DeepSeek-R1 in Clinical Medicine: Advancing AI-Driven Diagnostics, Decision Support and Medical Education

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ABSTRACT

DeepSeek, a rising artificial intelligence (AI) company in Hangzhou, China, introduced DeepSeek-R1, an advanced reasoning model that rivals top large language models such as GPT-4 and Gemini, while operating at significantly lower costs. Its innovative architecture, which includes multi-head latent attention and a mixture of experts, enhances efficiency, reduces computational demands, and improves the processing of long text. DeepSeek's open-source approach has accelerated AI adoption, particularly in clinical medicine, where it supports intelligent diagnosis, surgical planning, and personalised treatment. With multimodal integration capabilities, it processes imaging, pathology, and real-time patient data to optimise decision-making. Notably, DeepSeek can significantly enhance medical education through interactive simulations and virtual training. However, challenges such as interpretability, data privacy, and cultural adaptability remain unresolved. Despite these hurdles, the advancements introduced by DeepSeek in AI-driven healthcare hold promise for enhancing clinical decision support, medical imaging, and patient-doctor communication, thereby positioning it as a transformative force in the field of medical AI.

Key Words: *DeepSeek, Artificial intelligence, Clinical decision support, Healthcare technology*.

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INTRODUCTION

Recently, artificial intelligence (AI) has witnessed unprecedented rapid developments. On 20 January 2025, DeepSeek, a small AI company based in Hangzhou, China, launched its efficient reasoning model, DeepSeek-R1, which quickly caused a global sensation and was hailed as an AI revolution.[1,2] The performance of DeepSeek-R1 is comparable to that of leading large language models (LLMs), such as ChatGPT (OpenAI) and Gemini (Google); however, its underlying model, LLM V3, achieves this at a significantly lower construction cost than current top LLMs. Additionally, it requires fewer computational resources and significantly fewer chips than similar leading models.[2] Deep--Seek's open-source strategy has actively accelerated AI popularisation and development. By leveraging deep pre-training and continuous learning, it efficiently extracts knowledge associations from vast structured datasets, delivering outstanding natural language understanding and generation, particularly for Chinese.[3-7] In complex clinical settings, where physicians must make precise decisions, DeepSeek's advanced architecture strengthens AI-driven diagnosis and decision support. This review outlines DeepSeek's technological progress, with a focus on its clinical applications.

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Overview of DeepSeek-R1 and its Technical Innovations:

DeepSeek's technical architecture integrates multiple innovative AI technologies, with its core design focused on efficiency, low cost, and multimodal support.[8,9] DeepSeek-R1, the latest version, adopts a deeper network structure and larger model scale to enhance performance. It employs a multi-head latent attention mechanism—such as examining a case from different perspectives—which then distils key details into compact latent vectors, thereby reducing memory use and accommodating long reports. A mixture-of-experts in architecture assigns tasks to specialist sub-models, automatically balancing their workloads. Multi-token prediction produces multiple words simultaneously, enabling smoother and faster responses, while sparse attention filters out irrelevant data. Available through a secure application programming interface or local deployment, it operates at roughly one-twentieth the cost of GPT-4. DeepSeek employs robust multimodal processing to combine imaging, pathology reports, and real-time data. Its continuous learning engine updates clinical guidelines and research, providing timely and accurate knowledge to support clinical decision making, intelligent diagnostics, personalised treatment recommendations, and broader medical AI progress.

Clinical Applications of DeepSeek-R1:

DeepSeek has developed clinical decision support systems across multiple medical fields.[4,10,11] Specifically, in neuro-oncology, DeepSeek integrates augmented reality (AR) imaging data to automatically generate three-dimensional tumour

models, providing precise visual support for preoperative planning. Additionally, DeepSeek has been optimised for the epidemiological characteristics of Chinese patients, demonstrating superior adaptability in decision-making for conditions such as cerebrovascular diseases and traumatic brain injuries. Compared to its international counterparts, it aligns better with clinical needs in China. Furthermore, in clinical pharmacies, DeepSeek has significant advantages in terms of understanding and reasoning capabilities. In a simulation test for the 2024 Taiwan Pharmacist Exam, DeepSeek achieved an accuracy rate of 85.7%, outperforming GPT-4o (with a score of 75.0%).[11] These findings suggest that DeepSeek possesses strong multimodal data processing capabilities and provides accurate, efficient, and locally adapted decision support, further demonstrating AI's potential in clinical decision-making.

DeepSeek's medical imaging system uses proprietary deep-learning algorithms to automatically annotate chest computed tomography (CT) images with clinical-grade accuracy, to rapidly detect lung nodules, and to classify them as benign or malignant. Its multimodal fusion combines imaging features with patient histories and laboratory results to perform association analyses and automatically produce structured diagnostic reports, markedly improving diagnostic accuracy and consistency.[12]

DeepSeek surgical intelligence platform offers comprehensive support throughout the surgical process, from preoperative planning to intraoperative navigation, and it facilitates precise and personalised surgery. Importantly, virtual reality (VR) simulation systems can reconstruct patient-specific anatomical structures, allowing surgeons to rehearse surgical procedures in 3D prior to an operation. For example, in pituitary adenoma surgeries, the system can automatically identify dangerous blood vessels in the cavernous sinus region, intelligently plan the optimal approach path, thereby reducing intraoperative risks and enhancing surgical safety. Intraoperative navigation, combined with real-time image analysis and AI-driven path optimisation, can assist surgeons in making more precise decisions. Postoperatively, DeepSeek employs a multidimensional data-fusion system that continuously captures vital signs, neurological function scores, and imaging data through wearables, thereby enabling real-time monitoring of the patient's status. During rehabilitation, it formulates dynamic recovery plans tailored to individual characteristics and delivers medication reminders and cognitive training through natural-language dialogue, thereby streamlining rehabilitation and improving long-term outcomes. This integrated intelligent platform not only enhances the precision and safety of surgical procedures but also provides comprehensive intelligent support for perioperative management and postoperative rehabilitation.[12]

To ensure international applicability, including in Pakistan's healthcare settings, DeepSeek-R1 employs a modular architecture that can be tailored to diverse clinical workflows and data standards, such as HL7 FHIR for electronic records and DICOM for imaging. Its deployment package includes configurable compliance modules designed to align with local regulators, including the Drug Regulatory Authority of Pakistan and the UK's Medicines and Healthcare Products Regulatory Agency. The continuous-learning pipeline accepts region-specific datasets—such as local electronic health records, imaging archives, and epidemiological registries—to fine-tune its recommendations. Collaboration with local clinical teams enables language localisation, integration of national guidelines, and adjustment to routine practice patterns. Validation studies in Pakistani hospitals are essential to confirm real-world performance and to guide further refinements across diverse healthcare environments.

Enhancing Medical Education Through DeepSeek:

DeepSeek transforms clinical medical education through virtual case simulations and interactive modules that let students construct virtual patients with common and rare diseases. It delivers diagnostic and therapeutic simulations with real-time feedback and evidence-based corrections. Multimodal imaging, integrated with AR/VR, provides 3D anatomical models and surgical simulations, enabling mastery of imaging features and operative techniques. Personalised learning paths address knowledge gaps, such as customised electrocardiogram interpretation modules or atrial fibrillation treatment guideline analysis. For clinical reasoning, DeepSeek designs diagnostic puzzles and ethical-dilemma simulations that help students identify disease causes and weigh medical ethics. It also strengthens teamwork and doctor–patient communication through multidisciplinary consultation scenarios and virtual patient encounters. As an open-source, free-access platform, DeepSeek lowers primary care education costs, enables offline guideline deployment, and automates integration of new research. It has demonstrated high accuracy in disseminating cardiopulmonary resuscitation (CPR) guidelines across age groups, broadening first-aid knowledge with free resources.[13] In skills assessment, AI acts as a standardised examiner, evaluating interview techniques and clinical decision-making, generating structured feedback, and analysing group learning data to optimise course design. Balancing technological innovation with ethical standards is crucial. Expert review mechanisms play a crucial role in ensuring content accuracy and preventing over-reliance on AI, which may undermine independent thinking, as well as upholding data privacy regulations. Ultimately, DeepSeek aims to achieve an efficient, accessible, and compassionate revolution in medical education.

DeepSeek for Clinical Research and Big Data Analytics:

DeepSeek's medical big-data platform uses blockchain to meet Chinese legal requirements for data security and integrates advanced natural language processing to extract key clinical information and support decision-making. For research, it manages multicentre data with intelligent cleaning and feature-engineering optimisation, cutting retrospective study preparation from months to weeks and accelerating produc-

tivity. Nonetheless, analysing unstructured records, especially specialised texts such as surgical notes, remains prone to errors. Additionally, reconciling Chinese data rules with global health-privacy standards poses challenges, requiring institutions and patients to balance DeepSeek's benefits against potential privacy risks when selecting online or offline deployment.[4,5,14]

Improving Patient–Doctor Communication with AI:

DeepSeek's patient–doctor communication system uses a knowledge graph to create personalised health education plans. Readability algorithms optimise scientific content, so patients across all educational levels can accurately understand it. During pituitary adenoma follow-up, its postoperative videos significantly improve adherence to medical instructions. An academic intelligence module automatically tracks global clinical trials and supplies physicians with tailored literature briefs, thereby enhancing research efficiency.[9,12] Conversely, one study evaluating six LLMs in a Chinese setting showed that while all were able to detect domestic violence, only GPT-o1, Claude 3.5 Sonnet, and Sonar Large correctly identified suicide risk. In constant, GPT-4o, DeepSeek-R1, and Gemma2 2b misclassified it as a normal psychological response. Notably, none of the models recognised the cultural nuances of the specific method of suicide, underscoring the need to enhance LLMs' cross-cultural mental-health competence.[15]

Ethical, Legal and Operational Challenges:

DeepSeek faces several challenges in its clinical application. First, the interpretability of decision-making in complex cases needs improvement, especially when multimodal data conflicts occur, such as discrepancies between imaging and laboratory results. Importantly, a lack of transparency in the reasoning of the model can undermine clinical trust. Second, the current training datasets have limited coverage and do not include national multicentre, multi-subspecialty structured datasets, limiting performance in professional areas.[16] Third, responsibility delineation in human-AI collaboration remains underdeveloped. When AI recommendations conflict with clinical practice, no clear legal framework exists that can resolve medical disputes. Additionally, as for other mainstream LLMs, DeepSeek suffers from the 'hallucination' issue, generating seemingly plausible but incorrect medical information,[5,17] and no safety assessment report for medical scenarios has been released.[18] Finally, its defence against adversarial attacks and the risk of data breaches remain uncertain.

Future Directions and Recommendations:

To realise DeepSeek-R1's clinical potential, we recommend a multi-pronged strategy. Clinicians and engineers should co-develop a cross-validation platform that unites real-world data from leading hospitals with domain-specific knowledge graphs, thereby strengthening model reasoning and enlarging the dataset to represent diverse patient populations. Concurrently, an incremental federated-learning framework with drift-detection will enable secure, cross-institutional collaboration while tracking performance longitudinally. Finally, prospective multicentre studies must benchmark DeepSeek-R1 against current state-of-the-art models (*e.g.*, GPT-4 and Gemini),[19] assessing diagnostic accuracy, influence on clinical decision-making, and patient outcomes relative to existing standards of care. Clinicians, data scientists, and regulators must jointly craft policy frameworks that clarify data governance, model transparency, accountability, and adherence to local and international healthcare rules. Bespoke clinical trials—from radiology and pathology to AI-guided treatment planning—are needed to evaluate efficacy, safety, cost-effectiveness, and user acceptability. A three-tier review process (AI suggestion, physician confirmation, and multidisciplinary review), reinforced by third-party AI safety certification and full disclosure of testing protocols and privacy safeguards, will secure rigorous human oversight and foster trust. Together, these measures will enable DeepSeek-R1 to become a reliable, ethical, and clinically transformative tool for patient care.

CONCLUSION

DeepSeek is an advanced AI platform that blends multimodal data processing, augmented- and virtual-reality surgical intelligence, and other cutting-edge tools to improve medical decision-making, diagnostics, and personalised therapy across disciplines. These technologies sharpen pre-operative planning, intra-operative navigation, and postoperative care. Interactive simulations and streamlined data management raise the efficiency of medical education and research, while 5G connectivity enables remote surgical consultations that support primary healthcare institutions. Progress must, however, remain clinically driven. Despite obstacles such as interpretability, limited datasets, and responsibility frameworks, continued refinements position DeepSeek to transform medical AI ethically and reliably. Therefore, the authors urge clinicians and academics to conduct prospective multicentre validation studies comparing DeepSeek-R1 with other leading models and to collaborate with regulators and professional bodies to develop robust policy and governance frameworks, thereby ensuring global clinical value.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
YC, SW: Conception, design, acquisition, analysis, interpretation, drafting, and critical revision of the manuscript.

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