ARTIFICIAL INTELLIGENCE IN THE PREDICTION AND DIAGNOSIS OF OSTEOMYELITIS: A COMPREHENSIVE REVIEW

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Abstract. *Osteomyelitis, a bacterial or fungal infection of bone, continues to pose diagnostic challenges due to its insidious onset and often nonspecific clinical presentation. Conventional diagnosis relies on physical examination, biochemical markers, and imaging modalities such as X-ray, CT, and MRI, which may fail to detect early disease. In recent years, artificial intelligence (AI), particularly machine learning (ML) and deep learning (DL), has emerged as a promising adjunct to clinical decision-making by improving diagnostic sensitivity, risk stratification, and prognostication. This review synthesizes current advances, evaluates performance metrics of AI methods in osteomyelitis detection and prediction, and identifies key limitations and future directions.*

1. Introduction

Osteomyelitis represents infection and inflammation of the bone and bone marrow, typically caused by hematogenous spread or contiguous extension from soft tissue infection. Early detection is crucial to prevent chronicity, pathological fracture, and systemic complications. However, diagnosing early osteomyelitis—particularly in high-risk populations such as patients with diabetes—is challenging due to overlapping clinical features and subtle imaging changes. Traditional interpretation of imaging, especially radiographs, yields limited sensitivity in early stages of the disease. This has driven interest in computational approaches that can extract latent patterns from multimodal data that may not be perceptible to clinicians.

Artificial intelligence (AI)—encompassing ML, DL, and explainable AI (XAI)—aims to augment diagnostics by learning complex patterns from large datasets, integrating clinical, laboratory, and imaging data to improve early detection and prediction.

2. AI for Imaging-Based Detection of Osteomyelitis

2.1 Deep Learning for Radiographic Interpretation

Deep learning (DL) models, particularly convolutional neural networks (CNNs), have been applied to identify osteomyelitis on standard radiographs and advanced imaging. A recent study validated a ResNet-50-based deep learning AI model trained to detect diabetic foot osteomyelitis on plain radiographs, achieving **sensitivity (92.8%) comparable or slightly superior to experienced clinicians** (90.24%) and a **high positive predictive value (0.97)**, although specificity remained suboptimal. https://www.mdpi.com/2076-3417/15/15/8583?utm_source=chatgpt.com

The higher sensitivity suggests DL can identify subtle radiographic features that may be missed in routine clinical practice. However, specificity limitations underscore the need for larger, balanced datasets and integration with clinical data for better discrimination between infection and other abnormalities.

2.2 Limitations of Imaging AI

Despite promising results in imaging analysis, AI models often yield **lower specificity** and tend to overclassify positive cases, particularly in high-prevalence specialist settings. https://doaj.org/article/15ac10d6b69d4b05a78a30d5b46d23e5?utm_source=chatgpt.com Additionally, high inter-center variability in imaging protocols and lack of standardized annotation frameworks can limit the generalizability of AI tools across different healthcare settings.

3. Machine Learning Models for Predictive Risk Assessment

Beyond image interpretation, traditional ML models have been used to *predict* osteomyelitis risk from structured clinical datasets. For instance, in mandibular actinomycotic osteomyelitis, multiple ML algorithms—including logistic regression, random forests, and support vector machines (SVM)—were developed to identify cases based on demographic and clinical variables, demonstrating the feasibility of non-imaging predictive modeling. https://link.springer.com/article/10.1186/s12903-022-02201-6?utm_source=chatgpt.com

In diabetic foot infections, **explainable machine learning models** using routine blood biomarkers and clinical data were shown to support differential diagnosis between soft tissue infection and osteomyelitis, providing clinicians with interpretable risk scores and decision support tools. https://link.springer.com/article/10.1186/s12911-025-03236-9?utm_source=chatgpt.com The XAI component is particularly important in clinical contexts, where "black-box" models are less acceptable without transparent reasoning.

4. Multimodal Approaches and Integration of Biomarkers

Successful AI systems often integrate multiple data types (imaging, biomarkers, clinical history). For osteomyelitis, combining MRI features with laboratory markers (e.g., C-reactive protein, white blood cell count) can improve diagnostic confidence. While specific multimodal models for osteomyelitis are still emerging, the broader field of orthopaedic AI shows that **integrated models outperform single-modality models** in disease detection and characterization. https://link.springer.com/article/10.1007/s44196-024-00718-y?utm_source=chatgpt.com

5. Challenges and Limitations

5.1 Data Availability and Standardization

AI performance critically depends on large, high-quality annotated datasets. Variability in imaging equipment, acquisition protocols, and reporting standards complicates model training and validation. AI applications in other bone diseases such as osteoporosis demonstrate that data heterogeneity can markedly influence sensitivity and specificity. https://www.mdpi.com/1648-9144/62/1/27?utm_source=chatgpt.com

5.2 Model Interpretability and Clinical Adoption

Black-box DL models may perform well statistically but lack explainability, which can hinder clinician trust and regulatory approval. Efforts in explainable AI (XAI)—as seen in recent diabetic foot infection studies—seek to bridge this gap by providing human-interpretable rationale behind model outputs. https://link.springer.com/article/10.1186/s12911-025-03236-9?utm_source=chatgpt.com

5.3 Ethical, Legal, and Regulatory Barriers

AI decision support must comply with medical device regulations, data privacy laws, and ethical standards. Regulatory bodies increasingly require evidence of clinical effectiveness and safety, often necessitating prospective multicenter trials.

6. Future Perspectives

AI in osteomyelitis diagnosis and prediction is rapidly evolving. Future research areas include:

- **Multicenter validation studies** to ensure robustness across populations and imaging systems.
- **Federated learning approaches** to enable model training on decentralized datasets while preserving patient privacy.
- **Integration with clinical workflows** through real-time decision support systems within electronic health records.
- **Hybrid human-AI models** where machine predictions are combined with clinician expertise to optimize outcomes.

Emerging frameworks like MONAI (Medical Open Network for AI) support the development of standardized DL pipelines for medical imaging, which can accelerate research in musculoskeletal infections. https://en.wikipedia.org/wiki/Medical_open_network_for_AI?utm_source=chatgpt.com

7. Conclusion

Artificial intelligence is poised to transform osteomyelitis prediction and diagnosis by enhancing early detection, improving risk stratification, and supporting clinical decision-making. While promising evidence exists—particularly for deep learning models analyzing radiographs and explainable ML using clinical data—significant challenges remain in data standardization, specificity, interpretability, and clinical integration. Future efforts should prioritize large-scale validation, transparent model design, and collaborative frameworks that bridge computational innovation with clinical practice.

References

- AI models for radiographic detection of diabetic foot osteomyelitis achieved high sensitivity compared to clinicians. https://www.mdpi.com/2076-3417/15/15/8583?utm_source=chatgpt.com

- Deep learning systems may yield high positive predictive value but lower specificity, indicating need for further refinement. https://doaj.org/article/15ac10d6b69d4b05a78a30d5b46d23e5?utm_source=chatgpt.com
- Machine learning algorithms have been applied to predict mandibular osteomyelitis with various models. https://link.springer.com/article/10.1186/s12903-022-02201-6?utm_source=chatgpt.com
- Explainable AI enhances clinician interpretation and differential diagnosis using biomarkers. https://link.springer.com/article/10.1186/s12911-025-03236-9?utm_source=chatgpt.com
- Systematic reviews in orthopaedic disease detection highlight AI's growing role across musculoskeletal conditions. https://link.springer.com/article/10.1007/s44196-024-00718-y?utm_source=chatgpt.com
- AI frameworks for medical imaging like MONAI facilitate standardized development processes.https://en.wikipedia.org/wiki/Medical_open_network_for_AI?utm_source=chatgpt.com