

Advances in pediatrics: new technologies in clinical practice

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Abstract

Over the past decades, digital innovation has profoundly transformed pediatric care, promoting more integrated, personalized, and continuous models of assistance across hospital, community, and home settings. This contribution explores the impact of three key technological domains: telemedicine, virtual and augmented reality, and artificial intelligence. Telemedicine has expanded access to healthcare services, improved monitoring of chronic conditions, and strengthened communication between healthcare professionals and families. Its rapid development during the COVID-19 pandemic demonstrated its value in ensuring continuity of care and supporting vulnerable pediatric populations. Virtual and augmented reality offer new possibilities in surgical planning, medical training, rehabilitation, and psychological support, helping reduce anxiety and pain during procedures while enhancing understanding of clinical pathways. Artificial intelligence enables the analysis of large volumes of clinical and behavioral data, supporting early diagnosis, predictive modeling, and personalized clinical decision-making. Despite these opportunities, the integration of emerging technologies into pediatric practice requires careful attention to ethical, organizational, and educational issues, including data security, equitable access, and professional training. Overall, digital technologies are reshaping pediatrics toward more accessible, efficient, family-centered care.

Key words: pediatrics; telemedicine; virtual reality; artificial intelligence; digital health.

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Introduction

In recent decades, pediatrics has undergone a profound transformation driven by the introduction of digital technologies and innovative solutions that have progressively reshaped care models, making them more integrated, flexible, and oriented toward continuity of care.¹ The development of digital infrastructures has strengthened the connection between hospitals and community-based services, improving communication among healthcare professionals, patients, and families and facilitating the management of clinical pathways over time.²

The integration of clinical practice with technological tools, from telemedicine platforms to remote monitoring systems, from wearable devices to artificial intelligence, now enables more personalized and proactive care.³ This approach is based on the continuous collection of clinical data, monitoring of chronic conditions, and timely interventions in case of deterioration. It promotes a child- and family-centered model of care and helps improve equity in access to services, particularly for patients living in remote areas or in vulnerable conditions.³

The spread of digital technologies has also supported a structural reorganization of pediatric care toward multidisciplinary and integrated models, in which care can extend into the home and involve coordinated collaboration among different healthcare professionals.⁴

In this context, digital health represents a key driver in the development of contemporary pediatrics, thanks to its ability to enhance the collection and analysis of clinical data, optimize diagnostic and therapeutic pathways, and foster greater participation of patients and caregivers in the care process.¹

This contribution provides an extrapolated and interpretative synthesis of the section on technological innovation in pediatrics presented at the conference "Pediatrics in Clinical Practice" (Milan, January 23–24, 2026), examines the impact of major emerging technologies, particularly telemedicine, Virtual (VR) and Augmented Reality (AR), and Artificial Intelligence (AI), on organizational models and pediatric care pathways. The aim is to highlight how the integration of technological innovation and clinical practice is contributing to the development of increasingly personalized, accessible pediatric care focused on continuity across hospital, community, and home settings.

Key areas of technological innovation

Telemedicine

The progressive integration of digital technologies into healthcare systems has, in recent years, led to a significant transformation of pediatric care models, helping to redefine care pathways

with a focus on continuity of care, personalization, and improved accessibility.⁵

Telemedicine represents one of the most rapidly developing areas within this process, forming part of the broader evolution of digital health, which has progressively expanded the delivery of healthcare services beyond the traditional boundaries of the hospital.⁶ Since the second half of the twentieth century, remote healthcare has been increasingly defined as a mode of delivering care when distance constitutes a critical factor. The World Health Organization has contributed to formalizing the concept of telemedicine within the broader domain of digital health.⁷

In Italy, regulatory development has accompanied this process: from the first provisions in the early 2000s to the national guidelines of 2014, the indications issued in 2020, and the guidelines of 2022, telemedicine has progressively been recognized as a structured mode of healthcare delivery and integrated into the organizational models of the National Health Service.⁸ Subsequent updates and initiatives linked to digital health and the National Recovery and Resilience Plan (PNRR) have further consolidated its application, promoting telemonitoring and interoperable platforms within care pathways.⁸

A decisive acceleration in the development and adoption of telemedicine occurred during the COVID-19 pandemic, which highlighted the need to ensure continuity of care even when access to hospital facilities was limited.⁹ In this context, remote care emerged as an essential tool to maintain the connection between hospital and community services, monitor patients at home, and guarantee access to care for the most vulnerable pediatric populations.⁴ The experience gained during the health emergency demonstrated how digital technologies can improve service organization, promote equity of access, and contribute to the sustainability of healthcare systems, transforming telemedicine from an emergency solution into a stable component of care pathways.

At the “Vittore Buzzi” Children’s Hospital in Milan (Italy), beginning in 2020, a progressively structured model of remote pediatric care was developed, initially based on active home surveillance systems and later evolving into an integrated digital care system.¹⁰ The implementation of a remote monitoring operations center enabled the management of a large number of patients and involved coordinated collaboration among hospital units, community services, and healthcare professionals in training.¹⁰ This experience laid the foundations for the creation of a virtual hospital model aimed at ensuring continuity of care after discharge through dedicated digital platforms and secure, traceable communication tools. The model is based on a flexible and modular telemedicine platform capable of adapting to different clinical contexts and integrating specialist modules for various pediatric disciplines, promoting interaction among specialists, primary care pediatricians, and families.¹⁰

Clinical applications of telemedicine in pediatrics are broad and diverse. In telecardiology, the possibility of performing and reporting electrocardiograms remotely allows timely specialist evaluation and reduces the need for in-person hospital visits.¹¹ Digital transmission of tracings through dedicated platforms enables the pediatric cardiologist to analyze tests rapidly, facilitating early diagnosis of potential abnormalities and monitoring of patients with known conditions, thereby improving continuity of care and reducing travel for families.

In the field of nutrition, telenutrition¹² enables monitoring of anthropometric parameters, assessment of adherence to dietary plans, and adjustment of nutritional regimens in patients with chronic or rare diseases. Through remote consultations, it is possible to

implement timely dietary modifications, support families in daily management, and ensure more regular follow-up while reducing the need for in-person visits.¹²

Tele-diabetology represents another important area of development, thanks to the use of sensors and devices for continuous glucose monitoring and the possibility of providing therapeutic education and follow-up remotely.¹³ Analysis of glycemic data shared via digital platforms allows the diabetes care team to optimize therapy, intervene early in cases of imbalance, and strengthen the self-management capacity of patients and their families.¹³

Similar applications extend to teleneurology, endocrinology, allergology, speech therapy, and pediatric palliative care, fields in which remote care helps reduce travel, improve treatment adherence, and ensure comprehensive management of both the patient and the family.^{9,14} In these contexts, telemedicine promotes collaboration between specialists and community services, supports long-term monitoring, and contributes to making care pathways more accessible, personalized, and sustainable.

A further area of development is advanced telemedicine, which integrates digital devices, sensors, and remote monitoring systems to expand the diagnostic, therapeutic, and follow-up possibilities of remote care.¹⁵ The use of home-based technologies enables more continuous and structured collection of clinical and functional parameters, providing clinicians with a dynamic view of disease progression and treatment effectiveness.¹⁶

The use of wearable devices allows prolonged monitoring of physical activity, heart rate, sleep, and other lifestyle indicators, providing useful data for the comprehensive assessment of pediatric patients.^{9,14} At the same time, tools such as home spirometers, portable tele-ultrasound devices, and sensors for telerehabilitation make it possible to perform functional assessments and clinical checks directly at home, reducing the need for hospital visits and facilitating the management of patients with chronic conditions or those requiring frequent monitoring.¹⁷

The integration of these technologies with data analysis systems and AI opens significant perspectives for the development of predictive clinical risk models and for the personalization of care pathways.¹⁸ Continuous analysis of collected data enables early identification of signs of deterioration, optimization of treatments, and tailoring of interventions based on individual patient characteristics. Preliminary data indicate high acceptance among patients, caregivers, and healthcare professionals, along with reductions in hospital stay duration and improvements in continuity of care, suggesting a potentially positive impact on the overall organization of pediatric services.^{11,19}

Overall, the adoption of telemedicine in pediatrics is an evolving process that is expected to consolidate through the creation of dedicated centers, stronger integration between hospital and community care, and the development of virtual hospital models capable of ensuring continuous monitoring, multidisciplinary teleconsultations, and personalized care pathways.²⁰ In this perspective, digital technologies represent not only a support to clinical practice but also a structural component of new pediatric care models aimed at improving accessibility, quality, and sustainability of healthcare.

Virtual reality and augmented reality: a new perception of reality

The introduction of VR and AR in medicine represents one of the most recent frontiers of technological innovation applied to

pediatrics, with implications for diagnosis, therapeutic planning, training, and the doctor–patient relationship.²¹ These technologies are part of the broader digitalization of medicine, in which the perception of clinical reality is progressively integrated with three-dimensional models and simulated environments, improving the understanding of anatomical structures and pathological processes. VR enables immersive experiences in fully simulated environments, while AR overlays digital elements onto the real world, offering advanced tools for the visualization and interpretation of clinical data.²¹

The foundations of these applications derive from the processing of radiological data, which can be transformed into high-fidelity three-dimensional models through segmentation, post-processing, and conversion into formats compatible with virtual environments.⁶ Once anonymized and validated, diagnostic images undergo volumetric reconstruction procedures that allow accurate identification of organs and anatomical structures. Subsequently, through the generation of three-dimensional meshes and optimization of digital models, it is possible to obtain high-resolution representations usable in immersive or interactive settings, useful both for simulation and advanced clinical visualization.⁶

The quality of the models depends closely on the precision of the original images and on subsequent validation and optimization phases, which enable the integration of radiological information with clinical and anatomical data. This process makes it possible to build reliable, navigable, and manipulable three-dimensional models useful for preoperative analysis and for sharing information among the different specialists involved in patient management.

This approach has applications across several areas of pediatric surgery and clinical practice, including congenital pulmonary and thoracic malformations, hepatobiliary anomalies, urogenital disorders, diaphragmatic hernias, and complex oncological conditions, supporting surgical planning and multidisciplinary discussion of complex cases.²² The possibility of exploring personalized three-dimensional models improves understanding of anatomical relationships, helps anticipate potential intraoperative challenges, and supports more accurate and shared surgical planning.

In the educational field, VR enables the reproduction of realistic clinical scenarios in controlled environments, facilitating the learning of procedures and the development of technical skills without risk to patients.²¹ AR, by integrating digital information into real-world settings, can support preoperative planning and intraoperative decision-making, improving orientation during surgical procedures and enhancing precision. The integration of virtual models and clinical data also contributes to the development of precision medicine, allowing more personalized planning and a better understanding of individual anatomical characteristics.¹

Beyond diagnostic and surgical applications, VR is increasingly used in the overall management of pediatric patients, particularly for psychological support, rehabilitation, and the reduction of pain and anxiety during procedures.²³ Immersive virtual environments designed to be engaging and age-appropriate can provide distraction during invasive or potentially stressful procedures, helping to reduce perceived pain and improve patient cooperation. In rehabilitation, interactive scenarios make exercises more motivating and allow objective monitoring of functional progress, facilitating adherence to therapeutic programs.²³ These tools can also be used to prepare children for procedures or diagnostic tests, improving understanding of the care pathway and communication with families.²³

However, the adoption of VR and AR also presents challenges, including implementation costs, the need to ensure high standards

of safety and data protection, integration with healthcare information systems, and the definition of shared validation models.²⁴ Issues related to interoperability between platforms and the assessment of the long-term impact of these technologies in clinical practice also remain.

Future perspectives point toward the development of increasingly integrated systems in which three-dimensional simulation, data analysis, and telemedicine converge within shared platforms, promoting collaboration among specialists and optimization of care pathways. In this context, technological innovation requires a balanced approach that combines development, implementation, and integration while maintaining a critical perspective focused on clinical effectiveness, safety, and the sustainability of healthcare systems.⁵

Artificial intelligence

AI is now one of the main drivers of technological innovation in medicine and, in particular, in pediatrics, where the analysis of large volumes of clinical, biological, and behavioral data opens new perspectives for early diagnosis, personalization of care, and support for decision-making processes.¹⁸

AI can be defined as the set of techniques and computer systems capable of performing tasks that, if carried out by a human being, would require abilities considered intelligent.²⁵ In this perspective, the focus is not on reproducing human cognitive processes but on emulating the outcomes and actions that characterize intelligent behavior. This pragmatic view has guided the development of numerous systems capable of supporting clinical practice through automated data analysis and the generation of predictive models.

The development of AI is not a recent phenomenon but the result of an evolution that began in the mid-twentieth century with the first artificial neural networks and the formal introduction of the term “artificial intelligence” in the 1950s.²⁶ After alternating periods of enthusiasm and disillusionment—characterized by reduced funding and limited practical applications, AI has experienced renewed expansion since the 2000s thanks to the availability of large datasets, increased computing power, and improvements in machine learning algorithms.²⁶ The development of deep neural networks and large language models has enabled performance comparable to human levels in several domains, making AI an increasingly pervasive tool in clinical practice and biomedical research.²⁶

In pediatrics, AI applications are rapidly expanding across numerous clinical areas.^{26,27} Recent literature highlights the use of machine learning models to predict length of stay in pediatric intensive care units, to diagnose and monitor respiratory, infectious, and metabolic diseases, and to manage chronic conditions such as asthma, allergies, and neurological disorders.²⁷ Additional areas of application include mental health, behavioral medicine, and the analysis of data from digital devices and telemedicine systems.²⁸ Commonly used paradigms include supervised machine learning, which enables the construction of predictive models from labeled data, and generative and language models capable of analyzing complex texts, images, and biological signals.

Among the concrete applications of AI in pediatrics are research projects that integrate digital technologies with remote clinical support. One example involves digital interventions for socially isolated youth and adolescents that combine telepsychiatry, cognitive rehabilitation, and automated speech analysis.²⁸ The use of deep learning algorithms makes it possible to extract clinically relevant informa-

tion from patients' speech, supporting therapists in assessing psychological status and tailoring interventions.²⁹

Additional applications include the use of generative AI models for the analysis of pediatric electrocardiographic signals.³⁰ AI enables the construction of dynamic models capable of representing physiological ECG variations during growth, allowing comparison between real signals and reference models and contributing to the definition of age-specific normal ranges. These approaches can improve diagnostic accuracy and support early identification of cardiac abnormalities, integrating with telemedicine platforms and remote monitoring systems.

Despite numerous opportunities, the introduction of AI into pediatric practice also raises ethical, organizational, and social issues. Key challenges include ensuring equitable access to technologies, protecting sensitive data, maintaining algorithmic transparency, and evaluating the impact of digital technologies on the development of children and adolescents.³⁰ The integration of AI into healthcare systems therefore requires a critical and informed approach focused on scientific validation of tools and appropriate training for healthcare professionals.¹⁸

In the near future, AI will likely be integrated into many of the tools with which pediatricians interact daily, from diagnostic devices to clinical data management software platforms. In particular, large language models may facilitate the structuring of clinical information, decision support, and communication with patients and families.²⁷ In this scenario, it is essential to develop foundational competencies that enable healthcare professionals to understand the potential and limitations of AI, promoting appropriate and responsible use of new technologies in pediatric practice.²⁷

Conclusions and future perspectives

The combined analysis of emerging technologies applied to pediatrics highlights how the digital transformation of clinical practice is no longer an experimental or sector-specific process but a structural trajectory of contemporary healthcare systems. Telemedicine, virtual and augmented reality, and AI represent distinct yet deeply interconnected domains that collectively contribute to redefining pediatric care models, with a focus on continuity of care, personalization of interventions, and integration between hospital, community services, and home settings.

Together, these technologies outline a new care paradigm in which the digital dimension becomes an integral part of pediatric clinical practice. The convergence of telemedicine, immersive systems, and AI paves the way for increasingly integrated models of care based on continuous data collection and analysis, multidisciplinary collaboration, and patient-centered approaches. However, implementing these innovations requires careful consideration of organizational, ethical, and educational aspects. It is necessary to ensure data security, system interoperability, equitable access to technologies, and the development of digital competencies among healthcare professionals so that technological innovation can translate into real improvements in health outcomes.

Future perspectives point toward the progressive consolidation of digital care models, with the integration of continuous telemonitoring platforms, predictive analytics systems based on artificial intelligence, and virtual environments for clinical simulation and training. The evolution toward increasingly connected, data-driven healthcare systems will require a multidisciplinary approach involving clinicians, engineers, data scientists, and healthcare pol-

icymakers in order to develop effective, safe, and sustainable technological solutions. In this context, pediatrics represents a particularly fertile field for experimentation and innovation, where the responsible adoption of new technologies can help build more accessible, personalized care models centered on the needs of children and their families.

References

1. Santamaría-Orleans A, Ortiz-González L, Pérez-Hernández M, Coronel-Rodríguez C. Impact of digitalization on pediatric practice and childhood health care in Spain: nationwide survey study. *JMIR Pediatr Parent* 2025;8:e75310.
2. Evans YN, Eisenstein E. The expansion of pediatric care through digital technology. *Curr Pediatr Rep* 2021;9:178–80.
3. Gu L, Chen L, Ma C. Application of digital technology in medical practice. *Front Public Health* 2026;14:1722648.
4. Zuccotti G, Calcaterra V, Foppiani A. Present and future of telemedicine for pediatric care: an Italian regional experience. *Ital J Pediatr* 2023;49:10.
5. Ezeamii VC, Okobi OE, Wambai-Sani H, et al. Revolutionizing healthcare: how telemedicine is improving patient outcomes and expanding access to care. *Cureus* 2024;16:e63881.
6. Cushing N, Fell B, Shahed KS, et al. Automated segmentation of medical images for 3D printing – voxel centric processing of spatially textured voxels. *Virtual Phys Prototyp* 2025;20:e2459811.
7. WHO. Global strategy on digital health 2020-2025. Accessed on 12-02-2026. Available from: <https://www.who.int/docs/default-source/documents/gS4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf>.
8. McKenzie B. Italy: New guidelines on telemedicine in home-care. Accessed on 12-02-2026. Available from: <https://www.globalcompliancenes.com/2022/08/08/italy-new-guidelines-on-telemedicine-in-home-care-28072022/>
9. Gherman A, Andrei D, Popoiu CM, et al. Multidisciplinary Telemedicine in healthcare during and after the COVID-19 pandemic: a narrative review. *Life* 2025;15:783.
10. Zuccotti GV, Bertoli S, Foppiani A, et al. COVID-19 and COVID-20: an Italian experience of active home surveillance in COVID-19 Ppatients. *Int J Environ Res Public Health* 2020;17:6699.
11. Mannarino S, Calcaterra V, Fini G, et al. A pediatric telecardiology system that facilitates integration between hospital-based services and community-based primary care. *Int J Med Inf* 2024;181:105298.
12. Calcaterra V, Verduci E, Vandoni M, et al. Telehealth: a useful tool for the management of nutrition and exercise programs in pediatric obesity in the COVID-19 era. *Nutrients* 2021;13:3689.
13. Yan Y, Li N, Tian C. Application of Digital tools in the care of patients with diabetes: scoping review. *J Med Internet Res* 2025;27:e72167–e72167.
14. Kadam SJ, Bongurala AR. Telemedicine in pediatrics: things to consider. *Clin Exp Pediatr* 2025;68:326–8.
15. Rossi M, Rehman S. Integrating artificial intelligence into telemedicine: evidence, challenges, and future directions. *Cureus* 2025;17:e90829.
16. Cecconi M, Hutanu AL, Beard J, et al. Unlocking opportunities to transform patient care: an expert insight on limitations and opportunities in patient monitoring. *Intensive Care Med Exp* 2025;13:24.

17. Strang A, Renner K, Smallacombe K, et al. Home monitoring using telehealth and mobile spirometry is feasible, acceptable, and accessible in children with asthma from rural and medically underserved areas. *Pediatr Pulmonol* 2025;60:e71109.
18. Fahim YA, Hasani IW, Kabba S, Ragab WM. Artificial intelligence in healthcare and medicine: clinical applications, therapeutic advances, and future perspectives. *Eur J Med Res* 2025;30:848.
19. Zuccotti G, Marsilio M, Fiori L, et al. Leveraging user-friendly mobile medical devices to facilitate early hospital discharges in a pediatric setting: a randomized trial study protocol. *Children* 2024;11:683.
20. Vallée A, Arutkin M. The transformative power of virtual hospitals for revolutionising healthcare delivery. *Public Health Rev* 2024;45:1606371.
21. Tene T, Vique López DF, Valverde Aguirre PE, et al. Virtual reality and augmented reality in medical education: an umbrella review. *Front Digit Health* 2024;6:1365345.
22. Pelizzo G, Pierucci UM, Marinaro M, et al. Virtual reality for preoperative planning and education in pediatric surgery: preliminary results for the treatment of congenital malformations and tumors. *World J Surg* 2025;49:1497–507.
23. Griffin A, Wilson L, Feinstein AB, et al. Virtual reality in pain rehabilitation for youth with chronic pain: pilot feasibility study. *JMIR Rehabil Assist Technol* 2020;7:e22620.
24. Iqbal AI, Aamir A, Hammad A, et al. Immersive technologies in healthcare: an in-depth exploration of virtual reality and augmented reality in enhancing patient care, medical education, and training paradigms. *J Prim Care Community Health* 2024;15:21501319241293311.
25. Bajwa J, Munir U, Nori A, Williams B. Artificial intelligence in healthcare: transforming the practice of medicine. *Future Healthc J* 2021;8:e188–94.
26. Oliveira AL, Figueiredo MAT. Artificial Intelligence: historical context and state of the art. In: Sousa Antunes H, Freitas PM, Oliveira AL, et al. eds. *Multidisciplinary Perspectives on artificial intelligence and the law*. Cham: Springer International Publishing; 2024: pp. 3–24. Available from: https://link.springer.com/10.1007/978-3-031-41264-6_1
27. Park T, Lee IH, Lee SW, Kong SW. Artificial intelligence in pediatric healthcare: current applications, potential, and implementation considerations. *Clin Exp Pediatr* 2025;68:641–51.
28. Rossetti MG, Perlina C, Girelli F, et al. Developing a brief telematic cognitive behavioral therapy for the treatment of social isolation in young adults. *Front Psychol* 2024;15:1433108.
29. Leal SS, Ntalampiras S, Rossetti MG, et al. Speech-based depression recognition in hikikomori patients undergoing cognitive behavioral therapy. *Appl Sci* 2025;15:11750.
30. Leone DM, O’Sullivan D, Bravo-Jaimes K. Artificial intelligence in pediatric electrocardiography: a comprehensive review. *Children* 2024;12:25.

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