Review

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Artificial Intelligence–Enabled Approaches to Enhance Maternal Vaccine Uptake: Implementation Opportunities, Challenges, and Ethical Implications

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Abstract

Maternal vaccination is an important component of antenatal care, yet uptake of influenza, pertussis, and more recently introduced vaccines such as respiratory syncytial virus (RSV) remains suboptimal in many settings. Barriers include inconsistent counselling, safety concerns, misinformation, and structural inequities affecting access to healthcare services. Artificial intelligence (AI) has emerged as a potential tool to support vaccine communication, clinical decision-making, and targeted public health interventions. This narrative review synthesizes current evidence and conceptual perspectives on the application of AI in maternal immunization. A structured search of PubMed and Google Scholar (up to February 2026) was conducted to identify relevant studies and conceptually informative contributions. Because the objective was conceptual synthesis rather than systematic evidence mapping, PRISMA methodology and formal study selection procedures were not applied. The literature suggests several domains in which AI may support maternal vaccination strategies. Predictive analytics may help identify individuals or populations at risk of under-immunization, enabling targeted outreach and precision public health planning. Conversational agents can provide scalable vaccine communication and counselling, while natural language processing enables monitoring of vaccine-related sentiment and misinformation across digital platforms. Clinical decision-support systems integrated into antenatal care workflows may support consistent provider recommendations and reduce missed opportunities for vaccination. Important challenges include data quality and representativeness, algorithmic bias, privacy and governance concerns, and limited evidence from low-resource settings. When implemented within ethically governed and human-centred health systems, AI-enabled approaches may contribute to strengthening maternal immunization programs while complementing—rather than replacing—the trusted provider–patient relationships that remain central to maternal vaccine acceptance.

Keywords: maternal vaccination; artificial intelligence; vaccine hesitancy; predictive analytics; conversational AI; clinical decision support; equity; digital health

1. Introduction

Maternal vaccination has become a central priority for global health authorities, including the World Health Organization and the CDC, as part of life-course immunization strategies designed to reduce neonatal mortality and the burden of infectious diseases [1]. In high-income settings, influenza and pertussis vaccines are routinely recommended during pregnancy, supported by extensive evidence confirming their safety and their ability to prevent severe maternal illness as well as infant hospitalizations and deaths. By translating these individual-level benefits into population-level

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protection, these long-standing programs have demonstrated that, when effectively delivered, antenatal immunization can generate substantial public health benefits [2].

The maternal immunization landscape has expanded considerably in recent years. Clinical trials, together with emerging real-world evidence on maternal respiratory syncytial virus (RSV) vaccination, have demonstrated meaningful reductions in severe RSV disease among young infants, underscoring the potential of antenatal immunization to mitigate early-life morbidity [3,4]. Given that RSV remains a leading cause of infant hospitalization worldwide, maternal vaccination may significantly influence child health outcomes [3,4]. At the same time, vaccines targeting Group B *Streptococcus* (GBS) are progressing through development and offer a promising approach to preventing neonatal sepsis, meningitis, and stillbirth. As GBS continues to contribute substantially to neonatal morbidity and mortality, a maternal GBS vaccine could reshape global perinatal infectious disease prevention [5].

Despite strong evidence supporting the safety and effectiveness of maternal vaccines, uptake remains inadequate in many regions [6]. Coverage varies widely across countries and population groups. Structural barriers—such as limited access to antenatal care, socioeconomic disparities, geographic constraints, and fragmented service delivery—hinder consistent vaccine provision. Psychological and social influences, including hesitancy, mistrust in healthcare systems, concerns about fetal safety, and exposure to misinformation, further shape maternal decision-making [7].

Pregnancy is a period marked by heightened vigilance and increased sensitivity to perceived risks. Many women prioritize fetal protection and may view vaccination as unnecessary or potentially harmful [8]. These concerns are often intensified by inconsistent messaging, insufficient counselling, and conflicting information circulating through digital and social media [9]. The COVID-19 pandemic underscored how quickly maternal immunization programs can be disrupted by misinformation, declining institutional trust, and rapidly shifting information environments [10]. Collectively, these challenges highlight the need for innovative, scalable, and adaptive approaches to strengthen vaccine confidence and uptake [11].

Artificial intelligence (AI) is increasingly applied in healthcare systems, offering new ways to address complex public health challenges. Advances in machine learning, natural language processing, and predictive analytics enable the integration of diverse data sources and support precision public health strategies. AI-enabled approaches can enhance vaccine promotion by identifying individuals at risk of under-immunization, tailoring communication, monitoring hesitancy in real time, and supporting healthcare providers through decision-support tools. By combining clinical, behavioral, and social data, AI systems can help uncover key drivers of maternal vaccine hesitancy and inform targeted interventions [12–14].

This narrative review synthesizes current evidence on AI-driven strategies to improve maternal vaccine uptake. It examines applications such as predictive analytics, conversational agents, natural language processing, and clinical decision support, while also addressing ethical, equity, and implementation considerations. By outlining both opportunities and challenges, the review aims to guide future research, policy development, and clinical practice. Given the rapid expansion of maternal immunization platforms and the parallel growth of digital health technologies, understanding how AI may support maternal vaccine uptake is increasingly relevant for public health planning.

To our knowledge, no prior review has integrated predictive analytics, conversational AI, NLP-based infodemic surveillance, and AI-enabled CDSS specifically within maternal immunization workflows; however, related reviews exist in broader immunization and maternal digital health domains. Overlapping content across sections has been consolidated to streamline the narrative and avoid redundancy while preserving conceptual clarity.

2. Methods

This narrative review aimed to synthesize current evidence and conceptual perspectives on the use of artificial intelligence to improve maternal vaccine uptake. A structured literature search was

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conducted in PubMed and Google Scholar to identify relevant studies published up to February 2026. Search terms included combinations of keywords related to maternal vaccination and artificial intelligence, such as: *"maternal vaccination"*, *"pregnancy immunization"*, *"artificial intelligence"*, *"machine learning"*, *"predictive analytics"*, *"chatbots"*, *"natural language processing"*, *"clinical decision support"*, *and "vaccine hesitancy"*. Studies were considered eligible if they addressed: i) AI applications relevant to vaccination or maternal healthcare, ii) digital health interventions influencing vaccine uptake or communication, iii) ethical or governance frameworks related to AI in healthcare.

Given the emerging nature of the field, the review included a range of evidence sources, including original research articles, randomized trials, systematic and narrative reviews, as well as policy analyses and conceptual papers that provided insights relevant to maternal immunization. Because empirical studies specifically evaluating AI interventions for maternal vaccination are limited, relevant evidence from related fields (digital health, immunization communication, and maternal healthcare) was also considered. The objective of this review was conceptual synthesis rather than exhaustive systematic mapping; therefore, formal systematic review procedures such as PRISMA flow diagrams, duplicate screening, and quantitative meta-analysis were not applied. Articles were selected based on conceptual relevance, methodological rigor, and relevance to maternal immunization.

3. Thematic Domains of AI Applications in Maternal Immunization

The literature reviewed in this narrative review highlights several domains in which artificial intelligence may contribute to strengthening maternal immunization programs. Although direct empirical evaluations of AI-based interventions targeting maternal vaccination remain limited, evidence from related fields—including digital health, vaccine communication, and maternal healthcare—provides valuable insights into how these technologies may support antenatal immunization strategies.

Table 1 summarizes the main domains in which artificial intelligence may be applied to maternal vaccination, including predictive analytics, conversational AI, natural language processing–based surveillance, and clinical decision-support systems. These technological approaches have the potential to address multiple determinants of vaccine uptake during pregnancy by improving risk identification, enhancing communication with pregnant individuals, monitoring the digital information environment, and supporting clinical decision-making within antenatal care.

Table 2 presents representative studies informing these domains. While many of the identified studies originate from broader vaccination, digital health, or maternal healthcare contexts, they provide important methodological and conceptual insights relevant to maternal immunization. Together, these studies illustrate the range of AI-enabled approaches currently explored in healthcare and highlight opportunities as well as limitations for their application in maternal vaccination strategies.

The following sections discuss these thematic domains and their implications for improving maternal vaccine uptake.

Table 1. Potential applications of artificial intelligence in maternal immunization programs.

AI Application	Potential Use in Maternal Vaccination	Public Health Opportunities	Key Challenges
Predictive analytics	Identification of pregnant individuals or communities at risk of under-immunization using clinical, demographic, and behavioral data	Targeted outreach, improved allocation of vaccination resources, early identification of hesitancy patterns	Data bias, limited representativeness of datasets, algorithmic fairness

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Conversational AI (chatbots, virtual assistants)	Personalized vaccine counselling, automated reminders, and responses to common concerns during pregnancy	Scalable communication, improved vaccine confidence, increased engagement outside clinical visits	Information accuracy, trust in AI systems, integration with clinical guidance
Natural language processing (NLP)	Monitoring vaccine sentiment and misinformation across social media and digital platforms	Early detection of misinformation trends, rapid public health response, improved risk communication strategies	Privacy concerns, ethical use of publicly available data
Clinical decision-support systems (CDSS)	Integration into antenatal electronic health records to prompt healthcare providers to recommend vaccines	Reduced missed vaccination opportunities, improved adherence to immunization guidelines	Workflow integration challenges, provider training, system interoperability

Abbreviations: AI — Artificial Intelligence.

Table 2. Representative studies informing AI-enabled approaches relevant to maternal immunization.

Study	Setting / Population	AI Approach	Study Type	Key Findings	Relevance to Maternal Immunization
Loomba S et al. (2021) [10]	UK and USA adults	Statistical modelling of misinformation exposure	Experimental study	Exposure to COVID-19 vaccine misinformation significantly reduced vaccination intent	Demonstrates the measurable impact of misinformation relevant to maternal vaccination contexts
Betsch C et al. (2012) [11]	Online / Web 2.0 users	Digital communication environments	Narrative review	Online environments influence vaccination decisions through peer interaction and emotional framing	Provides theoretical framework for digital communication strategies relevant to maternal vaccination
Topol EJ (2019) [12]	Healthcare systems	Human–AI collaboration	Perspective / review	AI can enhance diagnostic accuracy and personalized medicine when integrated with clinical expertise	Conceptual basis for AI-supported maternal healthcare and vaccine counselling
Rajkomar A et al. (2019) [13]	Clinical healthcare datasets	Machine learning	Review	Machine learning improves prediction, risk stratification, and clinical decision-making	Provides technical basis for predictive AI applications relevant to maternal immunization
Kumar S (2025) [14]	Healthcare systems	Patient-centered AI frameworks	Perspective article	Emphasizes transparent, participatory, and patient-centered AI in healthcare	Supports ethical and patient-centered AI tools for maternal vaccine counselling
Odone A et al. (2014) [19]	Various populations	Digital media interventions	Systematic review	Web-based and social media interventions can improve vaccine	Demonstrates digital communication strategies

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				uptake and coverage	potentially applicable to pregnant women
Omranian S et al. (2024) [20]	US nurses	Natural language processing and machine learning	Observational AI study	AI models predicted health belief model constructs and vaccine uptake	Illustrates potential of predictive AI for identifying vaccine hesitancy
Taseen S et al. (2025) [21]	Routine immunization programs; zero-dose children	AI-enabled digital tools and predictive analytics	Review	AI-supported tools improved identification of zero-dose children and enabled targeted outreach	Demonstrates how similar approaches could identify pregnant women at risk of under-immunization
Dankwa-Mullan I (2024) [22]	Public health systems	AI governance frameworks	Policy analysis	Highlights equity, bias mitigation, and community engagement in AI implementation	Critical considerations for ethical AI deployment in maternal immunization programs
Pavia G et al. (2024) [23]	Post-COVID-19 immunization programs	Digital health platforms and data integration	Review	Digital health systems improved immunization monitoring and responsiveness to coverage gaps	Relevant for monitoring maternal vaccination coverage and reducing missed opportunities
El Arab RA et al. (2025) [24]	Perinatal care pathways	Multiple AI applications (predictive analytics, NLP, CDSS)	Scoping review of reviews	AI tools improved risk prediction, workflow efficiency, and equity monitoring	Demonstrates how AI could be integrated into antenatal care pathways
Passanante A et al. (2023) [25]	Vaccine communication settings	Conversational AI / chatbots	Systematic review	Conversational AI interventions improved knowledge and engagement with vaccination information	Suggests scalable counselling tools for pregnant populations
Hou Z et al. (2025) [26]	Parents of middle-school girls	AI-powered vaccine chatbot	Cluster randomized controlled trial	Chatbot intervention significantly increased HPV vaccine uptake	Provides strong experimental evidence supporting chatbot-based vaccine communication
Huang LC et al. (2024) [27]	Social media users	Natural language processing (NLP) monitoring	Original research	NLP systems can monitor vaccine sentiment and hesitancy trends in real time	Enables early detection of vaccine misinformation affecting pregnant populations
Cockburn N et al. (2024) [28]	Maternity care settings	Clinical decision support systems	Systematic review and meta-analysis	CDSS improve adherence to clinical guidelines and maternity care outcomes	Demonstrates infrastructure for embedding vaccination prompts into antenatal workflows

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Obermeyer Z et al. (2019) [29]	US healthcare populations	Predictive risk algorithms	Original research	Identified racial bias in healthcare risk prediction algorithms	Highlights equity risks in AI systems relevant to maternal immunization
Chen IY et al. (2021) [30]	Healthcare AI systems	Ethical machine learning frameworks	Review	Proposes fairness, accountability, transparency, and bias mitigation strategies	Provides safeguards for AI-driven maternal vaccine prediction models
Floridi L et al. (2018) [31]	Global AI governance	Ethical AI framework	Conceptual framework	Introduces principles for a "Good AI Society" including beneficence and justice	Foundational ethical framework applicable to AI in maternal vaccination
Panteli D et al. (2025) [32]	Public health institutions	AI in public health systems	Policy analysis	Identifies governance needs, workforce training, and regulatory priorities	Guides integration of AI into maternal immunization policies
Khan M et al. (2022) [33]	Low-resource settings; maternal and neonatal populations	Machine learning and predictive modelling	Narrative review	AI tools support maternal and neonatal health through diagnostics and risk prediction	Demonstrates potential scalability of AI tools for maternal immunization outreach
Giaxi P et al. (2025) [35]	Obstetrics and midwifery care	AI and machine learning applications	Systematic review	AI tools improved risk assessment and decision support in obstetric workflows	Conceptual support for AI-enabled maternal vaccine counselling and risk identification

Abbreviations: AI — Artificial Intelligence; CDSS — Clinical Decision-Support Systems; NLP — Natural Language Processing; HPV — Human Papillomavirus.

Table note: No original empirical studies specifically evaluating AI-based interventions designed to increase maternal vaccine uptake were identified.

3.1. Determinants and Current Landscape of Maternal Vaccination

Maternal immunization is widely recognized as an important component of antenatal care and a key strategy for protecting both pregnant individuals and their infants from vaccine-preventable diseases. Vaccination against influenza during pregnancy has been shown to reduce severe maternal morbidity, hospitalizations, and adverse obstetric outcomes, while pertussis vaccination provides effective passive protection to newborns during the first months of life [2,15]. More recently, maternal immunization against respiratory syncytial virus (RSV) has demonstrated significant reductions in severe RSV disease among young infants, further expanding the scope of antenatal vaccination programs [3,4].

Despite strong evidence supporting the safety and effectiveness of maternal vaccines, vaccination coverage during pregnancy remains heterogeneous across countries and population groups. Higher uptake is generally reported in high-income settings, whereas low- and middle-income countries continue to face structural challenges related to healthcare infrastructure, workforce capacity, and competing public health priorities [7]. Disparities in vaccine uptake have also been documented within high-income countries, particularly among ethnic minority populations, migrants, and individuals with lower socioeconomic status.

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Health system factors play an important role in maternal vaccination delivery. Missed opportunities during routine antenatal visits remain common and may arise from limited consultation time, competing clinical priorities, or uncertainty among healthcare providers regarding vaccine recommendations [16]. Fragmented care pathways and incomplete documentation systems can further hinder the consistent identification and vaccination of eligible pregnant individuals [16].

Individual-level determinants also influence maternal vaccination decisions. Concerns regarding vaccine safety during pregnancy, perceived risks to fetal health, and varying levels of trust in healthcare providers and institutions may shape vaccine acceptance [17]. Behavioral science research highlights the importance of risk perception, trust, and social norms in influencing vaccination decisions during pregnancy [18].

Social and cultural contexts further contribute to the complexity of maternal vaccine uptake. Partners, family members, and community networks may influence decision-making, while previous experiences with healthcare systems can affect levels of trust and confidence in vaccination programs [8]. In addition, the increasing role of digital media as a source of health information during pregnancy has amplified both evidence-based communication and misinformation related to vaccination [19].

Taken together, these structural, behavioral, and informational determinants shape maternal vaccination uptake across diverse settings. Understanding these factors provides important context for evaluating how emerging digital and artificial intelligence–enabled approaches may support maternal immunization strategies.

3.2. Predictive Analytics and Precision Public Health

Predictive analytics is increasingly used in public health to identify individuals or populations at increased risk of adverse health outcomes or suboptimal healthcare utilization. In the context of immunization, machine learning methods enable the analysis of large and heterogeneous datasets, allowing patterns associated with vaccination behaviour to be identified more efficiently than with traditional analytical approaches [13]. These models may help detect pregnant individuals at higher risk of remaining under-immunized or expressing vaccine hesitancy, thereby supporting earlier identification of potential barriers to maternal vaccination [13,20].

Predictive models typically integrate multiple sources of information, including clinical records, sociodemographic characteristics, and behavioural indicators. Combining these data allows analytical systems to capture several determinants known to influence maternal vaccination uptake, such as access to care, socioeconomic conditions, and attitudes toward vaccination. In public health settings, these insights may help guide targeted outreach strategies and support more efficient allocation of healthcare resources [21].

Natural language processing and related AI techniques can further expand predictive capabilities by analysing unstructured data, including survey responses or electronic health record narratives. Such approaches have been used to identify vaccine-related attitudes and behavioural patterns in healthcare populations, demonstrating the potential of AI systems to anticipate vaccination behaviour and identify determinants of hesitancy [20]. However, studies specifically examining predictive AI models in maternal immunization remain limited.

Predictive analytics may also inform targeted intervention strategies aimed at improving maternal vaccine uptake. Examples include the use of digital reminder systems, tailored educational materials, and targeted communication strategies for individuals or communities identified as being at higher risk of under-immunization. Digital health platforms, including mobile health applications and telemedicine services, may facilitate the delivery of such interventions within antenatal care systems [21].

In addition to supporting individual-level interventions, predictive models can help identify structural disparities affecting maternal vaccination coverage. Analyses of population-level datasets may reveal patterns associated with socioeconomic disadvantage, migration status, or geographic

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barriers to healthcare access. These insights may support the design of more equitable immunization strategies while highlighting populations that may benefit from targeted support [22].

At the health system level, predictive modelling can also contribute to improved immunization planning. Forecasting models may help estimate vaccine demand, support supply chain management, and monitor emerging trends in vaccine hesitancy across regions or population groups. Such applications have been explored in broader immunization programs and digital health systems, illustrating how predictive analytics may contribute to more responsive vaccination strategies [23,24].

3.3. Conversational AI and Vaccine Communication

Conversational artificial intelligence (AI), including chatbots and virtual assistants, is increasingly used in digital health communication to provide interactive information and guidance to users. In vaccination contexts, these systems can respond to questions, address common concerns, and provide structured information about vaccine recommendations and safety [24]. By enabling interactive dialogue rather than one-way information delivery, conversational systems may facilitate user engagement and improve access to reliable health information [25].

Conversational agents can also deliver standardized vaccine messages while adapting responses according to user input. This capacity allows communication to be adjusted to factors such as literacy level, language preference, or specific information needs. In heterogeneous populations, such tailored communication strategies may help address barriers related to limited health literacy, uncertainty about vaccine safety, or difficulties accessing healthcare information [25].

Evidence from other immunization contexts illustrates the potential relevance of these tools for vaccine promotion. AI-based chatbot interventions have been shown to improve vaccine knowledge and increase vaccination uptake in some settings. For example, a cluster randomized trial evaluating an AI-driven chatbot intervention demonstrated increased uptake of HPV vaccination among parents of adolescent girls by providing reminders, personalized information, and responses to common concerns [26].

Conversational AI may also extend vaccine communication beyond clinical encounters. During pregnancy, individuals frequently seek health information through digital platforms, where exposure to inaccurate or misleading information may influence vaccination decisions. AI-enabled conversational tools can provide accessible, evidence-based responses outside healthcare settings, potentially supporting informed decision-making and reinforcing healthcare providers' recommendations. Such tools may be particularly relevant in settings where access to prenatal care or vaccination counselling is limited [27].

3.4. Natural Language Processing and Infodemic Surveillance

Natural language processing (NLP) is increasingly used in public health research to analyse large volumes of text generated across digital platforms, including social media, online forums, and other web-based communication channels. By processing these data streams in near real time, NLP systems allow researchers and public health authorities to monitor changes in public attitudes toward vaccination and identify emerging concerns or misinformation circulating in digital environments [27].

NLP-based analyses can also be used to examine longitudinal trends in vaccine confidence across different populations and geographic regions. By analysing user-generated content, these systems can detect recurring themes, emotional tone, and behavioural patterns associated with vaccine attitudes. Such approaches have been applied to assess vaccine-related discourse among both healthcare professionals and the general public, providing insights into factors that may influence vaccination intentions [9,20,27].

In the context of maternal immunization, digital discussions frequently include concerns related to vaccine safety during pregnancy, potential fetal risks, and other misinformation circulating through social media platforms. NLP-based monitoring systems can help identify such narratives and track their dissemination across online communities. Early detection of misinformation may

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assist public health authorities in developing targeted communication responses and providing evidence-based information addressing specific concerns [9].

3.5. Clinical Decision-Support Systems and Provider Engagement

Clinical decision-support systems (CDSS) are increasingly used in healthcare to assist clinicians in applying evidence-based recommendations during routine care. In maternity services, CDSS can be integrated into electronic health records and antenatal care workflows to support adherence to clinical guidelines and improve the consistency of preventive care practices. By linking patient information with guideline-based recommendations, these systems can generate automated prompts reminding healthcare providers to discuss and offer recommended vaccinations during pregnancy [28].

Within maternal immunization programs, CDSS may help reduce missed opportunities for vaccination by identifying eligible pregnant individuals and prompting clinicians to initiate vaccine discussions at appropriate gestational stages. Automated alerts, structured reminders, and risk-stratification tools can support healthcare providers in busy antenatal settings where competing priorities and limited consultation time may affect the delivery of preventive services. Integration of vaccination prompts into clinical workflows may therefore contribute to more consistent counselling and improved adherence to immunization guidelines [28].

Design considerations are also important for ensuring the acceptability and appropriate use of AI-enabled decision-support systems. Patient-centred approaches emphasize transparency, shared decision-making, and culturally appropriate communication in the development of digital health tools. In the context of maternal vaccination, these principles are particularly relevant because trust in healthcare providers and clear communication strongly influence vaccine acceptance. Ethical considerations—including data privacy, algorithmic bias, and equitable access to digital health technologies—must therefore be addressed when implementing CDSS in maternal healthcare systems [14].

3.6. Ethical, Legal, and Equity Considerations

The integration of artificial intelligence into maternal vaccination programs raises important ethical and legal considerations, particularly related to fairness, transparency, and accountability. AI systems trained on incomplete or biased datasets may inadvertently reproduce or amplify existing healthcare disparities. Evidence from algorithmic tools used in healthcare resource allocation has demonstrated that predictive models relying on cost-based proxies may underestimate the needs of marginalized populations, thereby reinforcing rather than reducing health inequities [29].

Ensuring equity is therefore an important consideration in the design, validation, and deployment of AI-enabled public health interventions. Ethical machine learning frameworks emphasize that fairness should be addressed throughout the entire AI lifecycle, including data collection, model development, implementation, and ongoing evaluation [30]. Participatory approaches involving pregnant individuals, healthcare professionals, and community stakeholders may also improve transparency, strengthen trust, and enhance the acceptability of digital health interventions in maternal care settings [22].

Legal and regulatory considerations are similarly important as AI tools become integrated into clinical and public health decision-making processes. The use of maternal and fetal health data raises questions regarding privacy protection, informed consent, and the responsible secondary use of personal health information. Robust data governance structures, secure data infrastructures, and clear communication about how health data are used are essential for maintaining public trust in AI-enabled health systems. In addition, accountability frameworks are needed to clarify responsibility when AI-supported tools influence clinical recommendations or public health actions related to vaccination [22].

Ethical governance of AI systems in maternal immunization can also be informed by established bioethical principles, including beneficence, non-maleficence, autonomy, justice, and explicability.

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These principles support the development of digital tools that complement clinical expertise, promote equitable access to preventive care, and respect patient autonomy. Ethical frameworks for artificial intelligence further emphasize the importance of human oversight, transparency in algorithmic decision-making, and continuous monitoring of societal impact [31].

In practice, evaluating fairness in AI systems may require subgroup-specific analyses—such as calibration, equalized odds, or predictive value parity—to detect potential disparities across different populations. Although the studies identified in this review did not report such metrics, these methodological approaches are increasingly considered important for assessing equity in AI-enabled healthcare systems.

Regulatory frameworks are also evolving to address the use of AI in healthcare. Emerging governance approaches—including the European Union Artificial Intelligence Act, regulatory guidance for software as a medical device (SaMD), and international technical standards—seek to establish requirements for safety, risk management, and post-market monitoring of AI-enabled health technologies.

3.7. Implementation and Health System Integration

The integration of digital health technologies into immunization programs has the potential to improve vaccination coverage, strengthen monitoring systems, and enhance the responsiveness of health services. Digital platforms can support vaccine tracking, facilitate data sharing across healthcare settings, and improve the identification of individuals who may have missed recommended vaccinations [23]. However, successful implementation requires careful consideration of operational, technical, and organizational factors within healthcare systems.

Introducing digital tools into routine clinical practice often requires dedicated training for healthcare providers and administrators. Without appropriate training and support, digital systems may be used inconsistently or their outputs may be misinterpreted, potentially affecting vaccination delivery or documentation. Effective implementation also depends on interoperability with existing health information systems. Limited compatibility between digital platforms and established infrastructures can result in fragmented data flows, duplication of work, and reduced efficiency in immunization programs. Addressing these challenges typically involves structured implementation planning, stakeholder engagement, and ongoing system evaluation [23].

Governance and regulatory frameworks also play an important role in supporting the safe and responsible use of AI-enabled digital health tools. Such frameworks generally include requirements for system validation, performance monitoring, documentation standards, and transparency regarding how algorithms function and are updated. Engagement with clinicians, patients, and community stakeholders can further contribute to the acceptability and trustworthiness of digital health technologies used in maternal healthcare settings [32].

In practice, the implementation of AI-enabled tools in maternal immunization programs may require mechanisms for monitoring system performance, evaluating potential biases, and ensuring that digital systems remain aligned with clinical guidelines. Post-implementation monitoring and periodic evaluation may help identify technical issues, assess equity impacts, and support continuous improvement of digital health tools within immunization programs.

4. Discussion

Maternal immunization is widely recognized as a key component of antenatal care, yet persistent gaps in vaccine uptake highlight ongoing limitations in communication strategies, healthcare delivery models, and public health infrastructures [15]. The synthesis presented in this review suggests that artificial intelligence does not introduce new determinants of maternal vaccine acceptance; rather, it provides new analytical and operational tools for addressing existing structural, behavioural, and informational barriers. Across several domains—including predictive analytics, conversational agents, natural language processing, and clinical decision-support systems—AI may support earlier identification of populations at risk of under-immunization, more tailored

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communication approaches, improved monitoring of vaccine-related discourse, and more consistent delivery of provider recommendations [13,20,23–25,28].

However, despite increasing interest in AI-enabled approaches in public health and digital health systems, the current evidence base remains limited. Most tools described in the literature are still at an early stage of development and consist primarily of pilot studies, conceptual frameworks, or feasibility assessments. Robust empirical evaluations examining the direct impact of AI-based interventions on maternal vaccine uptake are largely absent.

A notable observation emerging from this review is the lack of studies specifically designed to evaluate AI-enabled strategies targeting maternal vaccination. Instead, much of the existing literature derives from adjacent fields, including digital health communication, broader immunization programs, and maternal healthcare decision-support systems. Although these studies provide valuable conceptual and methodological insights, they do not yet constitute a coherent body of empirical evidence directly addressing maternal immunization.

Within this evolving landscape, predictive analytics represents one of the most frequently discussed applications of AI in vaccination programs. By integrating clinical, sociodemographic, and behavioural data, machine learning models may help identify individuals or communities at increased risk of under-immunization and support targeted outreach interventions [13,20,21]. Such approaches may also reveal disparities in vaccine uptake associated with socioeconomic disadvantage, migration status, or barriers to healthcare access, thereby informing more inclusive public health interventions [22].

Communication-focused AI tools may also play an important role. Pregnant individuals frequently seek health information outside clinical encounters, where exposure to misinformation can influence vaccination decisions [9,17,36]. Conversational AI systems have been explored as scalable tools for delivering consistent vaccine information, addressing frequently asked questions, and reinforcing healthcare provider recommendations [24,25]. In parallel, natural language processing systems may enable public health authorities to monitor vaccine-related discourse across digital platforms and identify emerging misinformation trends that could affect maternal vaccination attitudes [9,26].

Clinical decision-support systems provide another pathway for integrating AI within maternal healthcare workflows. By embedding guideline-based prompts within electronic health records or antenatal care systems, CDSS may help reduce missed opportunities for vaccination and improve the consistency of vaccine counselling during pregnancy [24,35]. When implemented with patient-centred design principles, such systems can support shared decision-making while preserving the central role of healthcare providers in maternal vaccine communication [12].

Despite these potential benefits, the implementation of AI-enabled tools in maternal immunization programs raises several ethical and practical challenges. AI models developed using non-representative datasets may reproduce existing healthcare inequities, particularly if marginalized populations are underrepresented in training data [29]. Ensuring fairness therefore requires diverse datasets, transparent model development processes, and continuous monitoring for potential bias [22,30]. Privacy protection and responsible governance of maternal and fetal health data are also essential for maintaining public trust in AI-supported healthcare systems [22].

Implementation challenges are likely to be particularly pronounced in low- and middle-income countries (LMICs), where structural barriers to maternal immunization—including limited access to antenatal care, workforce shortages, fragmented health information systems, and exposure to misinformation—may constrain the adoption of digital health technologies [33,34]. Furthermore, most AI models described in the literature have been developed using datasets from high-income countries, raising concerns regarding their transferability to different healthcare contexts. These considerations highlight the importance of integrating AI-enabled tools within broader maternal health and immunization strategies, supported by appropriate governance frameworks, digital infrastructure, and workforce training.

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Addressing these challenges will require context-specific implementation frameworks and rigorous evaluation of AI-enabled interventions in real-world maternal healthcare settings. Future studies should prioritize pragmatic research designs, including cluster randomized trials, stepped-wedge implementations, or adaptive evaluation frameworks capable of assessing both effectiveness and implementation outcomes. Key indicators may include vaccination uptake within recommended gestational windows, reductions in missed opportunities for vaccination, and improvements in the consistency of provider counselling.

Looking forward, a coordinated research agenda is needed to support the responsible integration of AI into maternal immunization programs. Priority areas include the development of large and representative datasets, the evaluation of real-world effectiveness of AI-enabled interventions, and the integration of digital tools with community-based engagement approaches to ensure cultural relevance and trust [21,23,30,32]. As maternal immunization programs expand with the introduction of vaccines such as RSV and potential future GBS vaccines, AI-based systems may also support demand forecasting, targeted program delivery, and improved monitoring of vaccination coverage [3–5].

Overall, the findings of this review suggest that AI-enabled approaches may contribute to strengthening maternal immunization strategies when implemented within ethically governed and contextually appropriate health systems. Importantly, these tools should be understood as complements to—rather than replacements for—the trusted relationships between pregnant individuals and healthcare providers that remain central to maternal vaccine acceptance. Future interdisciplinary collaboration between clinicians, public health experts, and data scientists will be critical for translating these conceptual opportunities into real-world maternal immunization strategies.

5. Limitations

This narrative review has several limitations. First, the available evidence on artificial intelligence applications specifically targeting maternal vaccination remains limited, and no empirical studies were identified that directly evaluated AI-based interventions designed to improve maternal vaccine uptake. As a result, the synthesis draws partly on evidence from related domains, including digital health communication, broader immunization programs, and AI applications in maternal healthcare. Second, the review followed a narrative rather than systematic methodology, and therefore did not apply formal study selection or quantitative synthesis procedures. Third, the literature included studies conducted in diverse healthcare contexts, many of which were based in high-income settings, which may limit the generalizability of findings to low- and middle-income countries. Finally, given the rapidly evolving nature of artificial intelligence technologies, new applications or empirical evaluations may emerge that were not captured within the time frame of this review.

6. Future Directions

Future research should prioritize the rigorous evaluation of AI-enabled interventions specifically designed to improve maternal vaccine uptake, moving beyond conceptual promise toward empirical validation in real-world antenatal care settings. Randomized and quasi-experimental studies are needed to assess the effectiveness, safety, and acceptability of predictive analytics, conversational agents, and clinical decision-support tools among diverse pregnant populations. Integrating AI systems into electronic antenatal records offers opportunities for automated prompts, risk stratification, and personalized counselling, but requires robust implementation science frameworks to ensure usability, workflow compatibility, and provider trust. Ethical and equity considerations must guide all future developments, including transparent model reporting, bias mitigation strategies, and participatory design approaches that involve pregnant individuals, midwives, and obstetric clinicians. Cross-disciplinary collaborations between

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immunization experts, data scientists, behavioral scientists, and public-health authorities will be essential to develop AI tools that are clinically meaningful, culturally sensitive, and aligned with maternal health priorities. As maternal immunization platforms expand globally, especially with the introduction of RSV and future GBS vaccines, AI-driven systems have the potential to support more responsive, equitable, and resilient vaccination programs—provided that future research generates the evidence base required for safe, ethical, and scalable implementation.

7. Conclusions

Artificial intelligence represents a promising set of digital approaches that may support maternal immunization programs through improved identification of populations at risk of under-immunization, enhanced vaccine communication, monitoring of vaccine-related information environments, and integration of decision-support tools within antenatal care. Although the available evidence suggests several potential applications, empirical studies directly evaluating AI-enabled interventions designed to increase maternal vaccine uptake remain limited. Future research should therefore prioritize rigorous evaluation of these technologies in real-world maternal healthcare settings, together with careful attention to ethical governance, data quality, and equity considerations. When integrated into existing health systems and implemented in ways that complement provider–patient communication, AI-enabled approaches may contribute to strengthening maternal vaccination strategies and improving health outcomes for mothers and infants.

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Abbreviations

The following abbreviations are used in this manuscript:

- **AI** — Artificial Intelligence
- **CDC** — Centers for Disease Control and Prevention
- **CDSS** — Clinical Decision Support Systems
- **GBS** — Group B Streptococcus
- **HPV** — Human Papillomavirus
- **ML** — Machine Learning
- **NLP** — Natural Language Processing
- **PRISMA** — Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- **RCT** — Randomized Controlled Trial
- **RSV** — Respiratory Syncytial Virus
- **WHO** — World Health Organization
- **mHealth** — mobile health

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