manuscript.

Acknowledgments

None.

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