18th International Congress of Anesthesiology, Critical Care and Pain

Artificial Intelligence in Pain Medicine: From clinical decision making to prediction of treatment outcomes

Alireza Khajehnasiri, MD
Assistant Professor of Anesthesiology and Pain Medicine
Dr. Shariati Hospital
Pain Research Center, Neuroscience Institute
Tehran University of Medical Sciences

18–20 November 2026 · Tehran, Iran · From Innovation to Resilience

Outline

1. Why AI matters in pain medicine
2. Fundamental concepts and AI tools
3. Clinical opportunities in pain care
4. Personalized chronic pain management
5. Evidence, implementation and outlook

1

Definition



- **Stanford University (Human-Centered Artificial Intelligence)**

- **Artificial Intelligence (AI)** is a term coined in 1955 by John McCarthy, Stanford's first faculty member in **AI**, who described it as "the science and engineering of making intelligent machines."

https://hai.stanford.edu/ai-definitions/what-is-artificial-intelligence-ai

• UNESCO Definition

- Artificial intelligence (AI) is a machine-based system and the branch of computer science focused on creating systems capable of performing some tasks that typically require human intelligence, such as understanding language, recognizing patterns, and making decisions.

- AI influences various fields, including education, social sciences, and information technology, and plays a significant role in promoting gender equality and advancing knowledge in natural sciences.

- https://www.unesco.org/en/query-list/a/ai



• IBM Definition

- Artificial intelligence (AI) is technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy.

https://www.ibm.com/think/topics/artificial-intelligence

2

Why Artificial Intelligence?



Chronic Pain: An Unmet Need

- Chronic pain reflects interacting biological, psychological and social factors.
- Identical diagnoses may have different pain experiences and treatment responses.
- Conventional strategies often involve trial-and-error treatment selection.
- Precision approaches require rich, patient-specific information.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

What Can AI Add to Pain Medicine

- Recognize complex patterns in heterogeneous clinical data.
- Support diagnosis, prognosis and treatment optimization.
- Identify potential pain subtypes and predict intervention response.
- Augment—not replace—clinician decision-making.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518. & Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:1 14980

AI, Machine Learning & Deep Learning

- **AI:** Broad computational approaches resembling human intelligence.

- **Machine Learning:** Learns relationships and predictions from datasets **(pattern recognition)** .
- Supervised vs Unsupervised Learning

- **Deep Learning:** Intelligent algorithms that **self-analyze**, adapt, and predict with little or no human involvement.
- Multilayer neural networks
- Can learn patterns from complex inputs.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

Learning Paradigms

- **Supervised learning:** labeled examples for prediction or classification.
- **Unsupervised learning:** discover previously unknown patient patterns or clusters.
- **Reinforcement learning:** adaptive decisions informed by feedback.

Input quality, labels and intended clinical outcomes remain fundamental.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

3

Personalizing Chronic Pain Care

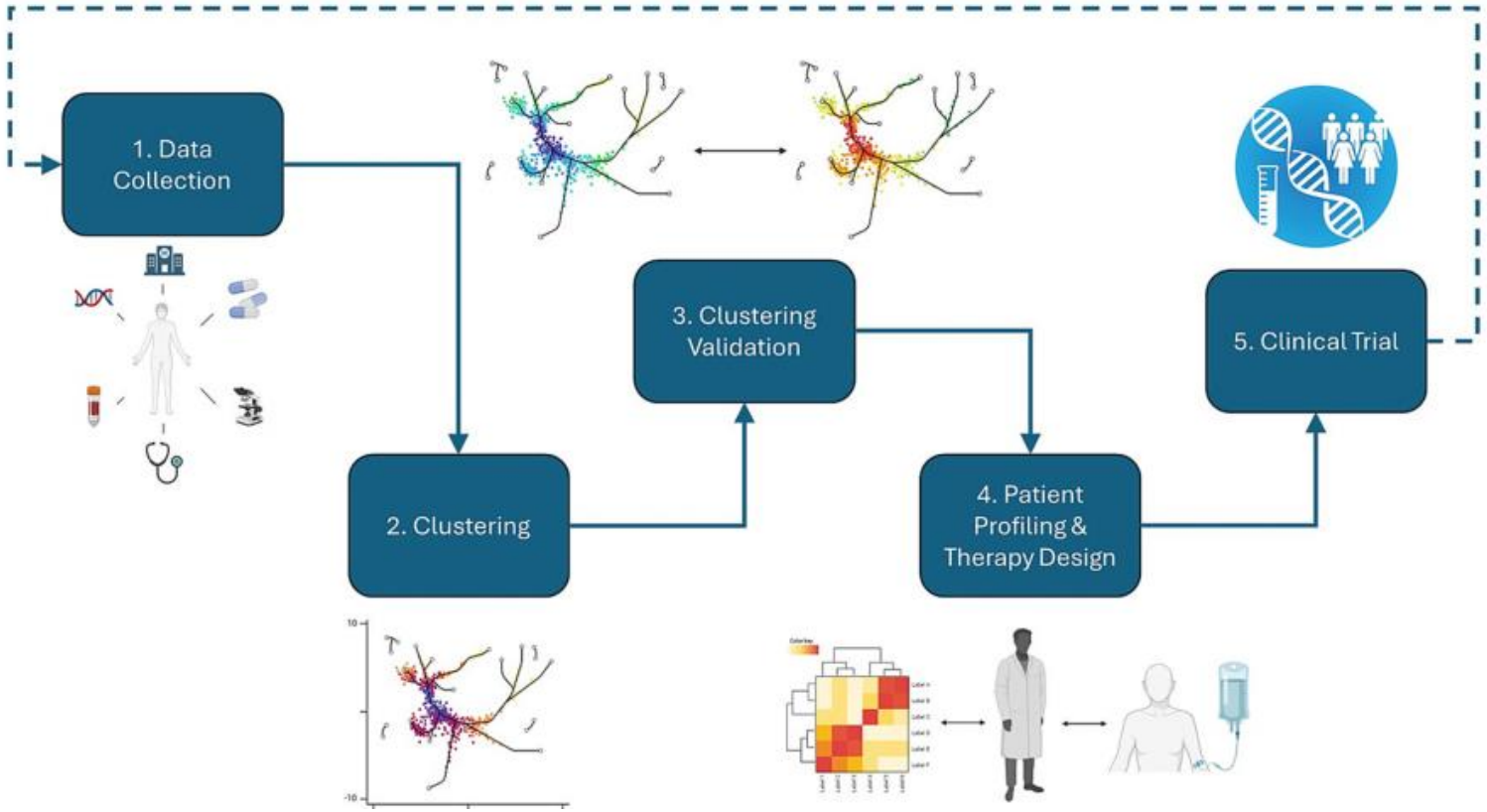


Core Clinical Insight

A single diagnosis does not imply a single pain mechanism or a single optimal treatment.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

Five-Step Precision Pain Roadmap



Original Figure 1: data → clustering → validation → profiling → clinical trial.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

Step 1 | Build a Rich Patient Dataset

- Record demographics, medical history and longitudinal symptoms.
- Include imaging, prior treatments, psychosocial and lifestyle factors.
- Capture heterogeneous dimensions of the individual pain experience.
- Data integration and reliability precede algorithm development.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

Step 2 | Discover Patient Subtypes

- Unsupervised algorithms group patients by shared manifestations.
- K-means and hierarchical clustering explore different cluster structures.
- DBSCAN and Gaussian mixture models offer alternative grouping approaches.
- t-SNE and UMAP help visualize high-dimensional patient patterns.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

Step 3 | Validate the Clusters

- Assess stability and separation of identified groups.
- Tools include silhouette score and Davies–Bouldin index.
- Compare results with annotated datasets when possible.
- Clinical significance matters beyond statistical separation.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

Steps 4–5 | Profiles to Treatment Response

- Use validated clusters to create patient-specific pain profiles.
- Develop targeted treatment hypotheses for different subtypes.
- Model likely therapeutic response and refine treatment strategies.
- Clinical studies are essential before introducing predictions into care.

Casarin et al. Transforming personalized chronic pain management with artificial intelligence: A commentary on the current landscape and future directions. Experimental Neurology. 2024;382:114980.

Personalization Is a Process

Measure → identify phenotypes → validate → tailor therapies → test outcomes.

4

The Future Pain Clinic

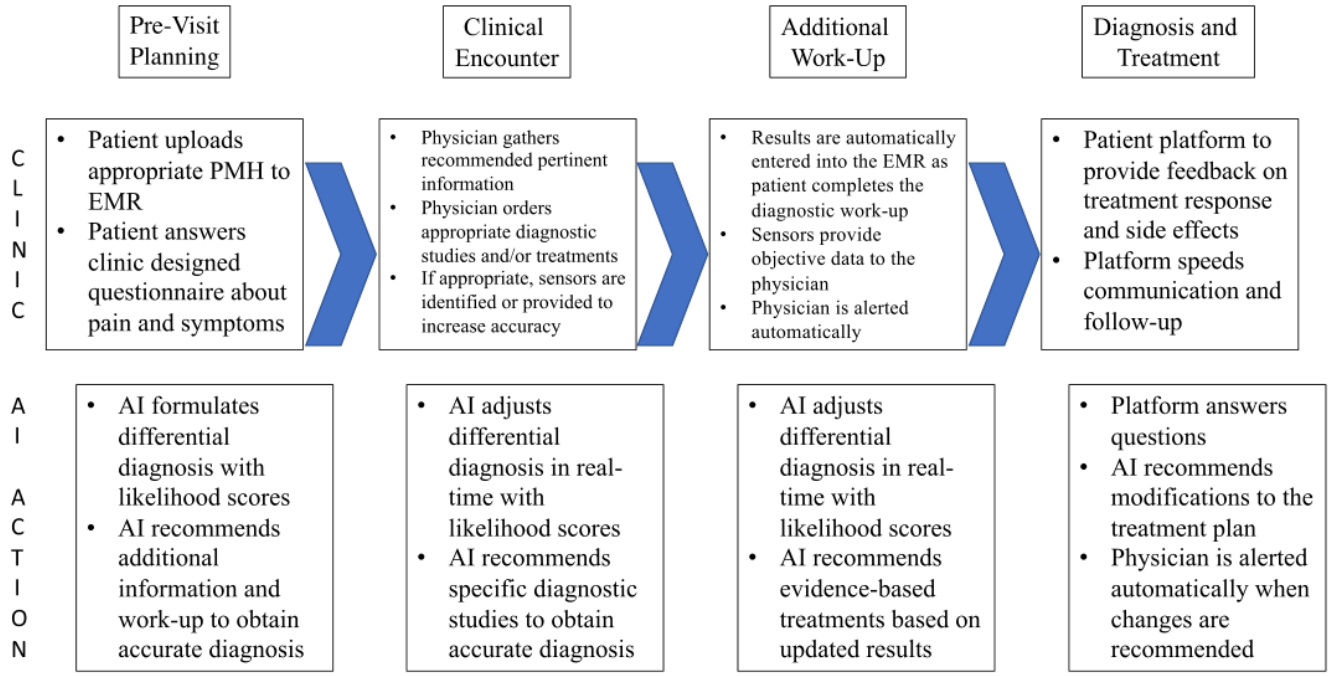


Where Do the Data Come From?

- Electronic health records and prior treatment outcomes.
- Pain history, symptoms, phenotypes and psychosocial variables.
- Imaging, biomarkers, physiologic signals and wearables.
- Multimodal information may improve patient characterization.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

A Future Pain Medicine Clinic



Original Figure 1: proposed (hypothetical) AI-supported clinic workflow.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

Before, During and After the Visit

- Pre-visit: patient-provided history and structured questionnaires.
- Encounter: continuously updated differential diagnosis and decision support.
- Additional work-up: results and sensor data integrated into the record.
- Follow-up: treatment response and adverse effects inform new recommendations.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

High-Value Clinical Applications

- Risk prediction and identification of likely treatment responders.
- Neuroimaging biomarkers and pain phenotyping.
- Potentially adaptive neuromodulation and treatment monitoring.
- Documentation and coordination through integrated data platforms.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

5

Clinical Evidence & Implementation



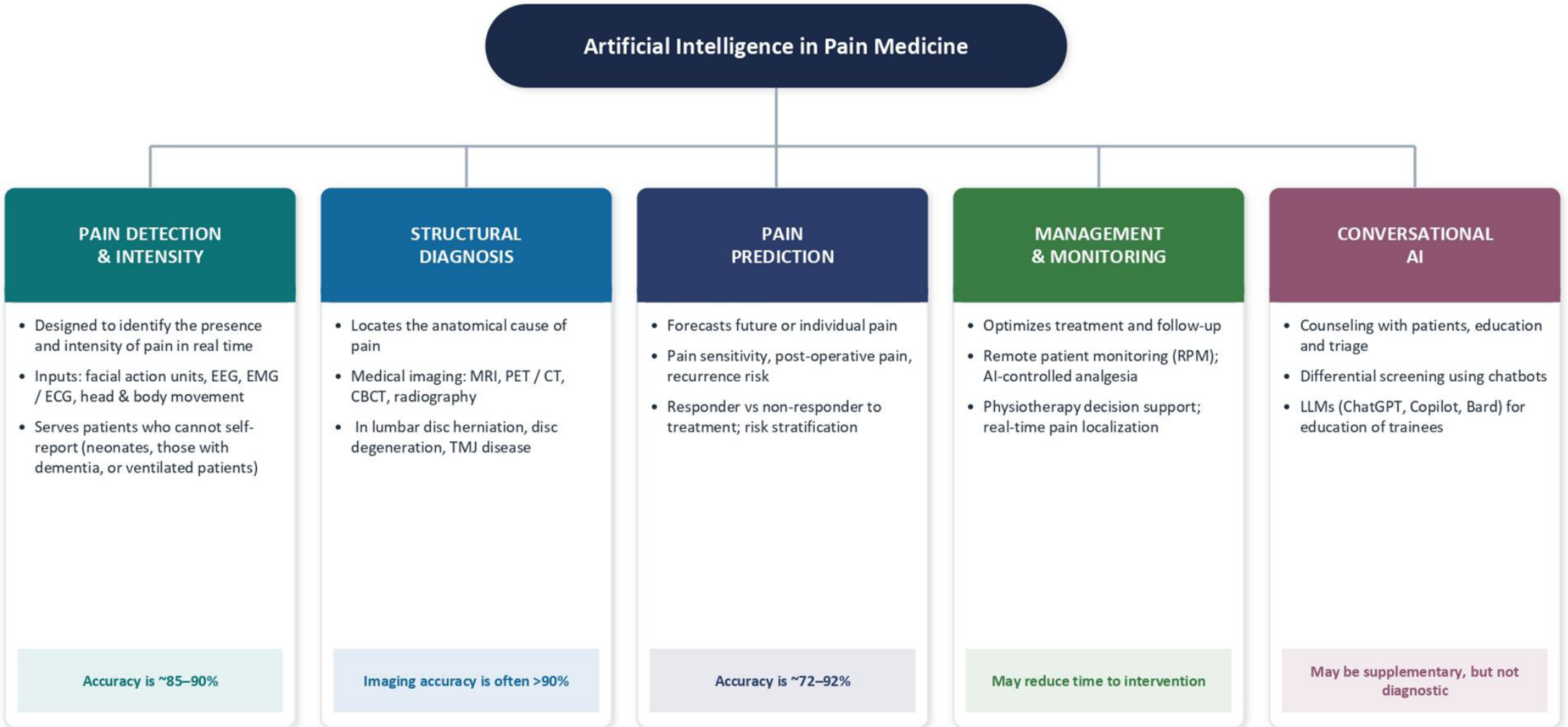
What Does the Recent Evidence Show?

- A 2026 scoping review included 47 studies of AI in pain care.
- Research examined pain detection, prediction and classification.
- Facial expressions, EEG, neuroimaging and physiologic signals were investigated.
- Many reported high model performance; external validity remains limited.

Viderman D, et al. Potential applications of AI in pain management. Front Pain Res. 2026;7:1871943.

.

Potential applications of artificial intelligence in pain management



Applications Across the Pain Continuum

- Automated pain assessment may help when self-report is unavailable.
- AI-guided ultrasound is already used for regional anesthesia assistance.
- Models are being investigated for persistent opioid use and SCS response.
- Clinical performance and regulatory readiness vary between use cases.

Adams MCB, et al. A roadmap for AI in pain medicine. Curr Opin Anesthesiol. 2025;38:680–688.

The Road to Safe Implementation

- 1. Define a clinically meaningful problem and outcome.
- 2. Develop with representative, high-quality data.
- 3. Validate across institutions and patient populations.
- 4. Implement with clinician co-leadership and ongoing assessment.

Adams MCB, et al. A roadmap for AI in pain medicine. Curr Opin Anesthesiol. 2025;38:680–688.

Limitations We Must Not Ignore

- Biased or incomplete datasets can worsen disparities.
- Black-box predictions may be difficult to interpret or audit.
- Small samples, overfitting and limited real-world testing restrict generalization.
- Privacy, costs and human therapeutic relationships are critical.

Vesly J. How Artificial Intelligence Will Change Pain Medicine. Faculty of Pain Medicine; 2026.

Three Take-Home Messages

1

Phenotype, not just diagnosis

AI may reveal clinically relevant differences between patients.

2

Prediction needs validation

High accuracy in a dataset is not proof of clinical benefit.

3

Keep the clinician central

Human oversight and trustworthy data must shape adoption.

Hagedorn JM, et al. Artificial Intelligence and Pain Medicine: An Introduction. J Pain Res. 2024;17:509–518.

The most critical question:
Will AI replace human physicians/care givers some day?

IRANIAN SOCIETY OF ANAESTHESIOLOGY AND CRITICAL CARE

Thank You for Your Attention