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Potential Applications of Artificial Intelligence and Machine Learning in Pain Medications in Saudia Arabia: A Narrative Review

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Abstract: **Background:** Pain management in Saudi Arabia is a complex clinical challenge due to variability in drug response, increasing opioid-related risks, and the demand for personalised treatment strategies. This narrative review evaluates the potential applications of artificial intelligence (AI) and machine learning (ML) for optimising pain medication management within the Saudi healthcare context, in alignment with Vision 2030. **Methods:** A narrative literature review was conducted using PubMed, Embase, Scopus, Web of Science, IEEE Xplore, and Google Scholar. Relevant studies addressing AI and ML applications in pain management, analgesics, opioid safety, and clinical decision support were identified and screened. The findings were synthesised thematically to highlight key domains of application. **Results:** Applications of AI and ML were identified in several domains, including prediction of pain chronicity, development of personalised medication regimens, opioid risk forecasting, medication safety, objective pain assessment, and remote monitoring. Predictive models demonstrated up to 85% accuracy. Real-time electronic health record (EHR) analysis reduced opioid-related adverse drug reactions by approximately 30%. Machine learning-driven personalisation improved pain relief by 20% and reduced opioid use by 15%. AI implementation reduced medication errors by up to 65% in polypharmacy settings. **Conclusion:** AI and ML demonstrate significant potential to transform pain medication management by enabling predictive, personalised, and safer approaches. However, challenges related to validation, bias, and implementation must be addressed to ensure effective clinical integration.

Key Words: Artificial Intelligence, Machine Learning, Pain Management, Saudi Arabia, Analgesics, Opioid Safety, Personalized Medicine

INTRODUCTION

Pain management through pharmacological interventions remains a cornerstone of healthcare in Saudi Arabia, where a diverse patient demographic and the prevalence of complex pain conditions necessitate highly individualized therapeutic strategies [1]. The challenges of inter-individual variability in drug response, the rising threat of opioid misuse, and the demand for personalized treatment regimens highlight the critical need for innovative approaches to optimize pain management [2]. AI and ML technologies offer groundbreaking solutions by leveraging sophisticated data analytics to refine pain medication strategies, enhance safety, and improve patient outcomes. These tools facilitate precise diagnostics, predictive modeling for treatment efficacy, and the development of tailored treatment plans, effectively addressing both acute and chronic pain [3].

In Saudi Arabia's rapidly evolving healthcare system, the integration of AI/ML aligns seamlessly with the Vision 2030 initiative, which prioritizes the adoption of advanced technologies to elevate the quality and accessibility of medical care [4]. By harnessing these technologies, Saudi Arabia can transform pain management into a more precise, safe, and patient-centered practice [5].

AI-driven tools, such as those for real-time analysis of patient data or predictive modeling of drug interactions, enable clinicians to make evidence-based decisions, reducing risks such as adverse drug reactions and opioid-related complications. These technologies can be adapted to Saudi Arabia's healthcare priorities, such as improving care for chronic pain patients and mitigating opioid misuse [6]. By integrating AI/ML into clinical practice, Saudi Arabia can advance its healthcare infrastructure, fostering a model

of pain management that is both innovative and aligned with international standards. This approach not only supports better therapeutic outcomes but also contributes to the broader goal of building a sustainable, technology-driven healthcare ecosystem under Vision 2030 [5,7]. Therefore, the review highlights the Potential Applications of Artificial Intelligence and Machine Learning in Pain Medications in Saudia Arabia.

METHODS

Published literature examining the applications of AI and ML in pain medication management was identified and reviewed with a particular focus on relevance to the Saudi Arabian healthcare system. The review aimed to explore how AI/ML can support pain management across multiple domains aligned with national healthcare priorities, particularly those outlined in Saudi Vision 2030.

A comprehensive search for relevant studies, including empirical research, conceptual frameworks, and narrative or systematic reviews, was conducted using PubMed, Embase, Google Scholar, Scopus, IEEE Xplore, and Web of Science. The search strategy utilised a combination of keywords and Boolean operators (AND, OR), including the following terms: [Artificial Intelligence], [Machine Learning], [Pain Management), (Analgesics), (Opioid Risk), (Medication Safety), (Drug Discovery), (Clinical Decision Support), (Remote Monitoring), and (Saudi Arabia).The results of the literature search relevant to the present topic were screened by title,keywords, abstract and then the whole publication. All searches were limited to the English language. Articles were not restricted by the date of publication.

RESULTS (THEMATIC SYNTHESIS)

Predicting Transition from Acute to Chronic Pain

In Saudi Arabia, AI and ML models play a critical role in identifying patients at risk of transitioning from acute to chronic pain by analyzing diverse datasets, including pain scores, medical histories, demographics, and psychosocial factors [8]. ML algorithms, trained on clinical data, predict this progression with high sensitivity, enabling early, personalized interventions to reduce long-term opioid dependence [9]. These predictive tools align with Saudi Arabia's Vision 2030 by promoting non-opioid options like NSAIDs or complementary therapies, enhancing patient-centered care and addressing the global opioid crisis [4].

Advancements in AI-driven tools have improved predictive accuracy, with a 2025 review noting that models integrating multimodal data, such as electronic health records [EHRs] and patient-reported outcomes, achieve up to 85% accuracy in forecasting pain trajectories [10]. Techniques like random forests and neural networks identify chronicity patterns, such as persistent pain or psychological distress, allowing clinicians to prioritize interventions like cognitive-behavioral therapy or low-dose analgesics [11]. Deep learning models, particularly for knee osteoarthritis, predict pain progression with 81% accuracy (AUC 0.807), though they focus on categorical outcomes [12].AI/ML also enhance medication safety by forecasting adverse drug reactions (ADRs). A 2025 study found that real-time analysis of electronic health records reduced opioid-related adverse drug reactions by 30% through early identification of at-risk patients, thereby preventing progression to chronic pain. Emergency departments are critical settings for identifying individuals at increased risk of opioid overdose. In this study, machine learning models were developed to predict overdose-related mortality within 12 months of an emergency department visit. By integrating electronic health records with mortality data, several models, including XGBoost, random forest, and regression, were trained and validated. Feature selection reduced the number of variables from 1,336 to 50. The models demonstrated strong performance, achieving approximately 92% accuracy, 75% precision, and 57% recall, with several key predictors identified from clinical notes. These results suggest that machine learning applied to both structured and unstructured electronic health record data can effectively identify high-risk patients, support timely interventions, and improve clinical decision-making in emergency care [13] . These predictive capabilities inform acute pain management strategies, minimizing overdose or misuse risks and supporting safer prescribing practices [14].

Koh *et al.* used MRI scans from 70 people as input for a combination of machine learning models, including a perceptron, a least mean square classifier, an SVM, and k-Means. By combining the models' outputs with a weighted sum, they detected lumbar disc herniation with 99% accuracy [15]. Wearable kinematic sensors and biopotential data further stratify pain risk and severity, achieving 60–90% accuracy in risk categorization, though limited to broad categories like high versus low risk [16].Despite these advancements, challenges persist, including limited categorization in predictive models and less effective facial expression-based pain detection. These limitations highlight the need for refined algorithms and broader clinical validation to ensure robust integration into Saudi Arabia's healthcare system [17].

Personalizing Pain Medication Regimens

AI facilitates tailored pain treatment plans by analyzing patient-specific factors, including genetics, demographics, and clinical profiles [18]. ML–driven personalisation resulted in a 20% improvement in pain relief and a 15% reduction in opioid use among patients with chronic pain, particularly for medications such as NSAIDs and opioids that exhibit variable individual responses. This study offers an innovative examination of artificial intelligence in pain management; however, the overall strength of evidence is limited. Although the use of advanced machine learning methods and multimodal datasets demonstrates technical robustness, the study is limited by its exploratory design, small pilot sample, and the absence of a clearly defined methodology consistent with established reporting standards. The lack of external validation, comparator groups, and clinically meaningful endpoints further restricts

the generalisability and translational relevance of the findings. Additionally, potential biases, including dataset heterogeneity, limited population representativeness, and algorithmic bias, are not comprehensively addressed. Therefore, while the findings are hypothesis-generating and underscore the potential of AI in pain management, they should be interpreted cautiously until confirmed by well-designed, large-scale clinical studies [19] . This approach enhances therapeutic outcomes while minimizing adverse effects.

In Saudi Arabia, AI and ML are revolutionizing pain management by enabling personalized medication regimens tailored to individual patient profiles. By analyzing patient-specific factors such as genetics, demographics, clinical histories, and prior medication responses, AI/ML models deliver precise treatment recommendations that optimize efficacy and minimize adverse effects [20]. A systematic review highlighted that ML-driven models can recommend non-opioid alternatives like NSAIDs or gabapentinoids for patients at high risk of chronic pain, reducing opioid dependence [21]. This aligns with Saudi Arabia's Vision 2030, which prioritizes advanced healthcare technologies to enhance patient outcomes and safety, particularly in the context of rising chronic pain prevalence due to an aging population and increasing chronic diseases [4].

Prescribing pain medications, a key component of managing acute and chronic pain, demands deep clinical pharmacology knowledge to ensure efficacy and safety [1]. Polypharmacy, common in patients with complex pain conditions like fibromyalgia or arthritis, involves multiple pain medications (e.g., NSAIDs, opioids, or pregabalin), increasing risks of drug interactions and adverse effects such as opioid dependence or gastrointestinal issues [1,22]. Saudi Vision 2030 prioritizes enhancing healthcare quality and safety, including addressing polypharmacy in pain management to reduce medication-related harm.as well, AI offers innovative tools to optimize pain medication regimens, predict adverse reactions (e.g., using ML to identify opioid misuse risk) and enhance drug safety by personalizing treatments for Saudi patients with chronic pain [22].These predictive capabilities are critical for acute pain management, where timely adjustments can prevent chronicity, and are supported by Saudi Arabia's growing digital health infrastructure, including EHR systems and telemedicine [23]. However, challenges such as data privacy, algorithmic bias from underrepresented demographics, and the need for clinician training must be addressed to ensure equitable and effective implementation [17]. By integrating local genetic and demographic data and fostering collaborations between healthcare providers and tech developers, AI/ML can bridge gaps in access to specialised pain management, delivering patient-centred care that aligns with global standards and local needs [24].

Forecasting Opioid-Related Risks

ML models have demonstrated significant potential in forecasting opioid-related risks, offering a proactive approach to mitigating misuse and overdose in pain management. By analyzing complex datasets, including patient demographics, prescription histories, and behavioral patterns, these models can identify individuals at elevated risk of opioid addiction or overdose with high accuracy [25]. A 2025 systematic review highlighted that ML-driven risk prediction enables clinicians to make informed decisions, such as adjusting opioid prescriptions or prioritizing non-opioid alternatives, thereby promoting safer prescribing practices [11]. This predictive capability is particularly vital in the context of the ongoing opioid crisis, where reducing unnecessary opioid exposure is critical to curbing addiction rates and preventing fatal overdoses [14].

The application of ML in opioid risk forecasting also enhances the precision of interventions by integrating diverse data sources, such as electronic health records and social determinants of health. These models not only identify high-risk patients but also provide actionable insights for tailored interventions, such as referral to addiction counseling or multimodal pain management strategies [26,27]. For instance , tools empower healthcare providers to balance effective pain relief with the minimization of addiction risks, fostering a more sustainable approach to opioid use [28]. However, challenges remain, including the need for robust model validation across diverse populations and addressing ethical concerns related to data privacy and algorithmic bias. Continued refinement of these technologies is essential to ensure their equitable and effective integration into clinical practice [17].

Enhancing Medication Safety and Reducing Errors

AI significantly enhances the safety and efficacy of pain medication management by leveraging advanced data analytics to address critical challenges in healthcare [11]. A systematic review of 53 quantitative studies, selected from an initial pool of 2,496 articles, investigated the impact of AI on clinical patient safety, with a focus on clinical alarms, reporting systems, and drug safety. Machine learning and natural language processing, particularly support vector machines, were widely applied across diverse patient populations, utilising data from electronic health records, regulatory databases, and specialised cohorts. The review also identified a lack of standardised validation frameworks and significant biases within AI models, such as institutional bias, under-representation of rare conditions, and incomplete clinical data. Notably, AI systems exhibited strong performance in detecting potential drug–drug interactions and adverse drug reactions. Evidence indicated a reduction in medication errors by up to 65 % in polypharmacy settings involving analgesics, including NSAIDs [29]. By analyzing extensive patient datasets, including medical histories and pharmacological profiles, AI provides clinicians with real-time, actionable insights, ensuring safer prescribing practices and minimizing harm, particularly in complex cases with multiple medications [26]. Additionally, AI personalizes pain management by tailoring pharmacological regimens to individual physiological and genetic profiles, optimizing therapeutic outcomes while reducing risks [27].

Beyond safety, AI transforms pain management through innovative applications and personalized therapies. AI-supported platforms deliver cognitive behavioral therapy (CBT) for chronic pain with outcomes comparable to traditional methods, while significantly reducing therapist time, thus improving access to scalable mental health solutions [30]. Novel approaches, such as myoelectric pattern recognition combined with augmented reality, have reduced phantom limb pain by 32–51%, offering promising solutions for complex conditions [31]. However, AI-based self-management apps show inconsistent results, with some improving pain outcomes through real-time monitoring, while others demonstrate no significant benefit compared to standard care. These findings underscore the need for further research to refine AI-driven tools and ensure their reliability across diverse populations, highlighting AI's transformative potential in creating a safer, more precise, and patient-centered approach to pain management [32,33].

Objective Pain Assessment for Medication Dosing

AI technologies have revolutionized objective pain assessment, offering innovative solutions to guide precise medication dosing. Computer vision techniques, particularly those employing ML algorithms for facial expression analysis, have emerged as powerful tools for evaluating pain levels in real time [34]. A 2025 review highlighted that these algorithms, by analyzing facial or physiological signals, can accurately assess acute pain, especially in non-verbal patients who are unable to self-report their discomfort [35]. This capability enables clinicians to make data-driven decisions about analgesic dosing, ensuring that medications are tailored to the patient's immediate pain experience [18]. Such advancements enhance treatment precision, reduce the risk of over- or under-medication, and address a critical gap in pain management for vulnerable populations, including pediatric, geriatric, or cognitively impaired patients [19].

The application of AI in objective pain assessment also mitigates the subjectivity inherent in traditional pain evaluation methods, such as patient self-reports or clinician observations. By integrating multimodal data—such as heart rate variability, skin conductance, and facial micro-expressions—AI systems provide a comprehensive and quantifiable measure of pain intensity [36,37]. These systems not only improve the accuracy of dosing decisions but also facilitate continuous monitoring, allowing for dynamic adjustments to medication regimens as pain levels fluctuate [36]. the potential of these technologies to standardize pain assessment across clinical settings, promoting consistency in care delivery [38]. However, challenges such as algorithm generalizability across diverse populations and the need for robust validation in real-world settings remain critical areas for future research to fully realize the potential of AI-driven pain assessment [17].

Accelerating Drug Discovery for Pain Relief

Artificial intelligence (AI) has emerged as a transformative tool in accelerating the discovery of novel pain medications, significantly enhancing the efficiency of drug development pipelines [39]. By leveraging advanced algorithms to analyze vast biological and chemical datasets, AI platforms can predict potential compounds' efficacy and safety profiles with unprecedented precision [40]. The capability of these platforms to identify promising non-opioid analgesic candidates, thereby reducing both the time and financial costs associated with traditional drug discovery processes [38]. This approach not only streamlines the identification of viable therapeutic agents but also addresses critical unmet needs in pain management, where safer and more effective alternatives to opioids are urgently required [30].

Integrating AI in drug discovery also facilitates the exploration of innovative therapeutic mechanisms, broadening the scope of pain relief options. By modelling complex interactions between compounds and biological targets, AI systems can prioritize molecules with optimal pharmacokinetic and pharmacodynamic properties, minimizing the likelihood of adverse effects [41]. Predictive capabilities enable researchers to focus resources on high-potential candidates, expediting preclinical and clinical development phases [28]. However, challenges such as the need for high-quality, diverse datasets and the validation of AI predictions in real-world settings remain. Continued advancements in AI methodologies and collaborative efforts between computational and clinical researchers are essential to fully realize the potential of AI-driven drug discovery for pain relief [17].

Enhancing Clinician Education on Pain Medications

AI-powered educational tools have significantly advanced clinician training in the safe and effective use of pain medications, fostering evidence-based prescribing practices [18]. By integrating interactive simulations and personalized learning modules, these platforms provide clinicians with dynamic, tailored educational experiences that enhance their understanding of pharmacological principles, drug interactions, and patient-specific considerations [42]. A 2024 review reported that AI-driven training programs, particularly those focused on imaging interpretation and procedural skills, improved clinicians' ability to make informed prescribing decisions for pain management [36]. Such tools enable healthcare providers to navigate complex clinical scenarios, ensuring that pain medications are prescribed with greater precision and alignment with current guidelines, ultimately improving patient outcomes [24].

Applying AI in clinician education promotes continuous professional development by adapting content to individual learning needs and clinical contexts. These platforms leverage data-driven insights to identify knowledge gaps and deliver targeted interventions like case-based simulations that mimic real-world prescribing challenges [32]. For instance , AI-enhanced training strengthens technical skills and cultivates critical decision-making abilities, enabling clinicians to balance efficacy and safety in pain management [28]. However, the effectiveness of these tools depends on their integration into existing educational frameworks and the availability of high-quality, up-to-date content. Ongoing

Table 1: Application Domain and Key AI/ML Contribution for Pain Medications

Application Domain	Key AI/ML Contribution
• Predicting Acute-to-Chronic Pain	Identifies at-risk patients; supports early intervention
• Personalised Medication Regimens	Tailors regimens based on genetics, history, and response
• Opioid Risk Forecasting	Predicts misuse or overdose using behavioural and EHR data
• Enhancing Medication Safety	Detects ADRs and drug interactions in real time
• Objective Pain Assessment	Uses facial recognition and biometric data to assess pain
• AI-Driven Drug Discovery	Accelerates development of novel analgesics
• Clinician Education Tools	Enhances prescribing knowledge through simulations
• Remote Monitoring and Prediction	Monitors chronic pain, predicts treatment outcomes

evaluation and refinement of AI-based educational platforms are necessary to ensure their scalability and relevance across diverse healthcare settings [3].

Remote Monitoring and Outcome Prediction

AI-driven remote monitoring systems have transformed the management of chronic pain by enabling continuous tracking of patient symptoms and facilitating timely interventions. These systems utilize advanced algorithms to analyze real-time data from wearable devices, patient-reported outcomes, and physiological signals, detecting early signs of pain exacerbation that may require clinical attention [18,20]. A 2025 review demonstrated that AI models can predict treatment outcomes for medications such as gabapentinoids and nonsteroidal anti-inflammatory drugs [NSAIDs], providing clinicians with evidence-based insights to select therapies with the highest probability of success [43]. By reducing the need for frequent in-person visits and enhancing clinical decision-making, these technologies improve patient access to care and optimize resource allocation in healthcare systems, particularly for those with persistent pain conditions [44].

Machine learning [ML] further enhances the precision of chronic pain management by predicting differential treatment responses and placebo effects with remarkable accuracy [34]. For instance, ML models analyzing brain connectivity patterns have achieved 92% accuracy in predicting responses to treatments like pregabalin versus milnacipran in fibromyalgia patients, enabling tailored therapeutic strategies [45]. Additionally, natural language processing (NLP) techniques have shown promise in predicting placebo responses, though their ability to directly predict treatment responses remains limited [41,45]. These advancements underscore the potential of AI to personalize pain management; however, challenges such as limited generalizability of predictive models and the need for robust validation in diverse populations persist [42]. Continued research is essential to refine these tools and ensure their equitable application across clinical settings [36]. Table 1 summarise the Application Domain and Key AI/ML Contribution for pain medications.

DISCUSSION

This narrative review offers a comprehensive and contextually grounded evaluation of the prospective applications of AI and ML in pain medication management within the Kingdom of Saudi Arabia. By mapping global innovations onto the strategic objectives of Saudi Vision 2030, the review identifies eight key domains—ranging from predicting transitions from acute to chronic pain to enhancing medication safety and facilitating remote monitoring—where AI/ML technologies hold transformative promise. In doing so, it bridges the gap between emerging technological capabilities and pressing clinical challenges, particularly the high prevalence of chronic pain and growing concerns over opioid misuse in the region [5,22].

A notable strength of the review lies in its contextualisation of AI/ML within Saudi Arabia's evolving healthcare landscape. It draws upon empirical evidence, such as predictive accuracies of up to 85% in identifying chronic pain trajectories and a reported 30% reduction in opioid-related adverse drug reactions, to substantiate its claims [46, 47] . For instance, a combination of techniques—including Constrained Local Models (CLM), Patch-Based Models, and image algebra—was employed to develop a system capable of accurately detecting pain in live video streams, even under poor lighting and with low-resolution cameras. This integrated approach led to a reduction in memory usage by 40%–55% and an improvement in processing speed by 20%–25%. The findings also emphasize the clinical potential of using machine learning to personalize analgesic regimens, resulting in more effective pain relief [7, 48]. By aligning these findings with national initiatives like the SEHA Virtual Hospital and the National Data Bank, the review underscores the feasibility of scaling AI-driven pain care solutions within a digitally advancing ecosystem [49].

The implications of this review extend across research, policy, and practice. It advocates for the development and clinical validation of locally relevant AI/ML models, investment in digital infrastructure, and targeted training to enhance AI literacy among clinicians. Regulatory frameworks will also be critical to ensure the safe, ethical, and effective deployment of AI tools. Furthermore, the integration of AI in remote monitoring and telemedicine offers particular promise for improving access to care in geographically underserved regions. However, challenges surrounding scalability, cost-effectiveness, and system interoperability necessitate careful planning—potentially through public-private partnerships or staged implementation models. The included SWOT analysis presents a balanced view, identifying both enabling factors and systemic barriers that must be addressed,as shown in Table 2.

Table 2: SWOTAanalysis for both Enabling Factors and Systemic Barriers that must be Addressed

Strengths	Weaknesses	Opportunities	Threats
Improves prediction of chronic pain transition	Dependence on large, high-quality datasets	Alignment with Saudi Vision 2030 and digital health initiatives	Ethical concerns around data privacy and patient consent
Enables personalised treatment plans based on patient data	Potential algorithmic bias due to underrepresentation	Development of localised AI models using national data banks	Regulatory gaps in AI governance and clinical use
Forecasts opioid misuse and enhances prescribing safety	Limited generalisability across diverse populations	Integration with SEHA Virtual Hospital and remote care	Public mistrust or resistance to AI-guided medical decisions
Supports real-time adverse drug reaction (ADR) monitoring	High cost of AI integration and infrastructure development	AI-enhanced clinician education and simulation platforms	Lack of standardised clinical validation across hospitals
Facilitates objective pain assessment for non-verbal patients	Complexity in clinician training and interface usability	Expansion of non-opioid and precision-based analgesic approaches	Risk of widening health inequities due to digital divides

On a global level, the review contributes to the broader discourse on AI in healthcare by demonstrating how a centralised health system like Saudi Arabia's may serve as a testbed for large-scale AI deployment, complementing similar initiatives in the United States and Europe [50]. It also opens avenues for future research into non-pharmacological AI applications, such as virtual reality and digital therapeutics, within pain management. To unlock AI's full potential in this domain, future efforts must focus on interdisciplinary collaboration, national pilot projects, and addressing concerns around data governance, algorithmic fairness, and clinical translation [20].

Despite considerable implementation challenges, Saudi Arabia is strategically positioned to emerge as a regional leader in AI-enhanced pain care. National projects such as the SEHA Virtual Hospital, the National Centre for Artificial Intelligence, and the Vision 2030 framework collectively provide a strong foundation for this transformation [49,51]. At the same time, persistent dissatisfaction with current pain services underscores the urgent need for patient-centred innovations [52]. By leveraging AI to personalise treatments, improve medication safety, and extend care through digital platforms, Saudi Arabia can drive meaningful, sustainable improvements in pain management. With sustained investment, stakeholder collaboration, and ethical oversight, AI and ML can serve not only as technological enablers but also as catalysts for equitable, high-quality pain care [51,53].

CONCLUSION

Artificial intelligence and machine learning offer significant opportunities to revolutionise pain medication management in Saudi Arabia, supporting a transition towards more predictive, personalised, and efficient models of care. From risk stratification and objective pain assessment to drug development and clinician training, AI/ML technologies are well-positioned to address key gaps in current pain management practices. These tools not only promise enhanced therapeutic precision and reduced adverse outcomes but also align with the Kingdom's broader ambitions under Vision 2030 to establish a world-class, data-driven healthcare system. However, their successful integration requires overcoming challenges related to data governance, algorithmic bias, clinical validation, and workforce readiness. As such, it is imperative to foster cross-sector collaboration, invest in digital infrastructure, and develop regulatory frameworks that ensure the ethical and equitable deployment of these technologies. By doing so, Saudi Arabia can emerge as a regional leader in AI-enhanced pain medicine, delivering scalable, sustainable, and patient-centred innovations in healthcare.

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Conflicts of Interest

The authors declare no conflict of interest.

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