**Recent Trends and Innovations in Pediatric Care**

**Abstract**

A symbiotic relationship exists between the two giants of humanity: Technology and health sciences. Newer advancements have led to paradigm changes in managing critically sick children. It is fascinating to observe how artificial intelligence (AI) has percolated into myriad aspects of healthcare delivery. Sophisticated medical devices offer a wide range of monitoring and applications available at bedside clinical practice. The advent of novel biomarkers has made diagnosing, predicting and managing many clinical conditions easier and drastically reduced the turnaround time compared to conventional methods. Evidence-based medicine has also led to exciting revelations and transformations in children's age-old practice of managing critical conditions.

With the above advances, the involvement of family members in clinical care and decision-making, as incorporated in the family-centered care models, has improved the clinical outcomes in children. The healthcare sector is poised for transformation on the shoulders of AI, genomics, and remote monitoring technology. Adopting novel opportunities & emerging technologies into our practice goes a long way in achieving optimal patient outcomes. However, one should also be aware of AI's legal, ethical and social implications on health care and ensure compliance with the existing regulatory framework. The paediatrics recent trends & innovations outlined in this chapter are only a glimpse into the ever-changing chasm of medical technologies from bench to bedside.

**Keywords**:- Artificial intelligence, Biomarkers, Electronic health records, Diagnostics, Genomics

**Introduction**

Modern-day paediatric practice comprises several challenges. Children are not miniature adults and have unique vulnerabilities that pose a significant dilemma for treating clinicians. Till a decade back, most of the evidence base was from the adult population with extrapolation to children. However, with the advent of newer devices with customizable features suited to different sizes and age-specific physiology, it is possible to generate high-quality research in paediatrics1. The immense momentum gained in technological advancement has improved the accessibility and quality of care for children2,3. Telemedicine, remote patient management systems, portable imaging facilities, newer biomarkers, automation and newer diagnostic methods have been pathbreaking changes of the era 4–6. Proteomics, genomics and precision medicine enable healthcare institutions to personalize healthcare and improve treatment outcomes7,8. AI, machine learning (ML), and immersive technologies will further enhance clinical decision-making and patient care.

The healthcare ecosystem in India is a study in contrasts. One aspect is the transition towards technological reforms regarding critical care patient flows, surge capacities and monitoring critically sick children9. The other aspect is the struggle for affordable resources to serve the larger demographic of our economy. COVID-19 has catalyzed the widespread acceptance and adoption of digitization in India10.

The futuristic take on paediatric healthcare can be summarized as A for artificial intelligence, B for biomarkers, C for computer applications, D for devices, E for evidence-based medicine, F for family-centric care model, and G for genomics and precision medicine.

**Artificial intelligence**

AI refers to any technique which enables computers to mimic human behaviour. It has seamlessly integrated into medical practice and research11. The term "artificial intelligence" was first coined by John McCarthy, an American scientist from the Massachusetts Institute of Technology in 1956. The growth of AI has exploded in the last few decades to the current AI dominance in all the major global industries in the 21st century.

The use of AI in the healthcare industry has had far-reaching consequences. It has provided large-scale data handling solutions such as electronic health records (EHR), medical big data management, and innovative health management systems12. AI-based clinical tools can augment conventional clinical decision-making in children by enhancing accuracy and standardisation13,14.

One of the most widely used AI tools is ChatGPT, which is a language-processing tool (LPL) with an unsupervised ML algorithm for unstructured and unlabelled data. It is currently being used and misused in multiple aspects of health care, such as literature search, analysis and summarising large volumes of data, preparation of manuscripts and clinical research projects15,16.

The use of AI has become ubiquitous in clinical medicine. The following are some key areas and applications of AI in pediatric medicine (**Figure 1**).

1. **Research** -AI has shown promising applications in medical research, especially in secondary research and evidence synthesis. AI-based tools and software such as Rayyan QRCI and Nested Knowledge help in intelligent and automated literature search, screening, data tagging, compilation, and evidence synthesis17,18. AI has a widespread scope of application in primary research in neonates and children, such as interpretation of investigations, clinical diagnosis of medical conditions, assessment of pediatric airways, mortality prediction, morbidity, inotrope requirement, length of hospital stay and other long-term outcomes19,20.
2. **Diagnostic dilemma**- In certain neurodevelopmental disorders, particularly autism spectrum disorder (ASD), AI has emerged as a promising diagnostic aid. Early diagnosis and intervention are crucial for optimal outcomes but are often complex in clinical practice. It requires subtle longitudinal observations by caregivers. AI has the potential to streamline this process by analyzing large amounts of observational data, such as speech patterns, facial expressions and body movements, to identify patterns and markers associated with ASD21. Childhood cancer is another arena of high-impact AI-mediated diagnostic capabilities. For instance, AI can decipher a child's genetic constitution and reference it with known cancer-related mutations to generate a customized treatment plan based on their unique susceptibility. This facilitates informed decision plans regarding the best possible outcomes22.
3. **Predictive modelling**- It also aids in predicting mortality rate, length of hospitalization and survival in life-threatening diseases requiring critical care support. The scope of these models was highlighted during the COVID-19 pandemic, where these tools helped predict the spread of infection, identify containment zones and predict mortality23,24.
4. **AI-driven virtual assistants** can provide children and adolescents with personalized wellness and mental health support. Parents and caregivers use them to access health information, which offers recommendations based on a child's age, medical history, and symptoms, assisting caregivers in making informed decisions25. In conditions such as autism, it can help with daily routine activities and delivering therapy to the children as they are more receptive to interactive robots than human beings.
5. **Intelligent Health Data analytics** involves exploiting healthcare-related data to optimize resources and improve the quality of care and clinical outcomes. This is increasingly used for precision medicine, disease prediction and outcomes, POC diagnostic devices and AI-based clinical decision systems26. Moreover, AI can help reduce the load on healthcare providers (HCPs) by automating routine tasks, such as data entry and appointment schedules, enabling them to prioritize patient care rather than administrative tasks.
6. **Operational management** includes forecasting demand, managing supplies, reporting bed utilization, inter-facility transfer, care progression, and discharge planning. Hospitals use this information to pre-empt resource allocation requirements, streamline patient workflow and allow clinicians to focus on delivering the best care for the patient.27

By harnessing the power of AI, paediatricians can make more accurate diagnoses, provide personalized treatment plans, and ultimately improve the quality of life for children and their families. Though the real purpose of AI in health care is to co-exist with the process of clinical decision-making by supporting and enhancing physician's decision-making, there are concerns with [patient safety](https://www.sciencedirect.com/topics/medicine-and-dentistry/patient-safety), algorithmic transparency, lack of proper regulation, liability & accountability, impact on patient-physician relationship and governance of AI-empowered healthcare.

**B-Biomarkers**

Biomarker research in health sciences has witnessed a significant impetus in recent years. Biomarkers are crucial in the diagnosis, progression, regression and treatment response. Bedside point-of-care(POC) devices using novel biomarkers have improved our diagnostic ability and reduced laboratory turnaround time, thus enabling timely decision-making. Adult biomarkers cannot be applied to children without due consideration of the impact of ontogeny on physiological functions. This has fuelled the development of novel biomarkers such as NGAL and KIM-1 for clinical use to assess acute kidney injury in neonates and children28,29.

Sepsis is the leading cause of mortality in critically sick children and, thus, a vital research arena for biomarker development. A recent study," The Pediatric Sepsis Biomarker Risk Model" (PERSEVERE), evaluated a panel of serum biomarkers for early diagnosis of sepsis and its association with mortality risk. Authors used complementary bioinformatics and ML to derive a list of candidate predictor genes for 28-day mortality30. Some of the evolving biomarkers in pediatric diseases are listed in **Table 1.**

1. **Computer and mobile health applications**

Health information can be accessed using mobile health apps through handhelds, headgear, garments and smartphones. With wireless connectivity and mobile devices, paediatricians receive critical child health data updates, enabling quicker diagnoses and eliminating errors. Technologies such as picture archiving and communication systems (PACS) have replaced conventional radiological film imaging. They also have provisions for remote access, transfer and integration with the hospital information system31.

Apps also offer learning simulations through real-life scenarios that promote positive decision-making and active learning in pediatric residents. Peer support-mediated interventions using social media networking apps have benefited Insulin-dependent Diabetes mellitus, nephrotic syndrome and bronchial asthma32. Patient home records can be digitized with the help of specialized asthma diary or insulin diary apps, thus helping to titrate therapeutic decisions effectively. A UK-based Neotree app regulates clinical workflows and guides HCPs when babies are admitted or discharged from neonatal wards33. **Table 2** depicts some of the commonly available AI-based health applications in paediatrics.

  iNICU intelligence is a cloud-based EHR platform that integrates bedside clinical observations and laboratory results and then analyses the data in comprehensive medical reports leveraging ML. It reduces manual errors and automatically generates discharge summaries and disease predictions.

Tele-ICU is a 'Hub and Spoke' model concept that gained popularity in the pandemic era. It aims to provide virtual access to the ICU expertise for critically sick children in remote areas, thus bridging the gap between rural and urban healthcare resources.

**D- Devices**

Pediatric critical care medicine has achieved significant milestones with advanced ICU ventilators, monitors and devices driven by patient needs. Some of these are discussed below.

1. **Near-infrared spectroscopy (NIRS)** is a novel technology based on non-pulsatile oximetry to determine regional tissue oxygenation34. Oxyprem is a Swiss-based device with a non-invasive reusable tissue oximeter that uses headgear to optimize oxygen use in premature babies35. It is being evaluated in pediatric acute kidney injury (AKI) and neurocritical care.
2. **(POC) Devices-** These enable rapid diagnosis, are either non-invasive or minimally invasive and assist in real-time dynamic management of several critical conditions36. Examples include point-of-care hemoglobinometers, lactate and ammonia meters, blood gas analyzers, troponin card tests, bilirubinometers and biochemistry analyzers.
3. **Intelligent ventilators**- using newer ventilation modes like neurally adjusted ventilatory assist (NAVA), closed-loop inspired oxygen (CLIO), adaptive support ventilation, High-Frequency Oscillatory ventilation (HFOV), and other hybrid modes enable better synchronization and breath-to-breath control37. The recent shift of focus to non-invasive ventilation using better nasal interfaces has also improved clinical outcomes.
4. **Prone ventilation beds** - In the wake of the COVID-19 pandemic, prone ventilation has emerged as one of the effective ways of managing Acute Respiratory Distress Syndrome (ARDS)38. Special kinetic beds are now available for facilitating proning of paralyzed ARDS patients on high ventilatory support.

**E-Evidence-based medicine**

Many concepts in pediatric critical care medicine have radically changed our understanding of the disease process compared to a decade ago. The change in the demographic profile of the patients, the impact of lifestyle and environmental factors, emerging antimicrobial and drug resistance patterns, and the ever-growing technological advances have made it mandatory for healthcare providers to keep abreast of these changes and apply evidence-based medicine to deliver high-quality care to the sickest children39.

**F-Family centric care (FCC) model**

FCC has replaced the conventional approach of separating a sick child in the ICU with limited parental access. The FCC model is a partnership approach to care involving the parents in caring for their child. It aims to provide child-friendly, holistic, empathetic health care with more communication between families and clinicians. The parents are involved in child care and the clinical decision-making process. Even though it is considered the gold standard of modern-day PICU care, there are some practical dilemmas. It might cause anxiety or exacerbate parental fears, especially if the child is unstable or has an unpredictable condition. It may also become a source of medicolegal issues for treating clinicians due to ignorance or misinterpreting standard ICU procedures. Thus, there needs to be an active effort by treating paediatricians to establish the trust and rapport of the caregivers and then strike a balance between confidentiality and engagement in care.

**G-Genomics and precision medicine**

Nearly seven million children are born with genetic disorders annually. For these children, life typically begins in intensive care. Various NICUs are heading towards a standardized protocol for screening genetic disorders by sequencing the human genome. In pregnancies with a higher risk of genetic diseases, antenatal genetic evaluations help in pre-emptive diagnosis and timely intervention.

Soon, "Gene Patri" will likely replace "Janam Patri". Couples opting for marriage would probably like to match their gene patri as genomics has come a long way in India. It is no longer cost-prohibitive to get entire genomic profiling done to anticipate genetic susceptibility or estimate the risk of genetic disorders in the progeny. With the availability of DNA microarrays, Array comparative genomic hybridization (ACGH), and Next-generation sequencing (NGS), it is possible to generate a complete imprint of genetic susceptibilities and integrate it with AI technology to predict the likelihood of cancers, drug responsiveness, rare syndromes and many neurometabolic disorders. These principles are embedded in precision medicine from the bench to the bedside.

**Conclusion**

The world of paediatrics is witnessing a sea change with the emergence of newer technologies, gadgets and aids. However, with every opportunity comes the responsibility of using it appropriately and ethically. The involvement of healthcare providers and local community support is essential for developing and implementing AI-based solutions to make them relevant, accessible, and aligned with the local context, thereby maximizing their positive impact.

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**Table 1: Novel biomarkers in paediatrics**

|  |  |  |  |
| --- | --- | --- | --- |
| **S No.** | **Biomarker** | **Indications** | **Disease** |
|  | Mass Spectroscopy-based newborn screen | Disease screening | Inborn errors of metabolism  Hematological conditions |
|  | Urinary NGAL | Several Disease prognostication | Acute renal failure |
|  | ADAMTS-13 | Disease stratification | TTP |
|  | Inhibin B | Assessment of treatment adverse effects | Chemotherapy-induced infertility |
|  | TGF-b1 | Assessment of treatment response | Marfan syndrome |
|  | Anti-islet cell antibodies | Disease risk | Type 1 diabetes |
|  | Factor VIII | Stratification | Hemophilia |
|  | Presepsin | Disease diagnosis | Pediatric sepsis |

**Table 2:- The top AI applications in paediatrics**

|  |  |  |  |
| --- | --- | --- | --- |
| **S. No.** | **Name** | **Developer** | **Features** |
|  | Little angel medical | Canada | Child health monitoring |
|  | ATMAN | TCAIR, DRDO | COVID-19 patients to test positive predictive value and accuracy of X-rays in disease classification. |
|  | Medicine from the sky | India | Drone-based deliveries of blood, vaccines, medical samples and organs. |
|  | Chexnet | US | An algorithm created to diagnose pneumonia |
|  | Cardio DL | US | AI-assisted cardiac imaging in the cloud |
|  | [Healthray](https://healthray.com/doctor/) | India | AI-enabled healthcare practice platform that integrates consultations, patient management, online doctor appointments, e-prescription, and EHR. |
|  | Ensofia | US-based | Its natural language conversational AI handles everyday tasks such as appointment management and prescription refills. |
|  | Pediametrix | US-based | AI and computer vision for reliable and accurate anthropometric measurement and monitoring through image processing and ML |
|  | Zoala | Singapore | It identifies mental stressors and helps in building mental resilience. |
|  | Curiedx | US-based | Image-based screening for common pediatric diagnoses such as fever, rash and sore throat. |
|  | **Safer** | Artificial Intelligence Company Thorn | This AI-powered tool detects child abuse images with around 99% accuracy |
|  | **Griffeye** | US Federal agency | It uses facial and image recognition tools to scan nude or inappropriate pictures to prevent child sexual abuse. |
|  | **Child Safe** | US | It assists organizations in mitigating the risk of online child abuse. |
|  | Elsa Health Assistant | US | Health providers input patient demographics, vitals, symptoms, and test results and receive insights and next-step recommendations about their patients' health.  Elsa supports common pediatric illnesses (rash, gastroenteritis, etc.), nutrition-related illnesses, high-mortality illnesses such as malaria, and sexual and reproductive conditions (including HIV/AIDS). It supports healthcare providers in identifying early childhood development milestones. |
|  | SAHELI | India | Restless Multiarmed Bandit (RMAB) framework to identify beneficiaries for outreach |

**Figure 1: Application of AI in paediatric healthcare system**



