

Hybrid Healthcare: AI-Driven Case Evidence from Czechia Practice [†]

Petra Petrova, Zuzana Dvorakova *  and Martina Caithamlova

Faculty of Biomedical Engineering, Czech Technical University in Prague, 27201 Kladno, Czech Republic; petra.petrova@cvut.cz (P.P.); martina.caithamlov@fbmi.cvut.cz (M.C.)

* Correspondence: zuzana.dvorakova@cvut.cz; Tel.: +420-733-651-733

[†] Presented at the International Conference on Electromagnetic Fields, Signals and BioMedical Engineering (ICEMS-BIOMED), Suceava, Romania, 7–9 May 2026.

Abstract

Hybrid healthcare integrates digital and in-person services across care delivery and governance, becoming central to modern health systems. Driven by technological advances and the COVID-19 pandemic, it reshapes care pathways, workforce organisation, and system management. Hybrid models can improve outcomes while reducing staff and administrative burdens. This paper presents a consortium-based exploratory review to conceptualise hybrid healthcare and define its core domains. Using qualitative analysis and two AI-focused case studies, it identifies five interrelated domains: operations, care pathways, education, governance, and data-driven personalised care. Findings, including evidence from Czechia, offer a practical framework for analysing hybrid healthcare transformation.

Keywords: hybrid healthcare; digital health; artificial intelligence; healthcare systems; telemedicine; governance; workforce

1. Introduction

Hybrid healthcare has emerged as a defining paradigm in contemporary health systems, driven by the convergence of digital infrastructures and traditional care delivery models. The rapid scaling of telemedicine and AI-enabled services—particularly during the COVID-19 pandemic—has accelerated this transition from discrete digital interventions to integrated socio-technical systems [1,2]. However, current research remains fragmented, typically analysing telemedicine, AI, or health information systems as isolated components rather than as interacting subsystems within a unified architecture.

This fragmentation represents a critical limitation. From an engineering perspective, healthcare systems are increasingly characterised by tight coupling between technological, organisational, and human components, where system performance depends not only on individual technologies but on their integration, interoperability, and coordination. Existing conceptual models do not adequately capture these cross-domain dependencies.

The concept of hybridity, widely discussed in public administration and governance, provides a useful starting point by emphasising the coexistence of multiple institutional logics [3,4]. However, its application in healthcare has remained largely descriptive, lacking formalisation in terms of system architecture, interaction layers, and operational constraints [5,6]. At the same time, advances in artificial intelligence, digital twins, and predictive analytics are enabling a shift toward anticipatory, data-driven, and adaptive care systems [7–9].



Academic Editors: L. Dan Milici,
Mihai Munteanu, Simona Miclăuș,
Paul Bechet and Radu Ciorap

Published: 7 July 2026

Copyright: © 2026 by the authors.
Licensee MDPI, Basel, Switzerland.
This article is an open access article
distributed under the terms and
conditions of the [Creative Commons
Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

This study addresses these gaps by proposing a multidimensional conceptual framework that explicitly models hybrid healthcare as a socio-technical system-of-systems. The contribution is twofold:

- (1) The identification and structuring of five interdependent system domains;
- (2) Empirical validation through case studies that demonstrate how these domains manifest in real-world implementations.

By bridging conceptual theory with applied system design, the paper contributes to the engineering-oriented understanding of healthcare transformation.

2. Methods

2.1. Secondary Source Analysis

The study employs a structured exploratory review designed to support theory-building and system conceptualisation rather than exhaustive synthesis. A multi-stage, expert-driven selection process was used to ensure both relevance and coverage across technological, organisational, and policy dimensions.

In the first phase, 45 sources were identified from major scientific databases using pre-defined inclusion criteria focused on digital health systems, AI applications, and healthcare governance. In the second phase (May 2025–January 2026), 32 additional sources were incorporated, including peer-reviewed publications, policy frameworks, and grey literature.

The analysis follows an analytically guided, non-systematic approach, appropriate for emerging domains where conceptual integration is prioritised over statistical aggregation. A combined inductive–deductive strategy was applied:

- Inductive coding to identify recurring system components and interactions;
- Deductive mapping to align findings with existing theories in Health Services Research and Implementation Science.

This approach enables the derivation of a generalisable system-level framework while maintaining sensitivity to empirical variation.

2.2. Case Study Design

To complement the conceptual analysis, two qualitative case studies were conducted using a multiple-case design with analytical replication logic. Cases were selected based on the following engineering-relevant criteria:

- Integration of digital and physical care components;
- Presence of AI or data-driven functionalities;
- Demonstrable interaction between technological and organisational subsystems.

Rather than aiming for statistical generalisation, the case studies provide analytical validation, illustrating how the proposed framework captures real-world system behaviour, constraints, and performance characteristics.

3. Results: Conceptual Framework

Hybrid healthcare is conceptualised here as a multidimensional socio-technical system composed of interdependent domains, each representing a critical layer of system functionality. Unlike linear or technology-centric models, this framework emphasises interoperability, feedback loops, and cross-domain dependencies.

The five domains can be interpreted as functional subsystems within an integrated architecture:

- Operations and Workforce Organisation → execution layer (human–system interaction, workflows) [6,10];
- Patient Care Pathways → service delivery layer (process integration across modalities);

- Education and Workforce Development → adaptation layer (capability formation and system learning) [11–13];
- Governance and System Management → control layer (regulation, coordination, constraints) [3,14];
- Digitally Enabled Predictive Care → intelligence layer (data processing, AI-driven decision support) [7–9,15].

The key argument is that system performance emerges from interactions between these layers, rather than from optimisation within any single domain. This explains why isolated digital interventions often fail to scale: they do not align with the broader system architecture.

4. Case Studies

4.1. *Protectu Remote Assistance System*

The Protectu initiative in Czechia demonstrates how remote assistance technologies can enable older adults to live independently while maintaining access to continuous support. In a context of population ageing and changing family structures, many seniors live alone and far from relatives, increasing the need for reliable home-based care solutions. Protectu responds to this challenge through a 24/7 remote assistance system combining wearable SOS devices with a central monitoring centre. The service allows immediate voice contact with operators, automatic alerts triggered by inactivity or unusual behaviour, and user localisation via mobile network infrastructure, ensuring rapid responses in emergencies.

Developed through a phased and adaptive process, the system integrated software, hardware, and telecommunications components before being piloted and gradually scaled into routine operation. It currently delivers around 103 assistance interventions per month and achieves a customer retention rate of approximately 95%, indicating strong trust and long-term acceptance. Users report a heightened sense of safety, while families value its reliability and availability.

Key success factors include system reliability, continuous operation, and integration with social care services. Challenges remain, particularly limited willingness to pay for preventive services and the need for substantial operational capacity to maintain uninterrupted support.

4.2. *DiaMáma*

The DiaMáma initiative is a digital health solution designed to support women with gestational diabetes in Czechia, where limited outpatient capacity and inconsistent patient education remain significant challenges. As a home-based programme, it integrates a web platform and mobile application delivering structured educational content, including video lessons, articles, and nutrition plans. The system also enables users to track dietary intake, monitor blood glucose levels, and access clear data visualizations, strengthening self-management beyond clinical settings.

Implemented between 2021 and 2023, the project followed a two-phase approach: initial research, development, and pilot testing, followed by real-world validation and refinement. A pilot study involving 64 participants showed that early users experienced reduced gestational weight gain, improved dietary habits, and fewer outpatient visits. Although no significant changes were observed in clinical outcomes—likely due to the limited sample size—the results indicate strong potential. Success was driven by interdisciplinary collaboration, early user involvement, and iterative design, despite challenges related to regulation and reimbursement.

5. Discussion

The findings confirm that hybrid healthcare is primarily an organisational transformation rather than a purely technological one. Hybrid systems require alignment across workforce structures, governance frameworks, and technological infrastructures [3,5]. AI plays a critical role in enabling predictive and personalised care, particularly through digital twin technologies and data-driven decision-making [7–9,15]. The key lies in integrating technological, human, regulatory, and ethical factors [16].

However, its effectiveness is constrained by data availability, interoperability, and organisational readiness. This highlights a key engineering principle: system capability is limited by its weakest component. The persistence of fragmentation and low interoperability indicates that current healthcare systems lack standardised architectures and interfaces, which are essential for scalable hybrid systems. Addressing these limitations requires coordinated design across technical, organisational, and regulatory domains.

6. Conclusions

This study positions hybrid healthcare as a system-of-systems architecture, characterised by the interaction of five interdependent domains. The proposed framework advances existing literature by moving beyond descriptive accounts toward a structured, engineering-oriented conceptualisation.

The primary contribution lies in demonstrating that healthcare hybridisation is not reducible to digitalisation but represents a reconfiguration of system architecture, requiring alignment across operational, informational, and governance layers.

Empirical case evidence confirms that system performance depends on integration, reliability, and alignment of incentives rather than on technological sophistication alone. This has direct implications for system design: future hybrid healthcare solutions must prioritise interoperability, scalability, and organisational fit. In this sense, hybrid healthcare should be understood as a stable and evolving configuration of complex adaptive systems, requiring continuous coordination between technological innovation and institutional transformation. This perspective provides a foundation for more rigorous engineering approaches to healthcare system design, evaluation, and optimisation.

Author Contributions: Conceptualization, P.P.; methodology, P.P.; validation, M.C.; formal analysis, M.C.; investigation, Z.D. and M.C.; resources, P.P. and Z.D.; writing—original draft preparation, Z.D.; writing—review and editing, Z.D.; supervision, M.C.; project administration, Z.D. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Erasmus+ project Hybrid Healthcare—Advancing Hybrid Management and Digital Technology in Healthcare Education (Project No. 2024-1-CZ01-KA220-HED-000251650), co-funded by the European Union. The funder had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data sharing is not applicable to this article.

Acknowledgments: The authors gratefully acknowledge the teams of the projects ProtectU (www.protectu.cz) (accessed on 1 June 2026) and DIAMAMA (www.diamama.cz) (accessed on 1 June 2026) for their valuable collaboration and support. Particular thanks are extended to Jan Muzik, Faculty of Biomedical Engineering, Czech Technical University in Prague, and First Faculty of Medicine, Charles University, for his expert guidance and insightful contributions to the case studies presented in this paper.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviation

The following abbreviation is used in this manuscript:

AI Artificial Intelligence

References

1. Darwish, A.; Hassanien, A.E.; Elhoseny, M.J.; Sangaiah, A.K.; Muhammad, K. The impact of the hybrid platform of internet of things and cloud computing on healthcare systems: Opportunities, challenges, and open problems. *J. Ambient Intell. Humaniz. Comput.* **2019**, *10*, 4151–4166. [\[CrossRef\]](#)
2. Dixon, D.; Sattar, H.; Moros, N.; Kesireddy, S.R.; Ahsan, H.; Lakkimsetti, M.; Fatima, M.; Doshi, D.; Sadhu, K.; Hassan, M.J. Unveiling the influence of AI predictive analytics on patient outcomes: A comprehensive narrative review. *Cureus* **2024**, *16*, e59954. [\[CrossRef\]](#) [\[PubMed\]](#)
3. Denis, J.-L.; Ferlie, E.; van Gestel, N. Understanding hybridity in public organizations. *Public Adm.* **2015**, *93*, 273–289. [\[CrossRef\]](#)
4. Correia, T.; Denis, J.-L. Hybrid management, organizational configuration, and medical professionalism: Evidence from the establishment of a clinical directorate in Portugal. *BMC Health Serv. Res.* **2016**, *16*, 161. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Kokko, P.; Laihonon, H.J. Performance management and hybridization of healthcare: Case of the accountable care organization. *Public Budget. Account. Financ. Manag.* **2021**, *34*, 411–429. [\[CrossRef\]](#)
6. Sartirana, M. Beyond hybrid professionals: Evidence from the hospital sector. *BMC Health Serv. Res.* **2019**, *19*, 634. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Elgammal, Z.; Albrijawi, M.T.; Alhaji, R.J. Digital twins in healthcare: A review of AI-powered practical applications across health domains. *Big Data* **2025**, *12*, 234. [\[CrossRef\]](#)
8. Li, X.; Loscalzo, J.; Firoj Mahmud, A.K.M.; Aly, D.M.; Rzhetsky, A.; Zitnik, M.; Benson, M. Digital twins as global learning health and disease models for preventive and personalized medicine. *Genome Med.* **2025**, *17*, 11. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Shen, M.-D.; Chen, S.-B.; Ding, X.-D. The effectiveness of digital twins in promoting precision health across the entire population: A systematic review. *npj Digit. Med.* **2024**, *7*, 145. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Ohrling, M. Challenges in hybrid management in healthcare: A study of the interplay between divisional managers and clinical directors in a decentralized healthcare organization in Sweden. *BMC Health Serv. Res.* **2026**, *26*, 145. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Car, J.; Ong, Q.C.; Erlikh Fox, T.; Leightley, D.; Kemp, S.J.; Švab, I.; Tsoi, K.K.F.; Sam, A.H.; Kent, F.M.; Hertelendy, A.J.; et al. The digital health competencies in medical education framework: An international consensus statement based on a Delphi study. *JAMA Netw. Open* **2025**, *8*, e2453131. [\[CrossRef\]](#) [\[PubMed\]](#)
12. Jacob, M.F.A.; Fandim, J.V.; Reis, R.J.J.; Hartvigsen, J.; Ferreira, P.H.; Saragiotto, B.T. Defining core competencies for telehealth in healthcare higher education: A Delphi study. *Musculoskelet. Sci. Pract.* **2025**, *75*, 103244. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Jiang, Q.; Deng, Y.; Perle, J.; Zheng, W.; Chandran, D.; Chen, J.; Liu, F. Education and training of telemental health providers: A systematic review. *Front. Public Health* **2024**, *12*, 1385532. [\[CrossRef\]](#) [\[PubMed\]](#)
14. McDermott, A.M.; Hamel, L.M.; Steel, D.; Flood, P.C.; McKee, L. Hybrid healthcare governance for improvement? Combining top-down and bottom-up approaches to public sector regulation. *Public Adm.* **2015**, *93*, 324–344. [\[CrossRef\]](#)
15. Chaparro-Cárdenas, S.L.; Ramirez-Bautista, J.-A.; Terven, J.; Córdova-Esparza, D.-M.; Romero-Gonzalez, J.-A.; Ramírez-Pedraza, A.; Chavez-Urbiola, E.A. A technological review of digital twins and artificial intelligence for personalized and predictive healthcare. *Healthcare* **2025**, *13*, 1763. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Vlasakova, M.; Muzik, J.; Holubova, A.; Fiala, D.; Arsand, E.; Urbanová, J.; Janíčková Žďárská, D.; Brabec, M.; Brož, J. A telemedicine system intervention for patients with type 1 diabetes: Pilot feasibility crossover intervention study. *JMIR Form. Res.* **2023**, *7*, e35064. [\[CrossRef\]](#) [\[PubMed\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.