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LITERATURE REVIEW OPEN ACCESS

AI in Pharmacology: Advancing Rural Nurse Practitioner Prescribing

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Abstract

Purpose: To explore the emerging role of artificial intelligence (AI) in improving pharmacologic decision-making for nurse practitioners (NPs) in rural primary care, highlighting clinical support, workflow integration, and ethical and legal responsibilities.

Methods: This narrative review examines recent literature, case studies, and AI-enhanced tools to evaluate AI's impact on prescribing safety and efficiency in rural health settings.

Findings: AI-driven tools, such as clinical decision support systems and predictive analytics, are increasingly available to assist nurse practitioners (NPs) in prescribing practices. In rural settings, where providers face unique challenges such as workforce shortages, patient complexity, and limited specialist access, AI offers promising solutions. Case studies demonstrate AI's ability to support pharmacologic decisions for chronic conditions such as diabetes and atrial fibrillation. However, ethical concerns—including bias, transparency, and informed consent—must be proactively addressed.

Conclusions: NPs practicing in rural environments are well-positioned to lead the ethical and

effective integration of AI into pharmacologic practice. By maintaining clinical accountability, ensuring patient understanding, and evaluating tools for rural relevance, NPs can use AI to improve medication safety and access while protecting patient trust.

Keywords: Artificial Intelligence, Nurse Practitioner, Pharmacology, Rural Health, Ethics, Clinical Decision Support, Medication Safety

AI in Pharmacology: Advancing Rural Nurse Practitioner Prescribing

Prescribing has become increasingly complex due to rising multimorbidity, polypharmacy, and time pressures (Tampaki et al., 2023; Delara et al, 2022). In rural primary care settings, these challenges are magnified by workforce shortages and limited access to specialists, often driven by rural hospital closures (McCarthy et al., 2021). Nurse practitioners (NP) in these environments often serve as the sole prescribing authority, requiring safe, evidence-based tools to support their decisions. Artificial intelligence (AI) has emerged as a potential ally, offering real-time clinical decision support, risk stratification, and personalized medication recommendations.

Rural health refers to the health and well-being of individuals living in areas that are geographically distant from urban centers, often characterized by low population density, little to no local access to healthcare facilities or providers, and limited access to medical specialists (Centers for Disease Control and Prevention [CDC], 2024). The National Rural Health Association ([NRHA], n.d.) highlights that rural communities often experience health disparities due to economic, geographic, and social barriers. These challenges include higher rates of chronic illness, limited broadband internet access, transportation difficulties, workforce shortages, and fragmented care networks—all of which directly impact healthcare access and delivery.

The Rural Prescribing Landscape

Rural providers often care for patients with multiple comorbidities who have limited healthcare resources (Carter-Edwards & Taylor, 2022; NRHA, n.d.). The NRHA reported rural Americans face disproportionately high rates of chronic illness, and 70% of rural counties are designated as health professional shortage areas. These designations reflect the limited availability of specialty care, reduced access to interdisciplinary teams, and fewer support personnel to assist with complex case management. In many rural clinics NPs serve as the sole prescribing authority—managing medication regimens, coordinating referrals, and making high-stake decisions with minimal on-site support, particularly in states where full practice authority has expanded their ability to evaluate, diagnose and prescribe independently (El Arab et al., 2025). A 2025 NRHA policy brief further emphasizes that workforce shortages are only part of this challenge (Weichelt et al., 2025). Workforce shortages in rural areas are compounded by geographic isolation, provider burnout, and fragmented care networks, all of which make it even more difficult to deliver coordinated, timely, and high-quality care. In this context, AI tools offer rural NPs timely, patient-specific insights that support safe, evidence-based prescribing.

However, the absence of nearby consulting specialists or team-based infrastructure can create real challenges. This is where artificial intelligence tools—such as clinical decision support systems (CDSS) or predictive analytics—can serve as a trusted aid. These technologies do not replace clinical judgment, but they offer meaningful support by helping identify medication interactions, dosage adjustments, or condition-specific risks in real time.

In rural settings where complexity is high and time is short (CDC, 2024), AI can function as a quiet but capable partner, helping NP make well-informed decisions, improve patient safety, and reduce the strain of practicing professional isolation.

AI Tools for Pharmacologic Support

Common AI applications in prescribing include CDSS, natural language processing, and predictive analytics (Aravazhi et al., 2025; Gómez-Cabello et al., 2024; Susanto et al., 2023; Kueper et al., 2020; Hamilton et al., 2021; Sendak et al., 2020). Clinical decision support systems tools analyze electronic health record data to recommend changes in medications or other therapies, flag potential drug-drug interactions, and guide renal dosing based on lab values. Recent reviews highlight that CDSS implementation in primary care has shown measurable improvements in treatment adherence, prescribing accuracy, and provider confidence, particularly when systems are designed to align with clinical workflow.

Predictive models may also estimate the likelihood of treatment adherence or predict complications based on comorbidities. These tools are especially valuable to NPs in rural settings, where access to specialists is limited and providers are often managing a high volume of patients with complex needs. In the rural setting, Artificial intelligence-driven tools serve as a valuable resource, supporting clinical decision making, reducing the strain of high patient volumes, and promoting safe, evidence-based prescribing.

While AI can streamline pharmacologic decisions, it is not without limitations. One emerging concern is the generation of non-existent or fabricated sources when AI tools are used to support clinical recommendations. Nurse practitioners should be cautious and verify any AI-suggested literature or guidelines using trusted clinical databases such as PubMed, organizational resources like the American Heart Association (AHA) or American Diabetes Association (ADA), or peer-reviewed journals. Critically appraising AI-generated content is essential to prevent the unintentional spread of misinformation and maintain evidence-based practice integrity.

All tools must be integrated thoughtfully, with clinicians maintaining accountability for final decisions (Sendak et al., 2020). Recent literature continues to highlight the importance of transparency and user-centered design in AI-enabled prescribing, ensuring these tools support —rather than replace —clinical judgment (Heidenreich et al., 2022; Liu et al., 2020; Price et al., 2024). The CONSORT-AI framework outlines key reporting elements such as describing AI's intended use, confirming validation in similar clinical settings, and detailing how outputs are reviewed in real-time practice (Liu et al., 2020). These reporting guidelines stress the importance of rigorous validation before AI tools are introduced into clinical workflow (Liu et al., 2020). Although CONSORT-AI was developed for clinical trials, its principles apply broadly to everyday

practice, particularly in high-responsibility environments like rural clinics. The guideline calls for clarity around how AI is used, whether it has been validated in similar settings, and how outputs are reviewed, errors documented, and recommendations incorporated. For rural NPs, adopting these best practices ensures that AI enhances clinical care without compromising safety, especially in communities where resources are limited, and oversight may be less formalized. Transparent documentation and validation processes are essential steps toward responsible, ethical, and effective AI use in rural healthcare.

For example, in a small rural health clinic serving a farming community with limited access to care, a NP may use an AI-enabled clinical decision support tool to guide the initiation of antihypertensive therapy. Artificial intelligence tools can supplement the input that urban nurses may more often receive from colleagues that are not readily available to consult in the rural setting. The tool analyzes the patient's current medications, recent lab results, and confirms whether recommended medications are covered by the patient's insurance and available through the local pharmacy. This helps the NP identify safe, guideline-based treatment options that are both clinically appropriate and practically accessible. The NP then reviews the AI output in the context of the patient's condition, preferences, and the realities of rural healthcare. The final prescribing decision reflects a thoughtful balance of clinical expertise, AI-generated insights, and local resource considerations. In the rural setting, AI functions as a supportive partner, not a directive force, allowing the NP to make informed, accountable decisions. Documenting how AI recommendations were interpreted and applied supports ethical, transparent, and responsible integration into rural clinical practice.

Scenario Examples

Note: These fictional case scenarios are intended for educational purposes and do not describe actual patients, therefore, no human subject considerations were involved.

Scenario 1

Case Description

A patient with type 2 diabetes, hypertension, and heart failure managed with multiple medications presented to the rural health clinic. The patient's suboptimal control of blood pressures and glycemic control combined with symptoms of dizziness and fatigued raised concerns about polypharmacy and drug interactions.

AI Application

The NP managing this patient used an AI driven medication management tool that analyzed the patient's current medications and recent laboratory results. The tool flagged a potential interaction between a beta-blocker and a diabetes medication, which may have contributed to the patient's hypoglycemia and dizziness, as documented in the ADA's clinical guidance on drug interactions in diabetes management (ElSayed et al., 2023). The AI driven tool recommended adjusting the patient's current medication by discontinuing the beta-blocker due to the identified

adverse interaction and initiating an angiotensin-converting enzyme (ACE) inhibitor to better manage heart failure in line with current AHA clinical guidelines. (Heidenreich et al., 2022). The AI tool also verified that the ACE inhibitor was covered by the patient's insurance and available at the patient's pharmacy.

Outcome

The NP followed the AI supported recommendation, discontinued the beta-blocker, and initiated an ACE inhibitor. These changes led to improved blood pressure control, better glycemic stability, and resolution of the patient's dizziness and fatigue. Importantly, the NP documented the AI tool's recommendation, clinical rationale, and shared decision-making process in the patient's record, reflecting ethical prescribing practices and accountability. By using AI as a decision support tool alongside quality clinical decision making, the NP upheld legal and professional standards while leveraging technology to reduce the risk of adverse drug events.

Scenario 2

Case Description

A 75-year-old woman with atrial fibrillation and heart failure was being managed on a warfarin regimen. Despite regular monitoring, her international normalized ration (INR) levels remained unstable, raising concerns about bleeding risk and suboptimal anticoagulation.

AI Application

The NP used an AI tool to assess the patient's risk profile. The tool calculated two standardized clinical scores. The first, CHA_2DS_2-VASc (Congestive heart failure, Hypertension, Age ≥75, Diabetes mellitus, Stroke/TIA/thromboembolism history, Vascular disease, Sex category) helps estimate stroke risk in patients with atrial fibrillation. The second, HAS-BLED (Hypertension, Abnormal renal/liver function, Stroke history, Bleeding risk, Labile INR, Elderly, Drugs/alcohol use), estimates the risk of major bleeding for patients on anticoagulation therapy.

Based on the results, the AI tool recommended transitioning from warfarin to a direct oral anticoagulant (DOAC) to reduce bleeding risk and improve therapeutic consistency—an approach supported by current atrial fibrillation management guidelines (January et al., 2019). The tool also suggested starting an angiotensin receptor-neprilysin inhibitor (ARNI) to improve heart failure outcomes, aligned with the national heart failure treatment recommendations (January et al., 2019; Heidenreich et al., 2022; Joglar et al., 2024). In addition, the AI tool confirmed that both the DOAC and ARNI were covered by the patient's insurance and available through her local pharmacy.

Outcome

Following the AI-supported recommendations, the NP discontinued warfarin and initiated a DOAC along with an ARNI. The patient's anticoagulation status stabilized, and her heart failure symptoms improved. She reported greater medication adherence, fewer side effects and increased satisfaction with her care. The NP documented the decision-making process, including how AI-

informed suggestions were reviewed in conjunction with clinical guidelines, patient-specific risks, and medication access. This approach reinforced ethical prescribing, maintained the NP's legal responsibility for final treatment decisions, and ensured that technology enhanced—rather than replaced—clinical judgment in a rural care setting.

While AI can provide valuable support, there are situations where its recommendations may not be safe or feasible. The following case illustrates how an NP identified that an AI suggestion was not appropriate and relied on clinical judgment instead.

Scenario 3

Case description

A 68-year-old woman with stage 4 chronic kidney disease (CKD), hypertension, and osteoarthritis presented to the rural clinic with worsening joint pain and difficulty sleeping. She reported regular use of over-the-counter supplements, including licorice root tea for blood pressure and turmeric capsules for pain relief. Insurance coverage was limited, and her local pharmacy carried only a small formulary of generic medications.

AI Application

The NP entered the patient's medications, lab results, and symptoms into an AI-enabled decision support tool. The system recommended initiating a nonsteroidal anti-inflammatory drug (NSAID) for osteoarthritis pain, citing evidence of improved mobility and quality of life in older adults. However, the NP recognized that NSAIDs are contraindicated in advanced CKD because of their risk of worsening renal function and electrolyte imbalance. The AI system also failed to account for the patient's use of licorice root, which increases the risk of hypokalemia and uncontrolled hypertension.

Outcome

The NP chose not to follow the AI-generated recommendation. Instead, the treatment plan included optimizing acetaminophen dosing, prescribing a topical analgesic, and counseling the patient on discontinuing licorice root due to its adverse cardiovascular effects. The NP also discussed non-pharmacologic interventions such as physical therapy and joint protection strategies. Documentation reflected the AI output, the rationale for rejecting it, and the safer, individualized management plan.

Reflection and Broader Implications

These scenarios highlight how AI tools can support complex decision-making in rural NP practice when applied with accountability and transparency. In these scenarios, the NP used AI as a resource to supplement, not replace, clinical judgment. The AI tools offered individualized insights into medication profiles, lab results, and potential drug interactions, but ultimate prescribing decisions were guided by the NP's professional evaluation, patient preferences, and rural-specific resource considerations.

The ethical use of AI in these rural settings required clear documentation of how AI-generated recommendations were incorporated into care planning. In each scenario, the NP documented which AI outputs were reviewed, how those insights informed treatment choices, and how patient-centered discussions shaped the final decisions. This transparent approach aligns with the CONSORT-AI guidelines, which stress the importance of reporting how AI systems are used, validated, and monitored in clinical care (Liu et al., 2020). Documenting whether AI recommendations match clinical guidelines and account for local access issues becomes especially important in the rural setting. Rural healthcare providers have less opportunity for error than their urban counterparts who have more immediately available resources. Artificial intelligence tools, when used correctly, offer great opportunity for timely and accurate patient care. Regular performance monitoring and error tracking are also emphasized by CONSORT-AI to ensure ongoing safety and appropriateness of AI tools (Liu et al., 2020).

By verifying insurance coverage, pharmacy access, and patient-specific risks, the NP in these case scenarios demonstrated how AI can be ethically integrated into rural practice. This clinical oversight allows AI to enhance patient care while keeping the NP fully accountable for safe, individualized decision-making.

Importantly, while structured reporting frameworks such as CONSORT-AI offer essential guidance for transparent documentation, they are only one component of responsible AI integration. The ethical obligations of the NP extend beyond reporting compliance. In rural practice, where NPs frequently serve as the sole prescriber, the application of AI demands an unwavering commitment to clinical accountability, patient safety, and legal responsibility. These ethical and legal dimensions form a critical foundation that must be considered alongside technical implementation, as explored in the following section.

Legal and Ethical Considerations

The ethical integration of AI in rural clinical care requires not only technical transparency but also ongoing attention to the legal and moral responsibilities of the NP. While AI tools provide valuable support, they do not replace the provider's ultimate accountability for clinical decisions. Nurse Practitioners remain responsible for prescribing choices and must rigorously document clinical reasoning whenever AI-generated recommendations are incorporated, particularly as liability frameworks continue to evolve (Price et al., 2024). This ethical duty is amplified in rural contexts, where resource limitations, reduced specialty access, and smaller margins for error place heightened demands on clinical vigilance.

Transparency with patients regarding how technology informs care fosters trust and strengthens therapeutic relationships (Cohen & Slottje, 2024). Recent work has proposed a competency-based framework for technology-enhanced practice, emphasizing the critical role of ethics, legality, and data security as essential domains for healthcare providers adopting AI tools (Perle et al., 2025). Artificial intelligence models are often trained on data derived from urban, insured, or majority populations, which may not fully represent rural communities. As Obermeyer et al. (2019) demonstrated, algorithms can unintentionally perpetuate bias if not carefully validated

across diverse populations. Nurse practitioners practicing in rural areas must remain vigilant, evaluating whether AI-driven recommendations are truly applicable to their patient population. Advocacy for equity in AI development is essential to ensure safe and appropriate care across all communities.

Ultimately, thorough documentation of how AI outputs are interpreted and applied within individualized care plans is critical for maintaining both ethical integrity and legal accountability. As Price et al. (2024**)** emphasize, legal responsibility remains with the clinician, regardless of the role AI plays in informing decision-making. In resource-limited rural settings, the margin for error may be narrower, underscoring the importance of careful, accountable integration of AI into clinical workflows.

Implementation Strategies

For NPs practicing in rural communities, integrating AI into prescribing does not require an all-or-nothing approach. Starting with simple tools such as interaction checkers or renal dosing calculators can build familiarity and confidence. Collaborating with pharmacists and IT specialists can help ensure HIPAA compliance and usability in everyday clinical workflows.

It is essential that NPs evaluate the real-world impact of these tools. Tracking outcomes like adverse drug events, medication adherence rates, and patient satisfaction can help NPs determine whether specific AI tools are enhancing patient care or simply adding to the complexity (Price et al., 2024) and adjust the use of tools accordingly. As James et al. (2022) suggests, we must remain skeptical but not cynical. Nurse practitioners bring a unique lens of compassion, clinical insight, and advocacy; traits that make them well-suited to guide ethical AI adoption in rural care.

NPs as Leaders in Ethical AI Integration

Nurse practitioners in rural practice are uniquely positioned to lead the ethical integration of AI into clinical care. Their close connection with patients and holistic approach to practice allow NPs to champion technology that is both transparent and centered on patient needs. Incorporating AI training into NP education, alongside support for rural-specific AI research, can impower providers to lead this transformation responsibly (El Arab et al., 2025). In these underserved areas, NPs can help overcome persistent access barriers by bringing AI-supported care into local communities, narrowing the gap between rural and urban healthcare resources (El Arab et al., 2025).

Importantly, by combining AI tools with attention to social determinants of health, NPs can ensure that care remains individualized, equitable, and responsive to the unique challenges their rural patients face (Benda et al., 2020). While these tools are increasingly available in urban academic centers, rural patients often experience delays in accessing such innovations, further widening the rural-urban gap (El Arab et al., 2025). An intentional approach to incorporating AI training into NP education is necessary to address the ethical concerns inherent in this technology. The algorithms that drive AI decision making are created by humans or based on data collected

and incorporated by humans; this will always carry some risk of bias (El Arab et al., 2025). Nurse practitioners must remain aware of these limitations and actively work to identify where AI systems may miss critical contextual information. In rural communities, where resource limitations often leave little room for error, the NP's clinical judgment remains irreplaceable.

Conclusion

Artificial intelligence holds great promise for enhancing pharmacologic safety and efficiency—particularly in rural settings where resources are limited. Nurse practitioners must continue to balance the benefits of AI with their legal and ethical responsibilities, maintaining sound clinical judgment, clear documentation, and transparency in decision making. Frameworks such as CONSORT-AI offer important guidance to ensure the responsible integration of AI into patient care (Liu et al., 2020). Including AI training in nurse practitioner education can further equip providers to adopt these tools safely and effectively. With thoughtful implementation, rural NPs are uniquely positioned to lead the ethical and equitable use of AI—expanding access, improving safety, and advocating for patient-centered care in rural communities.

Conflict of Interest

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