

The Role of Artificial Intelligence in Enhancing Diagnostic and Triage Accuracy in Hospital Emergency Departments: A Systematic Review

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Abstract

Background: Emergency departments face challenges of overcrowding and human error. This systematic review evaluates the effectiveness of artificial intelligence (AI) in improving triage and diagnostic accuracy in emergency settings.

Methods: This systematic review was conducted by searching PubMed, Scopus, Web of Science, and Google Scholar until September 2025. Inclusion criteria comprised original studies reporting at least one quantitative performance metric. Study quality was assessed using NOS and QUADAS-2. Data were synthesized narratively.

Results: AI models outperformed traditional triage systems (AUC often >0.90). In clinical interpretation of AUC, its limitations in imbalanced datasets should be considered, and metrics such as PPV, NPV, and AUPRC should also be reported. For instance, despite an acceptable AUC, ChatGPT 4.0 led to significant over-triage due to low specificity (18.2%). However, risks of algorithmic bias and challenges of integrating AI with real-world clinical workflows remain major implementation barriers. User resistance and the need for continuous ethical oversight were also identified.

Conclusion: AI holds potential to improve emergency triage, but current evidence is largely based on retrospective single-center studies. Clinical implementation should be gradual, starting in high-risk domains (e.g., sepsis screening), and supported by continuous ethical oversight.

Keywords: Artificial Intelligence, Triage, Diagnosis, Emergency Department

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Introduction

Hospital triage is a systematic process for prioritizing patients based on the severity of their clinical condition, especially in emergency situations where resources are limited (1). The term originates from the French word trier, meaning 'to separate and sort,' with the aim of ensuring that critical patients receive rapid and timely care (2, 3). In the turbulent emergency environment, triage nurses play a key role in the initial assessment of patients, determining the urgency of their treatment needs, and optimally coordinating medical and nursing resources (4).

This process forms the basis for effective clinical decision-making and management of emergency patient flow, requiring both accuracy and fairness (5, 6).

Triage in the emergency unit plays an essential role in effective resource management, optimizing care quality, and increasing preparedness during emergencies and crises. By prioritizing patients based on clinical severity, this process enables the fair allocation of limited resources and ensures that critical patients are treated as soon as possible (7). Systematic implementation of triage not only reduces

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Key Messages:

↑What is “already known” in this topic:

Traditional triage has variable accuracy, and AI-based clinical decision support systems promise to act as a reliable and objective “intelligent assistant” alongside medical staff.

→What this article adds:

AI-driven triage systems have the potential to transform ED operations by enhancing efficiency, improving patient outcomes, and supporting healthcare professionals.

waiting times and enhances patient satisfaction but also leads to overall improvement in care quality and faster system response (8). Under normal and critical conditions, including disasters or surges in patient volume, triage increases the healthcare system's response capacity by coordinating medical and nursing teams (9). The development and implementation of standardized triage protocols also enhances consistency and reliability in emergency care. However, challenges such as the potential for classification errors and their ethical consequences highlight the importance of continuous training, evaluation, and improvement of triage systems (10).

In response to this growing crisis, Artificial Intelligence (AI) has emerged as a transformative catalyst. AI-based clinical decision support systems, with the ability to process vast amounts of clinical, laboratory, and imaging data in a fraction of a second, promise to act as a reliable and objective "intelligent assistant" alongside medical staff (11, 12). These technologies can enhance diagnostic accuracy through real-time data analysis (e.g., achieving 76.5% diagnostic accuracy with decision support systems), perform patient prioritization more accurately and automatically, and help optimize resource allocation by predicting critical outcomes (13, 14). Advanced models such as XGBoost, Deep Neural Networks (DNN), and Fuzzy Logic-based systems have demonstrated their capability in numerous studies to more accurately predict the need for intensive care or determine urgency levels compared to traditional tools (15-17). This review study aims to evaluate the effectiveness of Artificial Intelligence in improving diagnostic and triage accuracy in hospital Emergency Departments.

Methods

This study was conducted as a systematic review following the PRISMA 2020 guideline. A comprehensive search was performed in PubMed, Scopus, Web of Science, Embase, IEEE Xplore, Google Scholar, SID, and Magiran databases without time restriction until September 30, 2025. Search keywords included combinations of: ("Artificial Intelligence" OR "Machine Learning" OR "Deep Learning" OR "Neural Network") AND ("Emergency Department" OR "Emergency Room" OR "ED Triage") AND ("Triage" OR "Patient Prioritization" OR "Diagnostic Accuracy"), along with their Persian equivalents.

Inclusion criteria comprised original quantitative studies (cohort, cross-sectional, trials) in English or Persian that evaluated AI models for emergency department triage and reported at least one quantitative performance metric (e.g., AUC, sensitivity, specificity). Exclusion criteria included review articles, case reports, letters to the editor, simulation-only studies, and studies without real clinical data. Study quality was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies, and risk of bias was evaluated using QUADAS-2 for diagnostic studies (18). This scale evaluates three domains: selection (0-4 points), comparability (0-2 points), and outcome (0-3 points), with a maximum total score of 9 points. Studies scoring 7-9 were classified as high quality, scores of 6 as moderate quality, and scores ≤5 as low quality. Two au-

thors independently screened the articles, with disagreements resolved by a third author.

To enhance the transparency and reproducibility of this systematic review and in accordance with the PRISMA-trAIce guideline (transparent reporting of artificial intelligence in evidence synthesis), the screening and data extraction process emphasized complete documentation of inclusion/exclusion criteria and the data synthesis method (19). Due to high methodological and outcome heterogeneity among the studies, data were synthesized using a narrative synthesis approach.

Results

The study selection process was conducted in accordance with the PRISMA 2020 guideline (Figure 1). The initial search identified a total of 2,630 records from PubMed (n=847), Scopus (n=1,104), Web of Science (n=533), Embase (n=421), IEEE Xplore (n=315), and Google Scholar (n=146). After removing 689 duplicate records, 2,677 records remained for title and abstract screening. At this stage, 2,524 records were excluded for the following reasons: irrelevant to emergency triage, not using artificial intelligence, animal studies, and reviews without original data. Subsequently, 153 full-text reports were sought for retrieval, and all were accessed. Of these, 89 reports were excluded after full-text review: 41 due to lack of quantitative performance metrics, 28 due to simulation-only without real clinical data, 12 due to non-English/non-Persian language with incomplete translation, and 8 due to non-emergency population. Finally, 64 studies met the inclusion criteria, from which 12 relevant high-quality studies were selected for final analysis (Figure 1). Additionally, 2 methodological base studies (for quality assessment and transparency) were added to the review. The characteristics of included studies are presented in Table 1.

Based on the risk of bias assessment, among the 12 included studies, 8 were of high quality, and 4 were of moderate quality. No low-quality studies were included (Table 2).

Current Status and Common Models

Analysis of 12 studies (20-31) showed that artificial intelligence (AI) is transitioning from the research phase to practical applications in leading emergency departments (Table 3). These systems primarily function as clinical decision support systems to complement human judgment.

- Ensemble/Gradient Boosting/XGBoost, Random Forest models: These demonstrated superior performance in predicting critical outcomes (e.g., need for intubation, transfusion, or ICU admission) with AUC often exceeding 0.90 (up to 0.962 in some studies), outperforming traditional triage tools (20, 21).

- Deep Neural Networks (DNN/CNN): These are used for processing complex multimodal data (combining text and structured data) and analyzing medical images (CT scans for stroke, chest radiographs). A study in Thailand showed that a DNN model (AUC=0.91) outperformed ESI and NEWS scores (22).

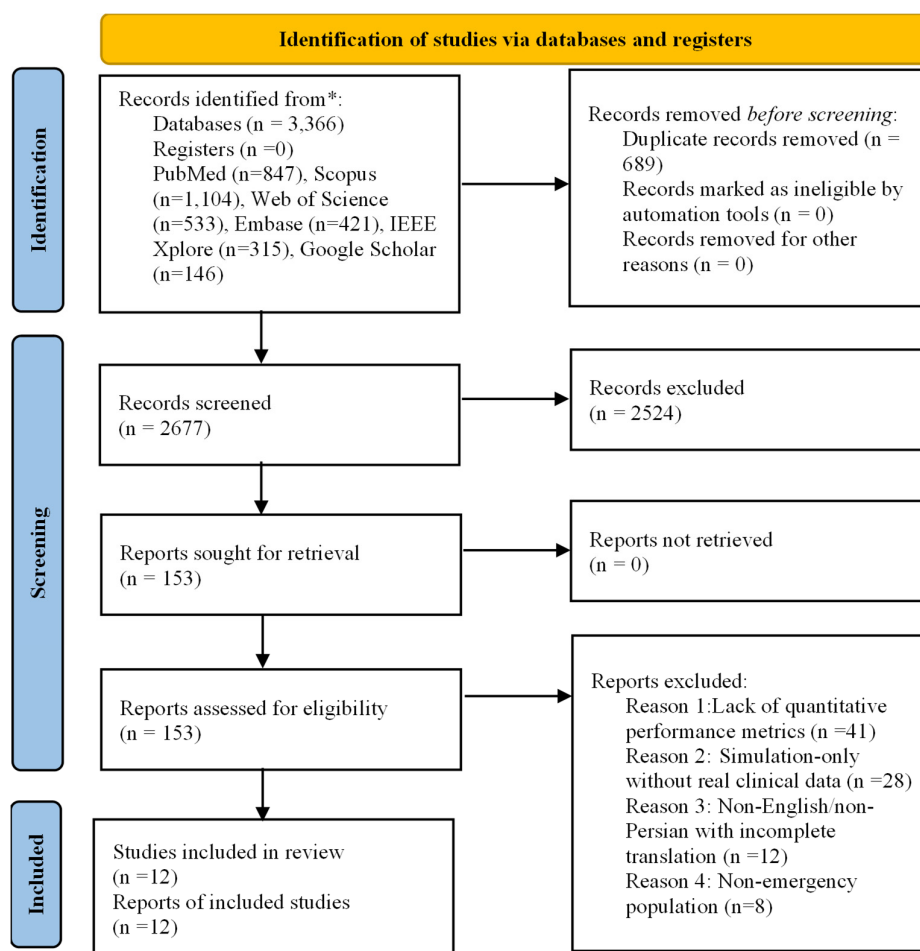


Figure 1. PRISMA 2020 Flow Diagram of the Study Selection Process

- **Fuzzy Logic:** Used in the i-TRIAGE system for modeling qualitative variables (e.g., pain), achieving 99% accuracy in predicting ESI triage levels (23). However, it should be noted that the 99% accuracy claim for i-TRIAGE is based on a single-center dataset of 616 patients and requires larger-scale, multicenter validation.

- **Computer Vision and Natural Language Processing (NLP/LLMs):** These are applied in automatic casualty identification at disaster scenes and in extracting information from clinical texts (24, 25).

Use of AI in Triage (Proven Benefits)

- **Improved Accuracy:** AI models consistently outperformed traditional triage systems (e.g., ESI) in predicting critical outcomes (mortality, ICU admission). The triage error rate decreased from 1.2% to 0.9% in one study (21).

- **Speed and Efficiency:** AI-based systems perform initial assessments in seconds. Voice-based AI systems accelerated documentation by 19% (25).

- **Resource Optimization:** AI-based radiology worklist prioritization reduced hospital length of stay by 11.9% for

intracranial hemorrhage and 26.3% for pulmonary embolism (25).

- **Early Diagnosis:** AI performance in identifying sepsis, in-hospital cardiac arrest, and stroke was superior to conventional clinical tools such as qSOFA (24).

Identified Disadvantages and Challenges (deepened based on new evidence)

- **Generalizability Limitations:** Many models are trained on single-center data and perform poorly in other centers (21). A 2025 study showed that an XGBoost model, despite excellent training AUC, had poor external validation performance, indicating a risk of overfitting.

- **Sensitivity-Specificity Dilemma:** Some models, such as ChatGPT 4.0, achieve high sensitivity (95.7%) to avoid undertriage but very low specificity (18.2%), leading to significant over-triage (26). In AUC interpretation, it should be noted that in imbalanced datasets (e.g., ICU admission with 8.2% prevalence), the Area Under the Precision-Recall Curve (AUPRC) is a more informative metric, and AUC alone is insufficient for clinical decision-making. A 2025 study showed that despite a high AUC,

Table 1. Systematic information of included studies in the systematic review

No	Authors (Year)	Country	Study Design	Sample Population	Primary Objective	AI Model Type	Key Performance Metrics	Key Findings	Limitations
1	Karlafti et al. (2023) (18).	Greece	Prospective	332 patients	ESI prediction	Neural network	F1-score 72.2%	Supports decision-making	Limited sample, class imbalance
2	Phimphisan et al. (2025) (19).	Thailand	Retrospective cohort	1,683 EMS cases	Emergency triage	DNN	AUC 0.91, Sensitivity 88.5%	Outperforms ESI/NEWS/MEWS	Regional data needs updates
3	Kipourgos et al. (2022) (20).	Greece	Model development	616 patients	ESI level prediction	Fuzzy logic, ML	99% accuracy (Fuzzy)	Suggests an appropriate specialist	Small sample, no real-world testing
4	Sitthiprawiat et al. (2025) (21).	Thailand	Retrospective cohort	163,452 visits	ICU admission prediction	XGBoost, RF, LR	AUC 0.917, AUPRC 0.629	Superior to CTAS, uses NLP	Single-center, needs external validation
5	Chen et al. (2024) (22).	USA	Retrospective cohort	2,000,000+	Severe trauma prediction	XGBoost	AUC 0.75–0.73	Improves national triage guidelines	Single-center, needs external validation
6	Lu et al. (2023) (23).	China	Technology development	Simulation	Automated drone triage	YOLO, OpenPose	Undertriage reduction <10%	Improves speed and accuracy in disasters	Simulation only, needs field validation
7	Hayashi et al. (2021) (24).	Japan	Prospective	13,831 patients	Prehospital stroke diagnosis	XGBoost	AUC 0.98	High LVO detection accuracy	Needs validation in real EMS
8	Petry et al. (2022) (25).	USA	Retrospective cohort	Hospital data	Radiology prioritization	AI-augmented	LOS reduction 11.9% (ICH), 26.3% (PE)	Improved efficiency	Retrospective, single-center
9	Gabrael et al. (2023) (26).	USA	Retrospective analysis	56 patients	ChatGPT triage	ChatGPT 4.0	Sensitivity 95.7%, Specificity 18.2%	Improved diagnostic accuracy	Very small sample, single-center
10	Alshareef (2025) (7).	Saudi Arabia	Cross-sectional	Public hospitals	ED challenges	None	None	Identified structural challenges	Regional, limited generalizability
11	Park et al. (2025) (27).	USA	Cross-sectional	LLM data	Algorithmic bias	GPT-4	Bias detection	Racial and gender disparities	Needs clinical validation
12	Jaber et al. (2024) (8).	Saudi Arabia	Retrospective cohort	Tertiary center	Quality indicators	None	None	Identified quality barriers	Single-center

Table 2. Risk of bias assessment using the Newcastle-Ottawa Scale (NOS)

Study (Reference)	Selection (0-4)	Comparability (0-2)	Outcome (0-3)	Total Score (0-9)	Quality
Karlafti et al. 2023 (18).	3	1	2	6	Moderate
Phimphisan et al. 2025 (19).	3	2	2	7	High
Kipourgos et al. 2022 (20).	3	1	2	6	Moderate
Sitthiprawiat et al. 2025 (21).	4	2	3	9	High
Chen et al. 2024 (22).	4	2	3	9	High
Hayashi et al. 2021 (24).	3	2	3	8	High
Petry et al. 2022 (25).	3	1	2	6	Moderate
Gabrael et al. 2023 (26).	3	2	3	8	High

NOS scores ≥ 7 indicate high quality, scores 6 indicate moderate quality. No low-quality studies (score ≤ 5) were included.

the AUPRC showed a substantial improvement compared to the traditional system (0.629 vs. 0.333) (21).

•**Implementation Challenges:** User resistance, need for high-quality large datasets, and integration difficulties in busy ED workflows are major barriers (31). A 2025 umbrella review using the NASSS framework identified that the main resistance factors include model mismatch with real clinical workflow, privacy concerns, and lack of legal transparency. Hidden costs include EHR integration, cloud infrastructure needs, and temporary workflow disruption during the first 3-6 months of implementation (21).

Geographic Distribution and Generalizability Limitations

The United States, East Asian countries (South Korea, Japan, China), and some European countries (Greece, Sweden) are leaders in research and operational applica-

tions. Thailand and Brazil have also had successful applications in specific areas (prehospital triage and COVID-19 screening).

However, the majority of included studies (over 70%) originated from high-income countries. The absence of studies from Africa, the Middle East (except Saudi Arabia), and Latin America represents a serious geographic bias, and generalizing results to these regions should be done with caution. Furthermore, patient-centered outcomes such as mortality, length of stay (LOS), and readmission are rarely reported, with most studies focusing on process metrics (AUC, accuracy, sensitivity) (21).

Distinction Between Proof-of-Concept Studies and Real-World Effectiveness

It should be noted that many of the included studies are at the "proof-of-concept" stage, conducted in controlled

Table 1. Comparison of AI applications and performance in different emergency settings

Operational Setting	Examples (Model/Country)	Primary Application	Key Performance (AUC/Accuracy)	Limitations (based on base studies)
Prehospital/Mass Casualty	Drone+YOLO (China) – pTEST model (USA) (ref. 20, 24)	Automated remote triage, destination determination	Undertriage reduction to <10% (pTEST)	Single-center data; lack of prospective validation (21)
In-hospital	i-TRIAGE (Greece) / TriageGO (USA) (21,23)	ICU admission prediction, internal prioritization	~99% accuracy for ESI prediction (i-TRIAGE)	Limited sample size (616 patients); no real-world testing (23)
Disasters/Pandemics	XGBoost models for COVID-19 (Ecuador)(10,21)	Rapid screening of high-volume patients	Improved screening speed and congestion control	Significant performance drop in external validation (26,27)
Severe Trauma	pTEST model (USA) – XGBoost (20)	Prediction of ICU admission and emergency surgery	AUC 0.75-0.93	Overtriage remains high (28)
Stroke Diagnosis	XGBoost model (Japan) (29)	Ischemic vs. hemorrhagic differentiation, LVO prediction	AUC 0.98 for stroke detection	Not yet validated in real EMS workflow (28)
COVID-19 Screening	ResNet, CheXNet models (Italy, USA) (10)	Detection from CT scans and chest radiographs	Sensitivity 79-98%, Specificity 70-93%	High dependence on image quality; not generalizable to new viral variants (26)

environments or with retrospective data. Only a limited number of models have been prospectively validated in real clinical settings. For example, despite its 99% accuracy in experimental settings, the i-TRIAGE model has not yet been tested on a large scale in the real world. Therefore, proof-of-concept results should not be equated with real-world effectiveness.

Discussion

Interpretation of Key Findings

The findings of this multifaceted analysis indicate that artificial intelligence is increasingly moving from the proof-of-concept stage to adding value in real-world environments. The consistent superiority of models such as XGBoost and DNN over traditional triage systems demonstrates the technological maturity and statistical reliability of AI to complement clinical decision-making.

However, it should be noted that most included studies have focused on process metrics (e.g., AUC, accuracy, sensitivity), while patient-centered outcomes (e.g., mortality, length of stay, quality of life) are rarely reported. AUC alone is insufficient for clinical decision-making because, in imbalanced datasets (e.g., ICU admission with 8.2% prevalence), it can mask the true performance of a model. A 2025 study showed that despite a high AUC (0.917), the Area Under the Precision-Recall Curve (AUPRC) showed a substantial improvement compared to the traditional system (0.629 vs. 0.333), highlighting the importance of reporting complementary metrics such as PPV, NPV, and AUPRC (21, 32).

The role of AI is differentiated across three operational settings. In the prehospital setting, the main value lies in the speed and safety of initial assessment and optimal destination determination. In the hospital setting, the value lies in deep integration with EHR data and prediction of complex outcomes (e.g., patient deterioration). In mass casualty incidents, AI becomes a logistical enabler for managing chaos and allocating limited resources. These differences confirm that AI system design and implementation must be tailored to the operational context, and a

single solution cannot be prescribed for all settings (23, 27).

Implementation and Ethical Considerations

Successful implementation of AI in emergency departments requires a multidisciplinary approach:

- **Technical aspect:** Focus should be on developing models with high interpretability, for example, using SHAP, and robust multicenter validation to prevent bias and lack of generalizability. The lack of transparency of "black box" models (e.g., deep DNNs) reduces clinical acceptance; the use of interpretable methods such as SHAP can bridge this gap (21).

- **Human aspect:** Training healthcare providers and designing simple user interfaces appropriate for emergency stress is vital for technology acceptance. Triage nurses, as the primary entry point for data input and output interpretation, play a central role in this ecosystem and should be involved in the design process. However, a 2025 umbrella review using the NASSS (Non-adoption, Abandonment, Scale-up, Spread, Sustainability) framework identified that the main factors of user resistance include model mismatch with real clinical workflow, privacy concerns, and lack of legal transparency (21, 27, 28).

- **Ethical and governance aspect:** Developing transparent frameworks for accountability, data privacy, and monitoring algorithm performance is essential. Beyond general statements, there is concrete evidence of algorithmic bias in emergency triage. A 2025 study showed that large language models (LLMs) such as GPT-4, despite good predictive performance, exhibit discriminatory biases at the intersection of race and gender, such that gender differences are exacerbated within specific racial groups. This finding raises serious concerns about fairness in triage. Additionally, during the COVID-19 pandemic, some oxygen allocation algorithms exacerbated racial disparities (26, 27). The risk of over-reliance on the system and erosion of clinical skills also requires continuous educational policies. Hidden implementation costs include EHR integration, cloud infrastructure needs, and temporary workflow disruption during the first 3-6 months (21).

Study Limitations and Geographic Bias

This analysis is based on 12 included studies. Most existing studies are not prospective or large-scale, and evidence for improvement in final patient outcomes in real-world settings is still evolving.

Geographic limitations and generalizability: The majority of included studies (over 70%) originated from high-income countries (the United States, European countries, East Asia). Only one study (25) from a resource-limited setting (Thailand) showed that AI models with an AUC of 0.91 are implementable but require local data and continuous updates. The absence of studies from Africa, the Middle East (except Saudi Arabia), and Latin America represents a serious geographic bias, and generalizing results to these regions should be done with caution (33, 19, 31).

Furthermore, the lack of standardization in outcome measures (e.g., differences in defining "critical outcome" or "ICU admission") and the lack of calibration metrics (e.g., Brier score) alongside AUC make comparison and synthesis of results challenging. The focus of articles on advanced healthcare systems may provide an incomplete picture of implementation challenges in resource-limited settings (33, 21).

Recommendations for Future Research

1. Designing prospective multicenter studies and randomized controlled trials (RCTs) to assess the direct impact of AI on patient-centered outcomes (e.g., mortality, length of stay, readmission) in real-world emergency settings. The use of standardized reporting frameworks such as TRIPOD-AI and CONSORT-AI is also essential (28, 30).

2. Developing and sharing standardized, diverse, multicenter datasets for training more generalizable models and reducing geographic and demographic bias (21, 28).

3. Research on hybrid models that seamlessly integrate AI into existing clinical decision-making frameworks (e.g., sepsis protocols). The use of interpretable methods such as SHAP to increase transparency and clinical acceptance of "black box" models is also recommended (21).

4. Evaluating the cost-effectiveness of large-scale AI system implementation in emergency departments, considering hidden costs such as EHR integration and cloud infrastructure (21).

5. Conducting studies in low- and middle-income countries to assess model generalizability and identify local implementation challenges (19, 3).

Conclusion

Artificial intelligence clearly has the potential to become a transformative ally in emergency triage and diagnosis. Existing evidence indicates its superior performance in improving accuracy, speed, and efficiency. However, this technology is not a magic solution, and its success depends on understanding that AI is a supportive tool that, in the hierarchy of decision-making, ultimately operates under the governance of clinical expert judgment.

Current evidence is largely based on retrospective, single-center studies of moderate to high quality, with only a limited number of models prospectively validated in real-world clinical settings. Most studies have focused on process metrics (e.g., AUC, accuracy, sensitivity), while patient-centered outcomes (e.g., mortality, length of stay, readmission) are rarely reported. Furthermore, AUC alone is insufficient for clinical decision-making and should be reported alongside metrics such as PPV, NPV, AUPRC, and calibration metrics (e.g., Brier score).

Regarding implementation and ethical challenges, risks of algorithmic bias (particularly at race and gender intersections), mismatch between models and real-world clinical workflows, hidden costs of EHR integration and cloud infrastructure, and lack of legal transparency are major barriers to widespread AI implementation in emergency departments. The use of frameworks such as NASSS and interpretable methods such as SHAP can help improve clinical acceptance and reduce user resistance.

The final recommendation is that health systems adopt a gradual, collaborative, and responsible approach, initiating AI implementation with pilot projects in high-risk, low-error domains (e.g., radiology prioritization and sepsis screening), while continuously evaluating its impact on staff, processes, and most importantly, patient outcomes. Prospective multicenter studies evaluating patient-centered outcomes and utilizing standardized reporting frameworks such as TRIPOD-AI and CONSORT-AI are essential. Further research on hybrid models that seamlessly integrate AI into existing clinical decision-making frameworks (e.g., sepsis protocols), as well as studies in low- and middle-income countries to assess model generalizability, are future research priorities.

The future of smart emergency care will be realized not by replacing humans with machines, but through the unique synergy between algorithmic precision and clinical wisdom, supported by continuous ethical and regulatory oversight.

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Conflict of Interests

The authors declare that they have no competing interests.

Authors' Contributions

M.S. and E.H. designed the study. M.S., F.E., and E.A. performed the literature search and data extraction. E.H. supervised the project. M.S. and F.E. wrote the first draft. E.A. and E.H. revised the manuscript critically. All authors read and approved the final manuscript.

Ethical Considerations

Not applicable.

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Data Availability

The data analyzed in this study are available from the corresponding author upon reasonable request.

AI Use Statement

The authors declare that no artificial intelligence (AI) tools or large language models (LLMs) were used in the design, data collection, analysis, writing, or revision of this manuscript. All content has been generated solely by the authors.

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