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AI technology for detecting dengue: A systematic review

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Abstract
This systematic review explores the potential and advancements of AI technology in the detection and diagnosis of dengue fever. Dengue, a mosquito-borne viral infection, poses significant public health challenges, particularly in tropical and subtropical regions. Traditional diagnostic methods are often time-consuming and resource-intensive, creating the need for innovative approaches. AI technologies, including machine learning and deep learning models, have demonstrated promising capabilities in enhancing early detection, improving diagnostic accuracy, and predicting outbreaks by analyzing large datasets such as clinical records, lab results, and environmental factors. This review synthesizes the current literature on AI applications in dengue detection, evaluating their effectiveness, limitations, and potential for integration into healthcare systems. Our findings suggest that while AI offers substantial improvements over conventional methods, further research is necessary to address challenges related to data availability, model generalization, and real-world implementation.

Keywords: Artificial intelligence, dengue, machine learning, deep learning, diagnosis, detection

1. Introduction
Aedes mosquitoes are the main vector of transmission for dengue fever, which is brought on by the Dengue virus (DENV). Particularly in areas where the disease is endemic, the illness can present with serious health risks and financial costs in the form of severe manifestations as Dengue Hemorrhagic Fever (DHF) and Dengue Shock Syndrome (DSS) (Barreto *et al*., 2021) [1]. Early detection and diagnosis of dengue are crucial for effective treatment and reducing mortality rates. Traditional diagnostic methods such as NS1 antigen testing, PCR, and serological assays, while effective, are resource-intensive and often not available in resource-limited settings (Chen *et al*., 2020) [3].
Artificial Intelligence (AI) technologies have emerged as promising tools in the medical field, revolutionizing the way diseases are detected, diagnosed, and treated. AI's ability to analyze complex datasets, including medical imaging, patient records, and environmental data, makes it a valuable tool for detecting dengue outbreaks and supporting clinical diagnosis. This review aims to evaluate the scope, effectiveness, and challenges of AI technology in detecting dengue, drawing from recent studies and literature.

2. Methodology
This systematic review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Relevant peer-reviewed articles published between 2015 and 2024 were identified through databases such as PubMed, IEEE Xplore, and Google Scholar. The inclusion criteria were:

- Articles discussing the use of AI techniques (machine learning, deep learning, etc.) for detecting dengue or predicting outbreaks.
- Studies that focused on algorithm development, validation, and application in clinical or public health settings.
- Exclusion of papers focusing solely on AI for vector control or treatment protocols without addressing detection.

3. AI Techniques Used in Dengue Detection

3.1 Machine Learning Models

Several machine learning algorithms have been applied in detecting dengue, especially for early diagnosis or outbreak prediction. The most commonly used models include:

- **Random Forest (RF):** RF models have been used for predicting dengue outbreaks by analyzing historical case data, weather patterns, and demographic factors. The model's ability to handle large datasets and provide feature importance makes it a popular choice in epidemiological studies (Iqbal and Islam, 2019) [8].
- **Support Vector Machines (SVM):** SVM has been utilized in clinical diagnosis by analyzing patient symptoms, laboratory results, and serological tests to differentiate between dengue and other febrile illnesses (Sajana *et al*., 2018) [14].
- **Decision Trees:** Decision trees offer interpretability and have been employed in both clinical diagnosis and predicting outbreak risk in specific regions.

3.2 Deep Learning Models

Deep learning, especially convolutional neural networks (CNNs), has shown promise in medical imaging analysis for diagnosing diseases like dengue. Key applications include:

- **Image-based Diagnosis:** AI systems using CNNs have been applied to analyze medical images such as blood smear slides to detect viral infections. These models offer automation in labs and assist in reducing the time for dengue detection (Mayrose *et al*., 2024) [10].
- **Neural Networks for Predictive Modelling:** Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks have been employed to predict dengue outbreaks by modeling temporal data such as historical weather conditions and dengue cases.

3.3 Hybrid AI Approaches

Several studies have combined machine learning and deep learning models with environmental and socioeconomic data to enhance the prediction accuracy of dengue outbreaks. These hybrid models leverage both structured (numerical) and unstructured data (text and images) to provide a more holistic view of outbreak patterns (Qi *et al*., 2018) [13].

4. Applications of AI in Dengue Detection

4.1 Clinical Diagnosis

AI models have demonstrated efficacy in augmenting clinical diagnosis, particularly when laboratory resources are limited. For instance, machine learning algorithms can analyze patient symptom data and provide risk scores for potential dengue infections. These systems have the potential to reduce diagnostic errors and expedite decision-making in clinical settings (Chandrasekaran *et al*., 2021) [2].

4.2 Outbreak Prediction

Predicting dengue outbreaks in advance allows public health authorities to implement preventive measures. AI models that integrate weather data, population density, and historical disease patterns have shown success in forecasting dengue cases, helping regions allocate medical resources more effectively (Chen *et al*., 2020) [3].

4.3 Remote Monitoring and Diagnostics

Mobile applications utilizing AI algorithms for detecting early symptoms or assessing environmental risk factors are becoming increasingly prevalent. These tools enable users in remote or rural areas to access diagnostic resources, improving healthcare outreach (Hernandez *et al*., 2019) [7].

5. Challenges in AI-based Dengue Detection

Despite its potential, the use of AI for dengue detection faces several challenges:

- **Data Quality and Availability:** AI models require large, high-quality datasets to function effectively. In many regions where dengue is prevalent, data is incomplete, unstructured, or unavailable, limiting model performance (Murthy, 2023) [11].
- **Algorithm Bias:** Machine learning models may reflect biases present in training data, leading to potential misdiagnosis or inaccurate predictions. Ensuring that datasets are representative of diverse populations is crucial for fairness (Fletcher *et al*., 2021) [6].
- **Infrastructure Limitations:** AI technologies often require significant computational resources, which may not be available in resource-constrained areas most affected by dengue (Kuo *et al*., 2024) [9].
- **Regulatory and Ethical Issues**: AI-driven diagnostic systems need regulatory approval, which can be a lengthy and complex process. Additionally, ethical concerns surrounding data privacy and algorithm transparency must be addressed (Nguyen *et al*., 2022) [12].

6. Future Directions

As AI continues to advance, its role in dengue detection is expected to grow. Future research should focus on:

- **Improving Data Integration:** AI models that integrate real-time data from multiple sources, such as climate data, vector control efforts, and clinical reports, will improve the accuracy of outbreak predictions (Desai *et al*., 2019) [4].
- **AI for Portable Diagnostics:** Developing portable, AI-powered diagnostic devices that can be used in low-resource settings will expand access to timely dengue diagnosis (Schwalbe and Wahl, 2020) [15].
- **Ethical AI Systems:** Addressing concerns about data privacy, fairness, and transparency in AI models is critical to ensure widespread adoption and trust in these technologies (Felzmann *et al*., 2019) [5].

Table 1: AI Technology for Detecting Dengue - Summary of Published Studies

AI Technique	Objective/Focus	Dataset Used	Results/Outcomes	Study
Machine Learning (RF, SVM)	Dengue outbreak prediction	Historical case data and weather patterns	Achieved an 85% accuracy in outbreak prediction.	Barreto *et al*., 2021 [1]
Deep Learning (CNN)	Predicting dengue outbreaks using climate data	Climate data (temperature, humidity, etc.)	CNN model predicted outbreaks with 88% precision.	Chen *et al*., 2020 [3]
Clinical Decision Support AI	Augmenting clinical diagnosis in resource-limited settings	Clinical records and patient symptoms data	Improved diagnostic accuracy by 12% over traditional methods.	Hernandez *et al*., 2019 [7]
RNN, LSTM	Public health surveillance and outbreak prediction	Historical cases, vector data, climate data	Achieved 90% accuracy in outbreak forecasting.	Nguyen *et al*., 2022 [12]
Hybrid AI (ML + Neural Networks)	Combined prediction and diagnostics from multiple data sources	Multi-source (environmental, socioeconomic) data	Hybrid approach improved prediction accuracy by 15%.	Chandrasekaran *et al*., 2021 [2]

7. Conclusion

AI technology offers promising advancements in the detection and diagnosis of dengue. From improving outbreak predictions to assisting in clinical diagnostics, AI has the potential to transform how we manage dengue outbreaks and reduce the disease burden. However, challenges such as data availability, algorithm bias, and infrastructure limitations need to be addressed. With continued advancements, AI could become an essential tool in the fight against dengue.

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