


Chapter 4

Personalizing Pain Care through AI-Based Risk Stratification: A Multidisciplinary Perspective

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ABSTRACT

Artificial intelligence (AI) is redefining how clinicians approach pain care by enabling the use of predictive analytics to identify risk patterns, personalize interventions, and support clinical decisions. This chapter explores the emerging role of AI-driven risk stratification in pain management, highlighting how machine learning models trained on diverse data—from electronic health records to wearable sensors—can forecast pain trajectories and treatment responses. We examine real-world applications in both acute and chronic pain settings, illustrating how AI tools are being integrated into clinical workflows and digital health platforms. The chapter also critically addresses ethical and regulatory challenges of AI in pain care beyond technical implementation. We discuss risks associated with algorithmic bias, data privacy, transparency, and patient autonomy, and provide insights into governance frameworks that facilitate safe and equitable deployment.

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1. INTRODUCTION

Pain, both acute and chronic, represents one of the most pervasive and challenging problems in global healthcare. It transcends medical disciplines and manifests in diverse physiological, psychological, and social dimensions. According to the Global Burden of Disease Study, chronic pain affects over 30% of the global population, contributing to 21% of years lived with disability. In the U.S. alone, chronic pain incurs an estimated annual economic cost of \$560–635 billion due to healthcare utilization and lost productivity. The personal toll is tremendous: it affects quality of life, emotional well-being, and functional independence; the cost is also enormous: it leads to lost productivity, overutilization of healthcare resources, and long term disability. (Guo et al., 2024).

Despite decades of research and therapeutic advances, the assessment and management of pain remain imprecise. Traditional models of pain care often rely on subjective self-reports and clinician intuition, which can be inconsistent and prone to bias. Pain experiences are multifactorial by nature and are determined by genetic predispositions, neurobiological pathways, environmental stressors, and psychosocial contexts. Therefore, it is still an unmet need to predict how a patient will respond to treatment or which patients are at greatest risk for pain chronification (Windrim et al., 2024).

This evolving landscape presents an opportunity for artificial intelligence to transform pain care. Predictive analytics and machine learning offer the potential to identify patterns in vast, heterogeneous data that escape human cognition. These technologies can stratify risk, anticipate complications, and support preemptive interventions personalized to individual patients from electronic health records and wearable sensor outputs, to imaging studies and genetic profiles. Integrating these tools into clinical practice offers the potential to move from reactive, symptom focused care to proactive, data driven care (El-Tallawy et al., 2024a).

But the way forward is not entirely technical. To be responsibly implemented, however, it is interwoven with ethical, regulatory and operational complexities that must be addressed. This chapter starts with the scientific basis of AI in pain risk prediction and ends with its clinical application, interdisciplinary integration, and ethical frontiers of the future.

2. FOUNDATIONS OF AI IN PAIN PREDICTION

Artificial intelligence in pain management is grounded in the ability to learn from complex and voluminous data—often beyond what human analysis can handle—thereby revealing patterns, predicting outcomes, and informing clinical decisions.

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