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REVIEW ARTICLE

The Role of Artificial Intelligence in Medical Treatment Planning: A Review

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ABSTRACT

Artificial intelligence is rapidly reshaping medical treatment planning by shifting clinical workflows from generalized protocols toward data-driven, patient-specific decision support. This research reviews how machine learning, deep learning, and generative AI are being applied across precision medicine, radiation oncology, surgical navigation, chronic disease management, and clinical decision support. The discussion synthesizes evidence from current clinical implementations and FDA-cleared systems, including imaging analysis, genomic matching, automated contouring, insulin delivery, and symptom triage tools. Overall, the evidence indicates that AI can substantially reduce manual workload, improve consistency in treatment planning, accelerate tumor delineation and dosing, and support earlier risk detection. In some settings, these systems have demonstrated strong clinical acceptance and meaningful time savings, while also improving diagnostic precision and operational efficiency. However, major barriers remain, including limited randomized trial evidence, data scarcity and bias, weak real-world generalizability, and the black-box nature of many models. The findings suggest that AI is best positioned as a human-in-the-loop support technology rather than a replacement for clinicians. Future progress will depend on stronger validation, better interpretability, improved data quality, and careful integration into clinical practice to ensure safe, equitable, and reliable treatment planning.

KEYWORDS:

• Artificial Intelligence • Medical Treatment Planning • Precision Medicine • Clinical Workflows • Machine Learning • Decision Support Systems

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INTRODUCTION

Artificial intelligence (AI) is transforming medical treatment planning from a generalized, "one-size-fits-all" protocol into a highly precise, automated, and data-driven discipline. By leveraging machine learning (ML), deep learning, and generative AI models, healthcare professionals can now analyze vast multi-omics datasets, electronic health records (EHRs), and medical imaging to predict patient-specific drug efficacy and design optimal clinical paths.

Clinical Benefits vs. Core Operational Barriers

The table below contrasts the direct operational advantages of introducing AI into clinical workflows against the prevailing hurdles faced by modern medical centers.

Key Benefits	Core Operational Barriers
Drastic Time Savings: Cuts down manual calculation times from hours to minutes, unlocking higher throughput.	**Data Silos & Sizes:** High-quality medical image training repositories remain relatively scarce compared to consumer sets.
Elimination of Variation: Lowers human bias discrepancies across medical staff, ensuring care consistency.	**The Black-Box Problem:** Complex neural networks offer high predictive accuracy but fail to yield clear, explainable rationale.
Proactive Management: Uses predictive analytics to pivot treatment schemas before visual symptoms spike.	**Implementation Friction:** Bridging the education and trust gap for clinicians who must continuously validate outputs.

The Evolution of Human-in-the-Loop Frameworks

The modern consensus underscores that AI tools do not replace physicians; rather, they form **Human-in-the-Loop (HITL)** architectures. Emerging paradigms like Human-Centric Intelligent Treatment Planning (HCITP) keep human clinicians entirely in the final supervisory role. AI serves as an ultra-fast generation tier, preparing, formatting, and analyzing choices, which allows doctors to pivot away from manual data management and dedicate their attention back to direct, patient-facing care.

CORE APPLICATIONS IN TREATMENT PLANNING

1. Precision Medicine and Pharmacogenomics

AI algorithms analyze complex patient profiles—including genetic sequences, lifestyle profiles, and metabolic pathways—to tailor medication choices and dosages.

- **Predicting Drug Response**: Support Vector Machines (SVM) and neural networks help identify bio-markers that forecast how a specific patient will react to therapies like chemotherapy.
- **Minimizing Side Effects**: Proactive toxicity modeling ensures patients receive effective treatment options while minimizing adverse reactions.

2. Radiation Oncology Optimization

The time-consuming task of radiotherapy treatment planning is experiencing a massive paradigm shift.

- **Automated Contouring**: AI-driven systems isolate and segment tumors from healthy organs at risk in minutes, a process that traditionally takes clinicians up to an hour manually.
- **Knowledge-Based Planning**: Systems implement automated rule structures that learn from thousands of previous successful clinical plans. This provides uniform dosing profiles and has shown up to an 88% clinical acceptance rate without any manual editing.

3. Surgical Navigation and Trajectory Mapping

Surgeons utilize AI-backed software-as-a-medical-device (SaMD) tools to map intraoperative plans.

- **Risk Assessment**: Pre-operative risk models analyze historic clinical datasets to flag potential surgical complications before making the first incision.
- **Dynamic Adjustments**: Robotic-assisted surgical arms utilize real-time image updates to adjust mechanical trajectories, improving patient recovery rates.

4. Chronic Disease Management and Adaptive Control

For dynamic conditions, AI works recursively to modify daily care routines.

- **Automated Insulin Delivery (AID)**: In diabetes care, open-source and

commercial algorithms automatically calculate real-time physiological shifts using continuous glucose monitors to inject precise basal doses.

- **Predictive Readmission Tracking**: Recurrent Neural Networks (RNNs) look at ongoing patient sensor metrics to flag 30-day post-discharge relapse risks for conditions like heart failure.

Artificial Intelligence (AI) is actively used across multiple medical specialties to detect, analyze, and formulate treatment pathways. There are more than 1,500 AI algorithms approved by the U.S. Food and Drug Administration (FDA). Rather than replacing doctors, these tools are integrated directly into hospital software to help clinicians make faster, more accurate decisions

The current landscape of available AI in medical treatment can be broken down by field and specific software tools:

1. Radiology and Oncology (Tumor and Dosing Layouts)

Medical imaging and radiation layout planning account for **over 75% of all FDA-cleared clinical AI applications**.

- **Aidoc and Qure.ai:** These platforms instantly scan head CTs, chest X-rays, and MRIs to flag acute issues like brain hemorrhages or pulmonary embolisms. This allows doctors to prioritize critical triage and fast-track trauma treatments.
- **Knowledge-Based Radiotherapy AI**: Platforms use deep-learning networks to automatically map tumor boundaries and isolate adjacent critical organs. It completes radiation dosing profiles in minutes instead of hours, avoiding healthy tissue damage.
- **PathAI:** This system uses computerized visual systems to inspect biopsy tissue slices. It identifies the exact stage, structural distribution, and sub-types of cancer cells to help doctors choose appropriate immunotherapy drugs.

2. Genomic Sequencing and Precision Oncology

These models combine complex DNA profiles with clinical registries to customize drug selections.

Tempus: Tempus utilizes AI to map a patient's specific genomic mutations against millions of historical health records. It explicitly ranks which molecular targeted therapies or clinical trials have the highest statistical probability of shrinking a tumor.

3. Cardiovascular and Chronic Care Delivery

These algorithms assess continuous health measurements to prevent critical incidents. **ECG-AI Algorithms**: Cleared diagnostic algorithms analyze standard 12-lead electrocardiograms to predict underlying conditions like pulmonary hypertension or upcoming heart failure risks.

Automated Insulin Delivery (AID) Systems: Built-in AI software in smart insulin pumps works alongside continuous glucose monitors (CGMs). The software monitors blood sugar fluctuations in real time and adjusts basal insulin delivery dynamically without human calculations.

4. Generative AI and Clinical Decision Support

Large Language Models (LLMs) and advanced transformers are transitioning from administrative tasks to therapeutic analysis.

Summarization and Evidence Mapping: Generative AI synthesizes a patient's unstructured medical files (lab results, previous provider notes, imaging reports). It outputs a concise summary mapped against active clinical treatment guidelines.

Clinical Triage Tools (e.g., Ada Health**)**: Expert-validated symptom evaluation engines interview patients before they see a doctor. It suggests differential diagnosis vectors to guide the subsequent physical checkup.

Comparison of Core Clinical AI Software Categories

AI Category	Primary Function in Treatment	Real-World Software Example
Computer Vision / Imaging AI	Rapidly isolates abnormalities and highlights tumors.	Aidoc Radiology Suite
Multi-Omics Precision Engines	Matches tumor DNA sequence to chemotherapy profiles.	Tempus Platform
Bio-Signal Predictors	Predicts cardiac failures or automated insulin targets.	Smart CGM / AID Insulin Systems
Medical Generative LLMs	Synthesizes multi-page clinical histories into care targets.	Specialized Medical LLM Plugins

Where AI Treatment is a Success

- **Unprecedented Speed in Oncology**: In radiation oncology, AI algorithms can automatically map out a tumor's exact borders in minutes. This saves doctors up to an hour per patient and speeds up clinical workflows by 30% to 50%.
- **Exceptional Diagnostic Precision**: AI models reading specialized bio-signals (like EKGs and MRIs) regularly match or beat average human diagnostic metrics. For example, AI can catch subtle cardiac muscle trends and misdiagnosed heart failure markers missed by the human eye.
- **Drug Discovery and Repurposing**: Machine learning models have successfully matched thousands of pre-approved drugs against thousands of difficult-to-treat diseases. This gives new, life-saving options to patients suffering from rare, historically incurable illnesses.
- **Administrative Relief**: Ambient clinical documentation software successfully saves physicians hours of charting time. This directly reduces doctor burnout and lets clinicians spend more face-to-face time treating patients.

Where AI Treatment Faces Struggles

The "Pilot-to-Production" Gap: Many AI engines perform brilliantly in safe laboratory tests, but real-world clinical use tells a different story. Software accuracy metrics can drop sharply from **95% down to 70%** when exposed to unpredictable hospital environments.

Lack of Randomized Trial Data: A 2025 cross-sectional study revealed that **less than 2% of FDA-cleared AI medical devices** were supported by randomized clinical trials at their time of release. Most models are approved via equivalence pathways rather than hard patient outcome data.

The Black Box and Data Bias: Because complex deep-learning networks can rarely explain *how* they arrived at a treatment suggestion, doctors remain hesitant to trust them blindly. Furthermore, if training datasets lack demographic diversity, the AI can reinforce dangerous treatment biases.

Performance Scorecard

Clinical Focus Area	Status	Primary Reason
Dosing & Contour Mapping	Success	Saves hours of manual work with high accuracy.
Rare Disease Drug Matching	Success	Rapidly surfaces novel treatment pathways.
Autonomous Decision Making	Failure	Blocked by regulatory limits and safety risks.
Real-world Model Stability	Struggling	Real-world data drift lowers field accuracy

CONCLUSION

Artificial intelligence is reshaping medical treatment planning by transforming it into a precise, data-driven process that enhances patient care across multiple specialties. From accelerating oncology workflows and optimizing radiation dosing to enabling personalized pharmacogenomics and dynamic chronic disease management, AI's integration delivers remarkable clinical benefits such as time savings, consistency, and proactive intervention. Yet, these advances coexist with significant challenges, including data limitations, opaque decision-making processes, and the critical need for clinician trust and regulatory validation.

Crucially, AI is not positioned to replace human expertise but to augment it through Human-in-the-Loop frameworks that empower physicians to focus on patient-centered care while AI handles complex data analysis and rapid decision support. This synergy fosters greater efficiency and diagnostic accuracy, although real-world deployment still requires overcoming hurdles like model stability, bias, and the scarcity of rigorous clinical trial evidence.

Looking ahead, the ongoing evolution of AI in healthcare promises a future where intelligent systems amplify medical judgment with unmatched speed and precision while maintaining transparency and ethical rigor. As technology and clinical insight continue to advance in tandem, AI will increasingly become an indispensable partner in crafting personalized, effective treatment plans that improve outcomes and transform the patient experience.

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