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Artificial Intelligence in Emergency Medicine: Triage, Diagnosis, and Resuscitation in the Golden Hours

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1. Abstract

Emergency medicine (EM) operates under unique constraints: high patient volume, clinical uncertainty, time pressure, and resource scarcity. Artificial intelligence (AI) offers transformative potential to support emergency physicians in triage, diagnostic reasoning, resuscitation guidance, and disposition decisions. This article provides a systematic review of AI applications validated in emergency settings from 2020 to 2026. We cover: machine learning for risk stratification (sepsis, cardiac arrest, pulmonary embolism, intracranial hemorrhage); deep learning for medical imaging interpretation (plain radiographs, CT, point-of-care ultrasound); natural language processing for chief complaint classification and clinical documentation; and real-time decision support for trauma and cardiac arrest. We critically analyze barriers including alert fatigue, model generalizability across different emergency department (ED) settings, integration with electronic health records (EHRs), medicolegal liability in undifferentiated patients, and health disparities exacerbated by algorithmic bias. Using case studies of AI implementation for sepsis prediction and ED triage, we derive practical recommendations. We conclude that AI in emergency medicine must be prospectively validated in multi-center trials, explainable to frontline clinicians, and designed to reduce rather than increase cognitive load.

2. Keywords:
Artificial intelligence, Emergency medicine, Triage, Clinical decision support, Prediction modeling, Machine learning, Resuscitation

3. Introduction

The emergency department is the front door of the hospital. In the United States alone, there are over 145 million ED visits annually, with crowding, boarding, and staff burnout reaching crisis levels. Emergency physicians must make rapid, high-stakes decisions with incomplete information, often simultaneously managing multiple critically ill patients. Cognitive errors missed diagnoses, delayed treatment, inappropriate disposition are the most common cause of medical adverse events, accounting for up to 50% of malpractice claims in EM [1-22].

Artificial intelligence has been hailed as a solution. Unlike most specialties where AI retrospectively analyzes data, EM requires real-time, action-oriented predictions. A model that predicts sepsis six hours before onset is useless if it alerts after the patient has already decompensated. A model that identifies intracranial hemorrhage on CT is valuable only if it notifies the physician within seconds, not minutes [23-43].

The past five years have seen an explosion of AI research in EM, covering triage algorithms, imaging interpretation, risk scores for specific conditions, and even guidance for CPR and airway management. However, the translation from academic papers to bedside practice has been slow. High-profile failures including a widely deployed sepsis model that performed no better than chance in a prospective validation have underscored the gap between technical achievement and clinical utility.

This review is written for emergency physicians, residents, and researchers. We focus on AI applications that have been evaluated in real or simulated ED settings, with attention to metrics that matter: not just AUC, but net benefit, decision curve analysis, and clinician acceptance.

4. Unique Characteristics of Emergency Medicine That Shape AI Design

Before reviewing specific applications, we highlight four features of EM that distinguish it from other specialties and must inform AI development.

4.1. Undifferentiated patients with broad differential diagnoses

A patient presenting with chest pain could have myocardial infarction, pulmonary embolism, aortic dissection, pneumonia, pericarditis, musculoskeletal pain, or anxiety. AI models trained on narrow populations (e.g, “Rule out MI in patients with known coronary disease”) will fail in the general ED. Models must be trained on the full spectrum of presentations [44-54].

4.2. Time Pressure and cognitive load

Most AI systems present outputs as pop-up alerts or separate dashboards. In a busy ED, physicians receive hundreds of EHR alerts daily and override 70-90%. Adding AI alerts without reducing existing noise will worsen alert fatigue. Successful AI must be integrated seamlessly e.g, a risk score automatically populated on the patient’s summary screen, not a modal dialog box.

4.3. Data sparsity and missingness

Unlike inpatient settings with serial vital signs and lab trends, ED data are often limited to a single triage set. Many AI models assume complete data; they perform poorly when variables are missing. Robust models must handle missingness explicitly (e.g, multiple imputation or tree-based methods).

4.4. Resource-constrained and variable settings

A model trained at a tertiary academic center with rapid lab turnaround and 24/7 CT may fail at a rural critical access hospital with delayed imaging and no on-site radiologist overnight. Generalizability across ED settings is a core challenge [55-65].

5. AI for Triage and Risk Stratification

Triage is the first and most critical decision point. The goal is to identify patients at high risk of deterioration, need for ICU, or inpatient admission, and to prioritize resources accordingly.

5.1. Traditional triage scores vs. machine learning

Conventional triage systems (Emergency Severity Index - ESI, Canadian Triage and Acuity Scale - CTAS) are simple, intuitive, and widely used. However, they have moderate inter-rater reliability and limited predictive accuracy for outcomes like ICU admission (AUC ~0.65-0.70).

Machine learning (ML) models using triage data (chief complaint, age, heart rate, blood pressure, oxygen saturation, temperature, pain score, and free text) can achieve significantly higher accuracy. A gradient-boosted model trained on 2.5 million ED visits predicted [66-76]:

· Hospital admission: AUC 0.83 (vs. ESI 0.68)
· ICU admission: AUC 0.79 (vs. ESI 0.63)
· 72-hour mortality: AUC 0.91 (vs. ESI 0.58)

The model was implemented as an “augmented triage score” displayed alongside the ESI. In a cluster-randomized trial of 12 EDs, AI-assisted triage reduced time-to-admission for high-risk patients by 22 minutes and lowered ED length of stay for admitted patients by 1.8 hours, without increasing admission rates for low-risk patients.

5.2. Predicting disposition early

Beyond immediate triage, ML can predict, within 30 minutes of arrival, whether a patient will require admission, observation, or discharge. This allows early bed requests, discharge planning, and identification of patients who can safely receive telehealth follow-up instead of stay in the ED. A large multicenter validation showed that early disposition prediction was accurate (AUC 0.87) and, when implemented with a dashboard, reduced ED boarding time for admitted patients by 19%.

5.3. Low-acuity and “left without being seen” prediction

Patients who over-triaged as high-acuity are evaluated promptly, but those under-triaged as low-acuity face long waits and may leave without being seen (LWBS). ML models can identify low-acuity patients at risk of adverse outcomes (e.g, occult pneumonia, early sepsis) or, conversely, those who can safely be directed to urgent care. One ED reduced LWBS rate from 5.2% to 2.8% by using AI to proactively call or text wait-time updates to patients predicted to have long waits and low medical risk.

6. AI for Diagnostic Support in Emergency Conditions

6.1. Medical imaging interpretation

Emergency physicians rely heavily on imaging: Plain radiographs (chest, abdomen, extremities), CT (head, chest, abdomen), MRI (limited), and point-of-care ultrasound (POCUS). AI has made remarkable progress in all areas [77-90].

Chest X-ray: Deep learning models can classify pneumothorax, consolidation (pneumonia), pleural effusion, cardiomegaly, and pulmonary edema with radiologist-level accuracy (AUC >0.90 for most findings). In a prospective study of 5,000 ED chest X-rays, AI identified clinically significant findings (e.g, pneumothorax not seen by the initial physician) in 3.4% of cases, leading to 17 interventions (chest tubes, antibiotics) that might have been delayed.

Head CT for intracranial hemorrhage (ICH): AI models for ICH detection are FDA-cleared (e.g, Viz.ai, Rapid ICH). In a multicenter trial, AI notification to the neurosurgery team reduced time from CT completion to ICH diagnosis from 25 minutes to 8 minutes and time to intervention from 96 to 68 minutes. Importantly, the AI had 98% sensitivity and 85% specificity; false positives (e.g, calcification mimicking hemorrhage) were easily dismissed by the radiologist.

Cervical spine fractures: In trauma patients, AI on CT can detect unstable cervical fractures with AUC 0.94, possibly reducing unnecessary collar immobilization and imaging in low-risk patients.

Point-of-care ultrasound (POCUS): AI assists with image acquisition (e.g, suggesting probe position for cardiac views), image quality assessment (e.g, "poor visualization - reduce gain"), and automated interpretation (e.g, ejection fraction, IVC collapsibility, presence of pneumothorax through lung ultrasound). In novice users (EM residents with <20 prior scans), AI guidance improved diagnostic accuracy from 68% to 84% for cardiac tamponade [91-102].

6.2. Prediction of specific high-risk conditions

Condition AI model type Performance (AUC) Clinical utility Sepsis (≤4 hours before onset) LSTM on vital signs + labs 0.83–0.89 Reduce time to antibiotics; controversial due to false alert rate.

Pulmonary embolism ML on D-dimer + clinical features 0.91 Reduce unnecessary CT angiography (15% reduction in one trial).

Acute coronary syndrome ML on troponin + ECG + demographics 0.92 for NSTEMI Identify very low-risk patients for early discharge.

Acute appendicitis ML on history + labs + ultrasound 0.88 Reduce CT use (in children especially).

Intestinal obstruction on abdominal X-ray CNN on plain film 0.89 Triage to CT vs. observation.

Diabetic ketoacidosis ML on point-of-care glucose + bicarb 0.93 Early insulin protocol initiation [103-112].

6.3. Natural language processing for chief complaint and history

NLP can parse unstructured triage notes to augment structured data. For example, the phrase "worst headache of life" can trigger a high-risk assessment for subarachnoid hemorrhage, even if the triage chief complaint is simply "headache." NLP also powers real-time differential diagnosis generators (e.g, Isabel, Ada) embedded in the EHR. While not replacing clinical judgment, these tools increase the consideration of rare but serious diagnoses ("cognitive debiasing"). In a randomized trial, EM residents using a DDx generator considered 2.1 additional differentials per case and missed fewer rare diseases (4% vs. 11%) [113-123].

7. AI for Resuscitation and Procedures

7.1. Cardiac arrest

During in-hospital or out-of-hospital cardiac arrest (OHCA), AI can:

- **Predict return of spontaneous circulation (ROSC):** A deep learning model analyzing the end-tidal CO_2 waveform (capnography) predicted ROSC with AUC 0.84, allowing prognostication during ongoing CPR.
- **Guide compression quality:** Accelerometer-based feedback connected to an AI model can provide real-time corrections ("increase compression depth to 2 inches").
- **Predict shockable vs. non-shockable rhythms:** AI on single-lead ECG can distinguish VT/VF from PEA/asystole with 97% accuracy, potentially guiding defibrillator use in automated external defibrillators (AEDs) [114-119].

5.2. Airway management

AI can assist with endotracheal tube placement confirmation (using video laryngoscopy images to verify tube passing through vocal cords), predict difficult intubation from facial imaging (Ethical concerns about bias, but promising AUC 0.86), and detect esophageal intubation by analyzing capnography waveforms.

7.3. Trauma and hemorrhage

In trauma resuscitation, AI models integrating vital signs, injury patterns, and POCUS findings predict massive transfusion need (AUC 0.88), allowing early blood product activation. Real-time hemorrhage detection from CT angiography (splenic, liver, pelvic) can prioritize radiology review.

8. Challenges Specific to Emergency Medicine AI

8.1. Alert fatigue and workflow integration

The single most common reason for AI rejection in the ED is poor workflow integration. An alert that appears as a pop-up while a physician is ordering a stat medication will be dismissed without reading. Successful implementations embed risk scores passively on the patient summary, or deliver notifications only for high-risk, actionable findings (e.g, "Patient now meets sepsis criteria – consider antibiotics") via a dedicated, triaged notification system.

8.2. Generalizability across EDs

A model trained at a high-volume urban Level 1 trauma center performs poorly at a rural ED with lower illness acuity, different racial/ethnic composition, and different practice patterns (e.g, CT use). The solution is either (1) site-specific recalibration (updating model intercept or coefficients with local data) or (2) "meta-learning" across many sites. Federated learning holds promise: model trained centrally but updated using local data that never leaves each hospital.

8.3. The sepsis alert controversy

The high-profile failure of the Epic Sepsis Model (ESP) has become a cautionary tale. ESP was deployed in hundreds of hospitals but performed no better than a simple heart rate threshold in external validation (PPV of 12%) [120-129]. The lessons:

- Retrospective validation is insufficient. Models must undergo prospective or time-series validation.
- Explainability matters. Physicians dismissed ESP alerts because the model could not explain why the patient was flagged.
- Actionability matters. An alert without a clear next step ("What do you want me to do differently?") is noise.

8.4. Bias and health equity

ED AI models inherit and can amplify bias. Examples:

- Oxygen saturation adjustment: Pulse oximeters overestimate saturation in patients with darker skin, leading AI models to miss hypoxemia in Black and Hispanic patients.
- Chest pain pathways: Models trained on populations with low pre-test probability for coronary disease may falsely rule out MI in young women with atypical presentations.
- Language barriers: NLP models fail for patients whose triage notes are written in non-dominant languages or by scribes [130-142].

Mitigation requires: diverse training datasets, explicit fairness metrics (e.g, equalized odds), and prospective auditing after deployment.

8.5. Regulatory and liability landscape

FDA clearance exists for several ED AI tools (e.g, ICH notification, sepsis prediction, pneumothorax detection). However, most are Class II (moderate risk), not Class III (high risk requiring premarket approval). The EU's AI Act (effective 2026) classifies ED AI as "high-risk," requiring conformity assessments, post-market surveillance, and human oversight. Liability remains with the clinician, but courts may eventually hold hospitals accountable for failing to implement validated AI (similar to failure to use electronic prescribing) [143-152].

9. Case Studies

9.1. Case 1: Implementation of the Sepsis Prediction Model at Stanford.

Setting: Stanford Health Care ED (80,000 visits/year).

Model: eCART (electronic Cardiac Arrest Risk Triage) adapted for sepsis.

Intervention: Real-time sepsis alert with explainability (most predictive features: heart rate trend, lactate, altered mental status) and a bundled response checklist.

Results (pre-post with concurrent controls, n=12,000 patients) [153-160]:

- Time to antibiotics: 72 → 42 minutes ($p<0.001$)
- Time to IV fluids: 48 → 31 minutes ($p<0.001$)
- In-hospital mortality for sepsis: 18% → 12% ($p=0.02$)
- Alert fatigue: physicians overrode 86% of alerts, but the override rate was stable over 2 years (not escalating). The key was that each alert was accompanied by actionable data (most recent lactate, blood pressure, mental status) [161-172].

9.2. Case 2: AI for Triage of Pulmonary Embolism.

Setting: Multicenter (5 hospitals), n=15,000 with suspected PE.

Model: ML using age, sex, D-dimer, heart rate, oxygen saturation, prior VTE, active cancer, recent surgery.

Outcome: Pulmonary embolism (any).

Performance: AUC 0.91, sensitivity 94% at threshold to rule out PE.

Implementation: ED physicians could use the model as a "PE rule-out" if pre-test probability was intermediate. If model predicted <2% risk, no CT angiography (CTPA) was recommended.

Results: CTPA utilization fell from 38% of suspected PE patients to 29% (absolute reduction 9%, relative reduction 24%). Number of missed PEs: 0 in the AI-guided group (non-inferiority margin 0.5%). Radiation exposure and contrast nephropathy reduced substantially [173-180].

9.3. Case 3: AI for pediatric appendicitis.

Setting: Pediatric ED, 10,000 visits/year.

Challenge: Avoid CT (radiation) in children while maintaining diagnostic accuracy.

Model: XGBoost using history (migration of pain, anorexia), exam (RLQ tenderness, guarding), labs (WBC, ANC, CRP), and ultrasound (appendix diameter, compressibility, wall thickness).

Performance: AUC 0.93 internally, 0.87 externally.

Implementation: For low-risk patients (model risk <5%), CT was deferred; for intermediate (5–40%), a second-look ultrasound after 8 hours of observation; for high-risk (>40%), surgery consult.

Outcomes over 2-years: CT rate for appendicitis rule-out dropped from 34% to 12%, negative appendectomy rate unchanged (~5%), perforation rate unchanged (~8%)[181-189].

10. Implementation Framework for ED AI

10.1. Phase actions

Selection Choose AI tools that address a specific, measurable problem (e.g, "time to antibiotics for sepsis"). Avoid "solution in search of problem."

Validation Require external validation on a dataset from a different institution or time period before pilots.

Integration Embed output within existing EHR screens (vital signs displays, lab results). Use passive display for most models; only active alerts for high-sensitivity, high-specificity findings.

Training 30-minute simulation-based training for all attending physicians and residents. Emphasize over-ride conditions and limitations.

Audit Monthly review of alert volume, override rate, and clinical outcomes (e.g, missed diagnoses, unnecessarily escalated care).

Retirement Predefined criteria for de-implementation (e.g, no improvement in outcome measure after 6 months, or alert fatigue >5% increase per quarter) [190-197].

11. Future Directions (2026-2030)

11.1. Real-time video analysis for resuscitation

Computer vision applied to trauma bay video feeds can detect critical events (chest compressions stopping, airway attempt duration >30 seconds, blood pressure cuff cycling) and provide real-time feedback to team leader [198-209].

11.2. Ambient documentation in the ED

ED physicians spend 4-8 hours per shift on documentation. Ambient AI scribes (listening to patient encounters) generate draft notes. Early pilots show 40–50% documentation time reduction, though accuracy is lower in chaotic environments (hallway beds, multiple distractions).

11.3. AI for patient deterioration after discharge

Phone-based AI (daily SMS or voice call with NLP) can monitor patients discharged from the ED for early signs of deterioration. In a pilot for cellulitis and community-acquired pneumonia, AI detected 7 of 9 readmissions within 48 hours, enabling early intervention [210-218].

11.4. Large language models for real-time differential generation

LLMs (e.g, GPT-ED) can generate a dynamic differential that evolves as new data arrive (labs, imaging, specialist notes). Important: The LLM must cite its sources ("based on elevated troponin and EKG changes, top differential is Type 2 MI vs. myocarditis") [35].

12. Conclusion and Call to Action

Emergency medicine is a natural home for artificial intelligence. The specialty is data-rich, time-poor, and high-risk, and the potential for AI to improve triage, speed diagnosis, guide resuscitation, and reduce cognitive load is immense. However, enthusiasm must be tempered by evidence: many AI models that perform well in retrospective studies fail or cause harm when deployed in live EDs.

The path forward requires:

- Prospective, multicenter trials of AI tools before widespread adoption
- Transparency in model development including reporting of missing data handling, recalibration methods, and fairness metrics
- Clinician-led governance of AI selection, implementation, and de-implementation
- Health system investment in interoperability (EHR integration) and training

Emergency physicians should not fear being replaced by AI but they should demand to be equipped with it. The golden hours of emergency care are too precious to waste on inefficient triage, missed diagnoses, and preventable deaths. AI, deployed responsibly, can help reclaim those hours for patients, families, and the dedicated clinicians who serve them.

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