

Transforming emergency medicine with artificial intelligence: From triage to clinical decision support



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Abstract Emergency medicine is undergoing a significant transformation due to the integration of artificial intelligence (AI), which is enhancing patient care, boosting operational efficiency, and revolutionizing clinical decision-making. This analysis examines the present applications and prospects of AI in emergency medicine, with a focus on its capacity to enhance diagnostic precision, improve triage systems, and tailor treatment strategies. Emergency departments worldwide are increasingly adopting AI-driven tools, including advanced triage systems, predictive analytics, and automated diagnostic support. These technologies have shown impressive abilities in medical image analysis, patient outcome prediction, and clinical documentation assistance. Nevertheless, the implementation of AI in emergency medicine faces obstacles such as data accessibility and quality, ethical issues, and the need for comprehensive regulatory frameworks. To ensure responsible AI system development and deployment, collaboration among healthcare professionals, data scientists, ethicists, and policymakers is essential. Future AI advancements in emergency medicine are expected to include improved predictive analytics, precise diagnostics, and individualized patient care. AI-enabled remote monitoring and telehealth services also show potential for alleviating pressure on emergency services and improving patient outcomes. As AI technology progresses, it is vital to address the constraints and challenges associated with its implementation, including data sharing, model interpretability, and potential biases. Ongoing research and stakeholder discussions are crucial to fully leverage AI's potential in emergency medicine while prioritizing patient safety, privacy, and equitable access to healthcare services.

Keywords: healthcare, diagnostics, ethics, regulation, telehealth, analytics

1. Introduction

The field of emergency medicine is experiencing a significant transformation due to the growing influence of artificial intelligence, which offers innovative approaches to enhance patient care and optimize operational efficiency in emergency healthcare environments (d'Elia et al., 2022). AI-powered tools are being implemented in emergency departments globally, encompassing a wide range of applications such as sophisticated triage systems, predictive analytics, automated diagnostic assistance, and resource allocation optimization (Grant et al., 2020). These technologies show promise in improving critical processes, enhancing diagnostic precision, and ensuring more effective use of limited resources, ultimately contributing to the delivery of high-quality, timely emergency care (Propp, 2012). A well-established application of AI in emergency medicine is the analysis of diagnostic images. AI systems have shown the capability to swiftly examine medical scans, including X-rays and CT scans, providing accurate and timely interpretations that often surpass human clinicians in certain tasks. Additionally, AI algorithms have demonstrated potential in forecasting patient outcomes, such as the probability of hospital admission or the risk of adverse events, enabling more informed decision-making and targeted interventions (Shafaf & Malek, 2019).

Moreover, artificial intelligence has demonstrated considerable promise in forecasting patient outcomes and tracking vital signs. These systems employ sophisticated algorithms and machine learning methods to examine extensive patient datasets, recognize patterns, and produce individualized risk evaluations and prognostic insights. Such information can guide clinical decision-making and the allocation of resources (Price & Cohen, 2018). An additional domain of AI application in emergency medicine involves the utilization of natural language processing to support clinical documentation and improve communication among healthcare professionals (Jiang et al., 2017). With the escalating number of individuals seeking emergency medical attention, conventional approaches may no longer be adequate to handle the growing demand (Grant et al., 2020). Artificial intelligence-based solutions, including computerized triage systems and forecasting analytics, can assist emergency departments in streamlining their operations, decreasing waiting periods, and ensuring prompt and appropriate care for patients (Alowais et al., 2023). Although the implementation of AI in emergency medicine is becoming more widespread, several obstacles and issues still need to be tackled (Picard et al., 2020).



2. Search Methodology

This review was conducted by considering research articles published in reputable, trustworthy, and credible journals, analyzing the articles using various methods, and presenting the review in a discussion-style format with straightforward explanations. The databases searched were PubMed, Google Scholar, and Web of Science, and only articles published within the last 10 years were included. The review followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework.

The inclusion criteria covered studies investigating AI applications in emergency medicine, including research on AI-powered triage systems in emergency departments, articles assessing the impact of predictive analytics for forecasting patient outcomes, studies examining the integration of AI in diagnostic imaging like CT scans or X-rays, literature discussing AI-based clinical decision support systems, research exploring AI-driven resource allocation in emergency healthcare, studies on AI applications in remote monitoring and telehealth, publications addressing the ethical considerations of AI in healthcare, case studies of AI in cardiac, trauma, or stroke management, and articles on AI's role in home-based care and patient monitoring. Conversely, the exclusion criteria involved articles not focused on AI in the context of emergency medicine, studies solely examining non-clinical AI applications, research related to AI in non-emergency medical fields, articles not addressing AI implementation challenges such as data quality or regulatory frameworks, and studies lacking empirical or practical evaluation of AI technologies.

Key terms used for the search are Artificial Intelligence (mesh Term: *Artificial Intelligence*), Emergency Medicine (mesh Term: *Emergency Medicine*), Clinical Decision Support Systems (mesh Term: *Decision Support Systems, Clinical*), Triage (mesh Term: *Triage*), Predictive Analytics (mesh Term: *Predictive Value of Tests*), Medical Imaging (mesh Term: *Diagnostic Imaging*), Machine Learning (mesh Term: *Machine Learning*), Natural Language Processing (mesh Term: *Natural Language Processing*), Telemedicine (mesh Term: *Telemedicine*), Health Equity (mesh Term: *Health Equity*), Resource Allocation (mesh Term: *Resource Allocation*), Remote Monitoring (mesh Term: *Remote Sensing Technology*), Outcome Prediction (mesh Term: *Prognosis*). Screening and the number of articles included in the final review are summarized in Figure 1.

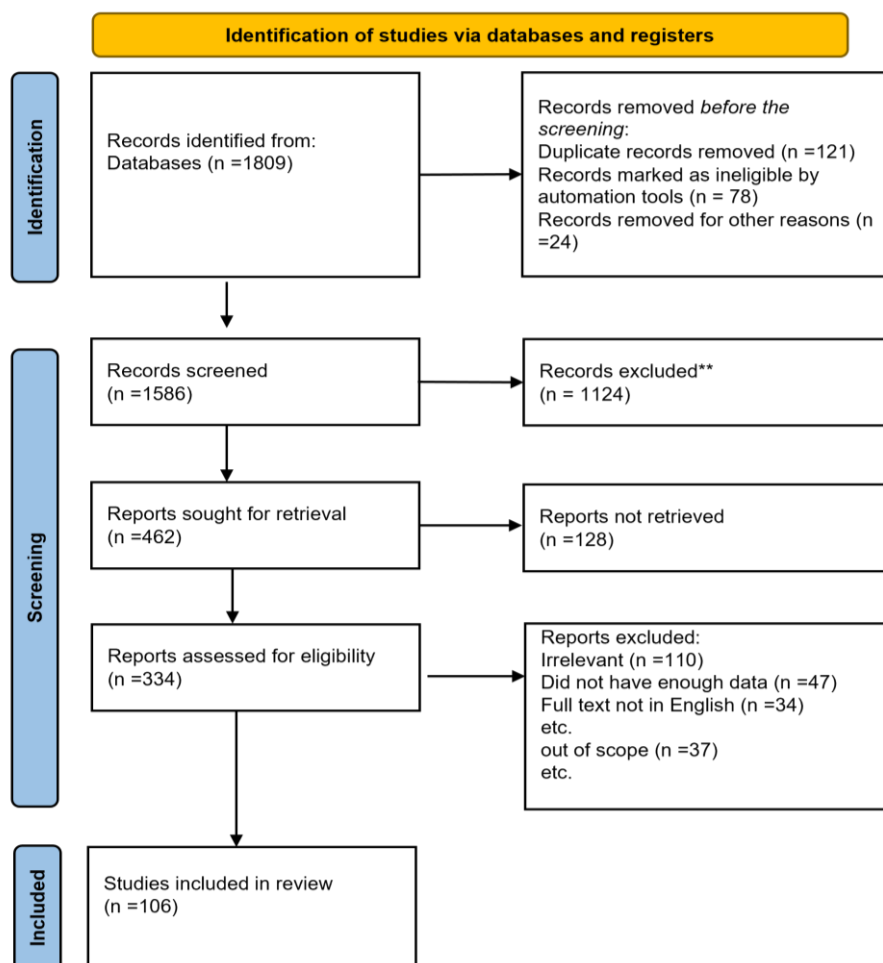


Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) flow diagram of the identification process for the sample of 82 articles included in this review.

3. Current Applications

3.1. Integration in emergency departments

In recent years, the assimilation of artificial intelligence into emergency departments has markedly elevated both patient care and operational efficacy. A prominent illustration of this is the deployment of TriageGO, an AI-driven triage framework, which has been adopted by renowned medical institutions, including The Johns Hopkins Hospital and Sibley Memorial Hospital. This sophisticated innovation fortifies the vital triage procedure by meticulously scrutinizing an extensive range of patient data spanning vital signs, medical history, and present symptoms to swiftly forecast potential acute complications. Moreover, it suggests the most judicious level of care tailored to each unique patient (Chen et al., 2021; Raita et al., 2019). TriageGO empowers healthcare professionals to swiftly identify patients at minimal risk, streamlining their assessment and treatment with precision. This innovative AI-driven tool substantially augments patient throughput in emergency settings, curtailing prolonged wait periods. By meticulously calibrating resource distribution, it guarantees that individuals receive appropriate care expediently, thereby elevating the efficacy and overall caliber of emergency medical interventions (Christ et al., 2010; Grant et al., 2020). The impact of AI in emergency medicine is shown in Figure 2.

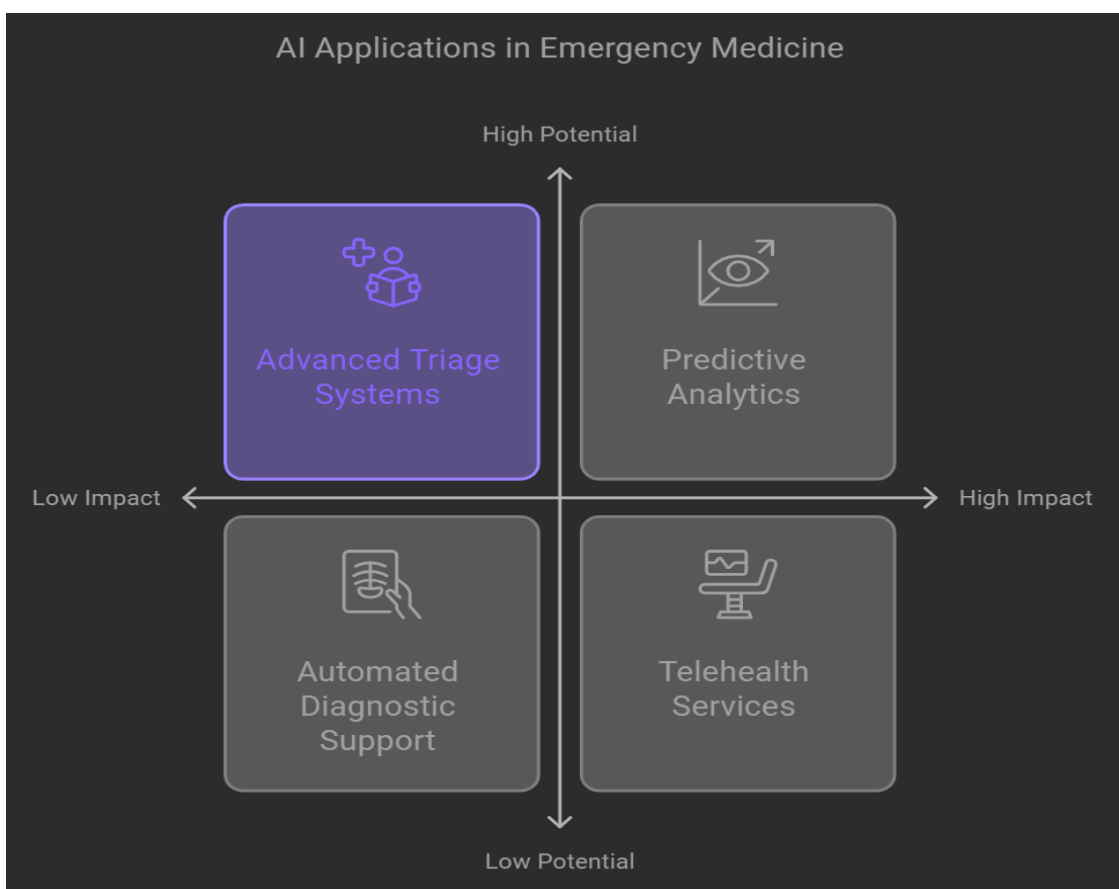


Figure 2 AI applications in emergency medicine and its potential and impact in various sectors of healthcare. *Source:* Chen et al. (2021); Raita et al. (2019).

3.2. Diagnostic support and predictive analytics

Artificial intelligence-driven diagnostic technologies have manifested exceptional potential in interpreting and scrutinizing medical imagery, including radiographs and computed tomography scans. These intelligent systems have, in certain diagnostic arenas, surpassed the capabilities of human practitioners (Poalelungi et al., 2023). Through their ability to swiftly assess images, pinpoint abnormalities, and furnish preliminary diagnostics, such AI-enhanced instruments hold the capacity to accelerate the diagnostic continuum, thereby augmenting the precision and efficacy of emergent healthcare delivery (Pesapane et al., 2018). Moreover, these algorithms extend their utility through prognostic analytics, with the aptitude to forecast patient trajectories, such as the probability of hospitalization or the risk of untoward clinical occurrences. This predictive prowess facilitates more enlightened decision-making, fostering the deployment of bespoke interventions that, in turn, amplify the caliber of emergency medical services (Janke et al., 2015). The process of predictive analysis using AI is shown in Figure 3.

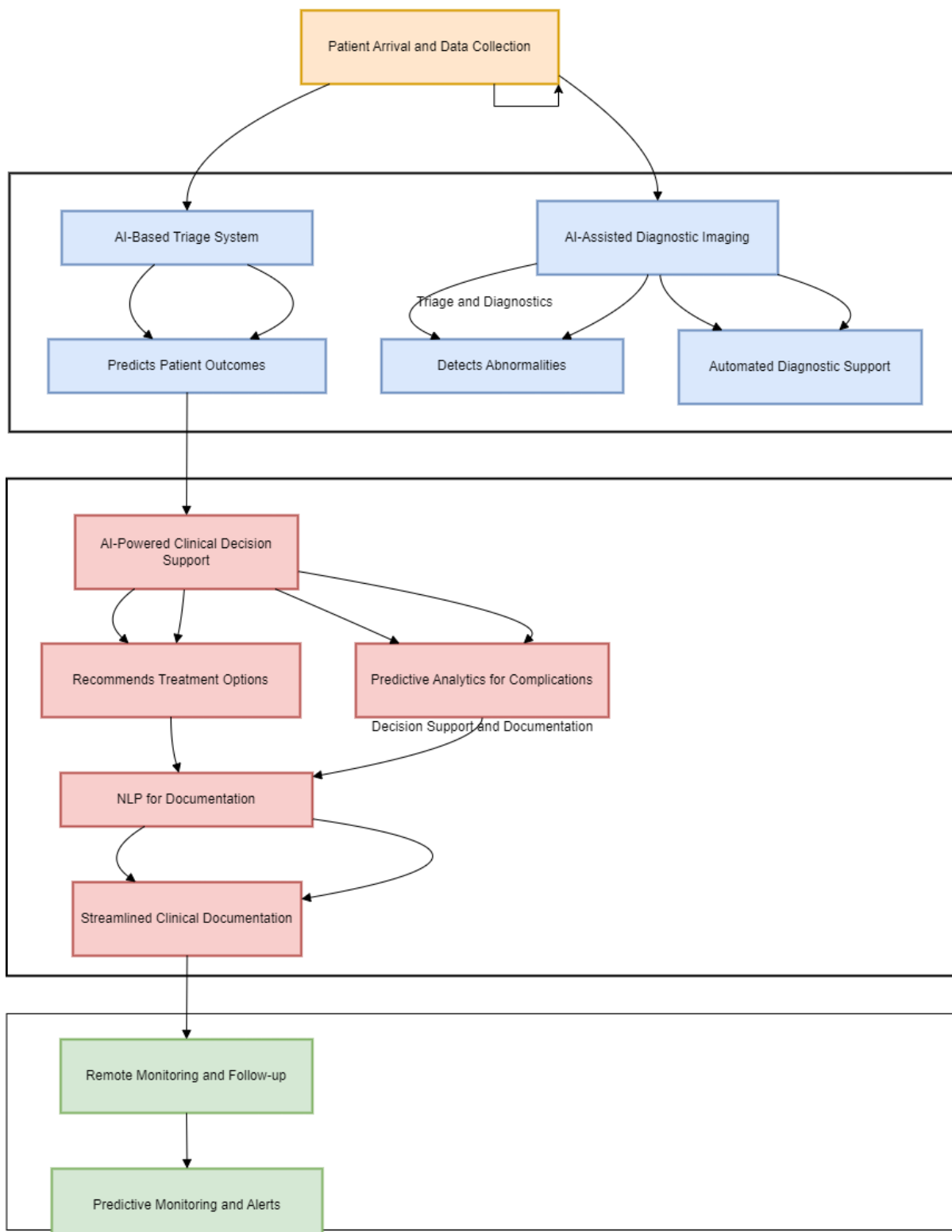


Figure 3 The process of predictive analysis using AI in the emergency department.

3.3. Clinical documentation and communication

In recent years, natural language processing methodologies have been increasingly utilized to streamline clinical documentation processes and augment communication amongst healthcare providers, particularly in high-pressure environments such as emergency departments (Zhou et al., 2022). AI-enhanced systems now possess the capability to autonomously generate intricate and exhaustive patient records by transcribing and interpreting dialogues between medical professionals and their patients. These sophisticated technologies substantially alleviate the administrative workload that often encumbers healthcare practitioners, thereby allowing them to allocate more time to direct patient care. Additionally,



these systems bolster the precision and thoroughness of medical records (Seibert et al., 2021). The ongoing evolution of these AI-based natural language processing systems ensures that the resulting patient documentation is not only comprehensive but also highly tailored to the specific needs and contextual nuances of each clinical encounter. This continuous refinement facilitates more astute clinical decision-making and ultimately enhances patient outcomes (Ganjizadeh et al., 2024).

3.4. Clinical decision support systems

In emergent clinical settings, AI-enhanced decision support mechanisms serve as augmentative instruments rather than substitutes for healthcare practitioners. These sophisticated systems harness the power of real-time data synthesis, offering clinicians nuanced insights that underpin more judicious therapeutic decisions (Alowais et al., 2023). Employing advanced machine learning methodologies, these systems perpetually refine their guidance, tailoring suggestions to the individualized circumstances of each patient encounter. A pertinent example within emergency departments involves AI-driven decision systems analyzing multifaceted patient data—encompassing symptomatic presentations, comprehensive medical histories, and critical vital metrics. Such systems can propose diagnostic investigations, therapeutic pathways, and immediate interventions (Chang & Chul, 2022). In symbiosis with the clinical acumen of medical professionals, these AI-based tools significantly mitigate diagnostic inaccuracies, bolster the efficacy of interventions, and elevate the overall quality and immediacy of care delivery. This is particularly vital in high-stakes environments where expeditious decision-making is paramount (Shamszare & Choudhury, 2023). By merging cutting-edge technology with human expertise, these systems provide a critical adjunct in optimizing clinical outcomes in fast-paced, high-pressure emergency scenarios.

3.5. Home-based and domiciliary care

Artificial intelligence's influence transcends the traditional boundaries of hospitals and clinics, making significant strides in the domain of domiciliary care. In these environments, AI-enhanced systems meticulously synthesize data derived from caregiver observations and patient surveillance technologies, creating bespoke risk profiles for individuals (Aggarwal et al., 2020; Shaik et al., 2023). These sophisticated algorithms adeptly anticipate the occurrence of various adverse events—ranging from falls to rehospitalizations thus empowering healthcare professionals to enact preemptive, precise interventions (Varnosfaderani & Forouzanfar, 2024). The predictive capacity of AI-driven analytics enables caregivers to act decisively, fortifying patient safety and optimizing care delivery even beyond the confines of institutional healthcare (Hazarika, 2020). By harnessing these cutting-edge insights, caregivers are better equipped to provide high-caliber care in residential settings, thereby fostering improved patient outcomes and elevating quality of life. The seamless incorporation of AI into home-based healthcare underscores the profound potential of this technology to revolutionize caregiving. It augments the ability of both patients and caregivers to navigate health challenges with greater autonomy and efficacy, all within the familiar sanctuary of the patient's home (Kuziemy et al., 2019).

4. Challenges and Limitations

4.1. Limitations of survey research

The employment of survey-based methodologies to probe the intersection of artificial intelligence and emergency medicine encounters several significant impediments. A primary issue stems from the absence of a universally accepted definition of AI, which may obfuscate participants' understanding and impair the precision of survey responses (Kirubarajan et al., 2020). Moreover, the digital nature of these surveys can diminish participant engagement and limit opportunities to elucidate intricate subjects (Emmert-Streib et al., 2020). To circumvent these obstacles, future inquiries should consider alternative qualitative techniques, such as in-depth interviews and focus group discussions, which offer a more nuanced exploration and facilitate a deeper comprehension of themes identified in initial survey investigations (Chenais et al., 2022).

A critical hurdle in harnessing artificial intelligence within emergency medicine revolves around the availability and quality of data. The healthcare data landscape is often fragmented and isolated across disparate systems and institutions, creating a formidable barrier to the effective deployment of AI-driven innovations (Davenport & Glaser, 2022). Overcoming this issue necessitates coordinated efforts to enhance data interoperability, enforce standards, and increase data accessibility. This would permit AI algorithms to leverage comprehensive, high-fidelity datasets essential for realizing their transformative capabilities (Ahmed et al., 2023).

Additionally, the relentless pace of AI advancements presents a distinctive challenge for both researchers and clinicians. As AI technologies evolve with unprecedented velocity, it becomes increasingly challenging to maintain a thorough grasp of emergent developments and their clinical ramifications in emergency medicine. Staying current with these rapid technological shifts while translating them into practical, impactful clinical applications will be an indispensable focus for the research community in the forthcoming years (Smith et al., 2021; Bajwa et al., 2021; Grant et al., 2020).

4.2. Ethical considerations

The integration of artificial intelligence into emergency medicine raises important ethical considerations that must be carefully addressed. Concerns around bias, transparency, and accountability in AI-powered decision-making systems are paramount, as these tools have the potential to exacerbate existing disparities or introduce new forms of discrimination if not designed and implemented with rigorous ethical principles in mind (Shams et al., 2023; Margetts, 2022). Ensuring the responsible and trustworthy development of AI in emergency care requires a multifaceted approach, including collaboration between clinicians, data scientists, ethicists, and policymakers (Markus et al., 2020). Key ethical principles, such as respect for autonomy, beneficence, and justice, must be prioritized throughout the AI development lifecycle, from the initial design stages to the deployment and ongoing monitoring of these systems in real-world clinical settings (Khan et al., 2022; Huang et al., 2022). Additionally, the issue of interpretability and explainability of AI algorithms poses a significant challenge, as healthcare professionals and patients alike must be able to understand the reasoning behind the recommendations and decisions generated by these systems. Addressing this challenge will be crucial in fostering trust and acceptance of AI-powered tools within the emergency medicine field (Markus et al., 2020; Grant et al., 2020).

4.3. Transition challenge

4.3.1. Access to care

Marginalized communities, often overlooked in the design of AI-based health interventions, face distinctive challenges that are insufficiently addressed by conventional AI frameworks (Alami et al., 2020). These disparities in AI technology development can inadvertently entrench existing inequities in healthcare access and delivery. This neglect amplifies the difficulties these populations encounter in receiving equitable healthcare services. If AI solutions are not thoughtfully crafted to cater to the intricate needs of these disadvantaged groups, they risk reinforcing the barriers they seek to dismantle, thus widening healthcare disparities (Miller et al., 2020; Sherry et al., 2016). Moreover, ignoring the tailored needs of these communities when devising AI tools in domains such as emergency medicine may perpetuate or even exacerbate the systemic inequities that marginalized populations routinely face. This could undermine global efforts to establish inclusive and equitable healthcare systems, further thwarting the objective of universal healthcare. Without deliberate consideration of the unique circumstances of socioeconomically vulnerable groups, AI-driven innovations may fail to contribute to the overarching goal of eliminating disparities and enhancing healthcare accessibility for all (Dankwa-Mullan et al., 2021).

4.3.2. Workforce transition

The swift incorporation of artificial intelligence into the realm of emergency medicine constitutes a formidable task in orchestrating the metamorphosis of the healthcare workforce. As AI-enhanced systems gain ubiquity, healthcare practitioners—including emergency physicians, nurses, and auxiliary clinical personnel—must evolve, acquiring novel competencies that empower them to effectively collaborate with and govern the deployment of these technologies (Goldsack & Zanetti, 2020). Shifting the workforce toward digital fluency and equipping them with the capacity to leverage AI-generated insights necessitates a multidimensional strategy. This would encompass specialized training, comprehensive education, and the cultivation of new interdisciplinary proficiencies that meld clinical acumen with technological adeptness (Bajwa et al., 2021). Neglecting to sufficiently prepare healthcare professionals for this digital revolution may trigger resistance, erode trust in AI platforms, and squander critical opportunities to exploit these technologies in refining clinical decision-making, elevating patient outcomes, and amplifying operational efficiency within emergency care frameworks (Kansal et al., 2022; Vaio et al., 2020). Ensuring the effective management of this workforce evolution is paramount to achieving the seamless integration of artificial intelligence into emergency medicine practices. Failure to do so may jeopardize the profession's ability to fully realize the transformative potential AI holds in shaping the future of emergency care (Shafaf & Malek, 2019; Alowais et al., 2023).

4.4. Environment bias

In the intricate sphere of emergency medicine, the socio-environmental landscape within which data acquisition occurs presents the potential for significant skew in AI model performance. Elements such as social health determinants—spanning economic standing, educational attainment, and access to healthcare infrastructure—alongside spatial distinctions like urban versus rural environments, necessitate comprehensive integration into the datasets that inform these AI frameworks. Neglecting to adequately incorporate these pivotal contextual variables can engender biased health prognoses and AI-driven forecasts, which in turn disproportionately affect vulnerable patient demographics. Such oversights risk perpetuating and even deepening pre-existing inequities in healthcare delivery and outcomes (Leslie et al., 2021; Dankwa-Mullan et al., 2021).

4.5. Privacy and confidentiality

The intricate nature of healthcare data, particularly within the sphere of emergency medicine—where patient information is frequently produced under acute, high-pressure scenarios—elicits profound concerns surrounding privacy and confidentiality, especially with the integration of artificial intelligence (AI) systems (Davenport & Glaser, 2022). Given that AI

platforms often handle vast repositories of personal data, safeguarding the sanctity of patient privacy assumes paramount importance. Core apprehensions encompass data security vulnerabilities, the principle of informed consent, and the looming potential for data exploitation (Racine et al., 2019). Instituting stringent security protocols is essential, particularly for demographic groups possessing limited English proficiency. It is crucial to ensure that consent documentation is both lucid and comprehensible to a diverse patient population. Furthermore, it is imperative to delineate explicit guidelines and assign accountability for the ethical application of AI-derived insights (Goldberg et al., 2024). Instituting stringent security protocols is essential, particularly for demographic groups possessing limited English proficiency. It is crucial to ensure that consent documentation is both lucid and comprehensible to a diverse patient population. Furthermore, it is imperative to delineate explicit guidelines and assign accountability for the ethical application of AI-derived insights (Hlávka, 2020). Regular assessment and revision of these protocols are indispensable to guarantee their continued relevance and effectiveness as AI technologies evolve and advance (Geis et al., 2019). A thoughtful, deliberate approach to addressing privacy and confidentiality concerns is fundamental in fostering public trust. This is pivotal in enabling the successful incorporation of AI into emergency medicine, all while maintaining an unwavering commitment to the highest standards of patient-centered care (Crigger et al., 2022).

4.6. *Decision making and risk of bias*

In the realm of emergency medicine, the imperative for delineating unambiguous protocols and ethical frameworks governing the integration of AI technologies cannot be overstated. Healthcare professionals must be meticulously trained in the judicious application of these advanced tools, ensuring they possess a comprehensive understanding of both their potentialities and inherent constraints, alongside the biases that may inadvertently manifest (Ferrara, 2023). It is essential that robust oversight mechanisms be entrenched within institutional governance structures to guarantee that AI-enhanced clinical decisions adhere rigorously to established medical guidelines and ethical doctrines (Gill et al., 2022). To safeguard patient welfare, periodic evaluations, including audits and impact assessments, must be conducted to preemptively address any unforeseen outcomes or detriments to patient care. By proactively navigating these ethical quandaries and cultivating a climate of conscientious innovation, the medical community stands poised to fully exploit the capabilities of AI in augmenting emergency medicine. However, this must occur with an unwavering focus on patient-centric care and the preservation of public confidence (Erdélyi & Goldsmith, 2022; Wu & Liu, 2023). It is particularly critical that these protocols delineate the precise scenarios in which AI-driven modalities may be appropriately employed, alongside the evaluative criteria for their deployment and the requisite governance mechanisms to maintain accountability and ensure ethically sound use (Corrêa et al., 2023). Moreover, transparency must be a cornerstone of these guidelines, mandating that healthcare providers offer clear communication to patients regarding the role of AI in their care and actively involve them in the decision-making continuum (Markus et al., 2020). Through the establishment of these comprehensive ethical frameworks and the promotion of a culture committed to responsible AI integration, the healthcare sector can ensure that these transformative technologies advance emergency medicine in a manner that remains faithful to the highest standards of ethical, equitable, and patient-focused care (Lekadir et al., 2023).

4.7. *Oversight and regulation*

The rapid adoption of AI technologies in healthcare has outpaced regulatory frameworks. Currently, regulations are lacking in the United States, but forthcoming changes are expected, as highlighted in the White House's "Blueprint for an AI Bill of Rights." This document outlines guiding principles for the design and implementation of AI systems, emphasizing safety, non-discrimination, data privacy, and user notice. It is incumbent upon stakeholders to maintain stringent vigilance as artificial intelligence technologies advance, ensuring that the vast potential benefits are realized without undermining patient safety or the caliber of healthcare services. For AI systems deployed in emergency medicine to function optimally within ethical and operational boundaries, it is imperative that regulatory authorities and healthcare entities engage in a concerted effort. This collaboration should aim to forge explicit guidelines, establish robust standards, and implement comprehensive oversight frameworks that govern the full lifecycle of AI—from development through to deployment and continual monitoring. Without such measures, the unregulated proliferation of AI risks introducing significant ethical, clinical, and operational dilemmas. Thus, preemptive, well-coordinated regulatory strategies are essential to strike a balance between innovation and the unwavering protection of patient safety and the quality of care (Blueprint for an AI Bill of Rights: Making Automated Systems Work for the American People, 2022).

4.8. *Transparency and trust*

To cultivate confidence in artificial intelligence systems, fostering transparency is indispensable. This necessitates providing stakeholders with access to comprehensive details surrounding the rationale behind design choices, the datasets employed during model training, and the designated applications of AI technologies (Kiseleva et al., 2022). Enhanced transparency can be facilitated through open-source platforms, although such measures may evoke apprehensions regarding the safeguarding of intellectual property. Equally vital is the need to confront ingrained biases within health-related datasets

to avert the perpetuation of existing disparities via AI implementations (Gerke et al., 2020). Healthcare practitioners must be thoroughly educated in identifying and understanding potential biases, along with their ramifications, to guarantee that AI-generated outputs are correctly interpreted and utilized in clinical contexts. By confronting the ethical, legal, and societal dimensions of artificial intelligence within the realm of emergency medicine, the healthcare sector stands to unlock the transformative capacity of these technologies, all while adhering to paramount principles of patient-centered care (Oliva et al., 2022; Hernandez-Boussard et al., 2020; Bajwa et al., 2021; Crigger et al., 2022; Lekadir et al., 2023).

5. Future Directions and Recommendations

The assimilation of artificial intelligence (AI) within the domain of emergency medicine unveils profound potential to revolutionize patient management and elevate operational dexterity. As the technological sophistication of AI advances, its practical utilizations are anticipated to proliferate, introducing avant-garde solutions to entrenched predicaments in urgent care environments. A particularly promising frontier is the cultivation of AI-driven systems designed for triage and clinical decision support, offering unprecedented accuracy and expeditiousness in critical moments. Figure 4 scope of AI in healthcare.

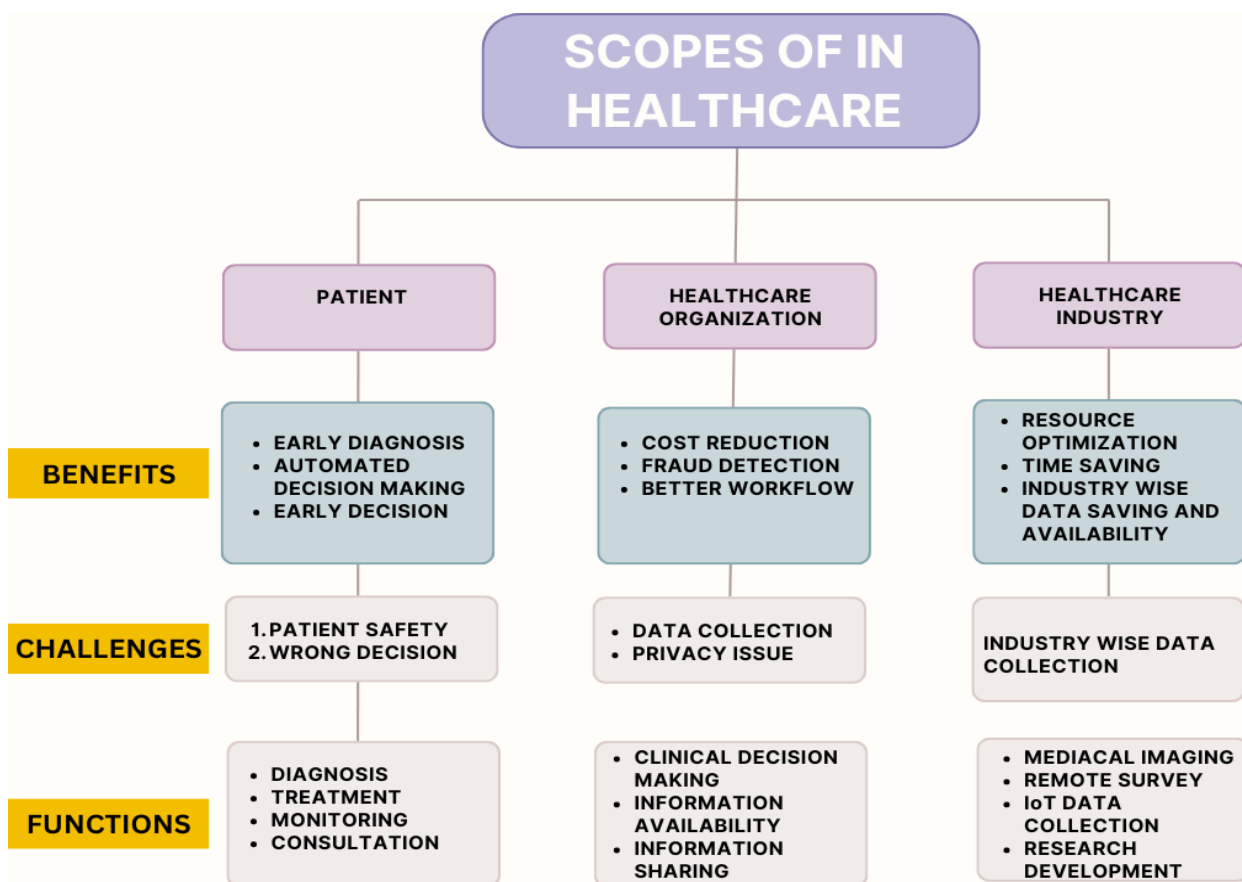


Figure 4 Future scope of AI in healthcare. Source: Janke et al. (2015).

5.1. Predictive analytics

The frontier of emergency medicine is increasingly shaped by the potential of sophisticated predictive analytics tools, underpinned by AI (Janke et al., 2015). Through the expansive utilization of electronic health records, AI algorithms are poised to unearth patients vulnerable to acute clinical downturns or life-threatening conditions, such as sepsis. This proactive identification paves the way for earlier, more decisive medical intervention, thereby substantially bolstering patient prognosis (Taylor et al., 2015). The progressive refinement of AI-enhanced clinical decision support systems is anticipated to include instantaneous notifications, ensuring healthcare teams are immediately informed when a patient's condition shows signs of deterioration. Such timely insights empower clinicians to deploy precise and expedited interventions, a capability that is crucial in the high-stakes realm of emergency care (Hernandez-Boussard et al., 2020). As predictive methodologies evolve, they are expected to play a pivotal role in optimizing patient care and resource allocation, offering an indispensable edge in the demanding landscape of emergency medicine (Janke et al., 2015).

5.2. Precision diagnostics and imaging interpretation



The vast landscape of medical innovation is now increasingly shaped by the transformative potential of AI, particularly in the realm of diagnostic imaging and precision diagnostics. The employment of AI-fueled algorithms, specifically within the fields of computer vision and deep learning, has unveiled a striking capacity for recognizing minute irregularities and intricate patterns in medical images—often with a precision surpassing that of seasoned human specialists (Gyftopoulos et al., 2019). This prowess becomes indispensable in acute care environments, where time-sensitive, accurate diagnostic assessments are paramount in directing immediate therapeutic strategies. The amalgamation of AI-enhanced precision diagnostics into clinical workflows not only facilitates more streamlined triage processes but also accelerates the identification of life-threatening pathologies. Such advancements promise more bespoke and individualized therapeutic approaches (Harry, 2023). Beyond imaging, AI-driven natural language processing (NLP) holds the potential to decipher the unstructured terrain of clinical documentation. This capacity allows for deeper, more comprehensive patient evaluations, creating the possibility for more refined diagnostic precision and timelier medical interventions (Saqib et al., 2023). Beyond imaging, AI-driven natural language processing (NLP) holds the potential to decipher the unstructured terrain of clinical documentation. This capacity allows for deeper, more comprehensive patient evaluations, creating the possibility for more refined diagnostic precision and timelier medical interventions (Huang et al., 2019; Poalelungi et al., 2023).

5.3. Personalized patient care

The evolution of emergency medicine is gravitating toward a more individualized paradigm of patient management. With rapid advancements in artificial intelligence (AI), intricate patient profiles can be perpetually updated and enhanced, paving the way for the development of anticipatory, bespoke therapeutic interventions tailored to the distinct physiological and genetic idiosyncrasies of each patient (Santana et al., 2017). This progression toward precision medicine within emergency care heralds the potential for substantial improvements in therapeutic effectiveness, patient prognosis, and holistic satisfaction (Santana et al., 2017; Louca, 2012; Sharma et al., 2015). These technological advancements promise to recalibrate the landscape of emergency care, mitigating disparities in access and fostering more equitable healthcare delivery.

5.4. Remote monitoring and telehealth

This trend is likely to continue, with a further increasing shift toward providing care outside of hospital settings. AI-driven remote monitoring tools and virtual assistants may empower patients to take a more active role in managing their health, allowing for enhanced self-monitoring and self-management of chronic conditions. This would reduce the load on emergency services for routine care, as patients would receive timely support and intervention through more advanced telehealth services. Healthcare providers will be able to stay in continuous contact with patients, enabling proactive management of health concerns, necessary treatment adjustments, and ultimately improving patient outcomes while easing the strain on emergency care. (Eastwood et al., 2023).

6. Ethical Considerations, Equity and Regulatory Frameworks

It is essential to address ethical issues related to the use of AI technologies in emergency medicine. As AI, Ethical matters concerning the application of AI technologies in emergency medicine must be addressed. As AI technologies rapidly evolve, AI tools should be developed based on principles of beneficence, nonmaleficence, and justice to reduce potential biases and ensure equitable access to care for all patients (Bostrom & Yudkowsky, 2014). Ethical frameworks must be prioritized by public health professionals and medical practitioners to fully exploit AI benefits without worsening health disparities (Gupta et al., 2020).

Additionally, as AI becomes more integrated into emergency medicine, clear regulatory frameworks will be essential, providing guidelines on product approval, accountability, and governance. These frameworks will foster innovation while ensuring patient safety and data privacy. Collaborative efforts among stakeholders, including governments and healthcare organizations, will be crucial for the responsible deployment of AI technologies in emergency medicine (Shams et al., 2023).

7. Case Studies

7.1. Clinical decision support systems (CDSS)

In several studies, artificial intelligence integrated with clinical decision support systems (CDSS) has been shown to improve situational awareness and enhance emergency department processes. For instance, a recent mixed-methods study in Japan developed a real-time CDSS aimed at predicting the onset of life-threatening conditions like aortic dissection (Fujimori et al., 2022; Dingel et al., 2024). In several studies, artificial intelligence integrated with clinical decision support systems (CDSS) has been shown to improve situational awareness and enhance emergency department processes. For instance, a recent mixed-methods study in Japan developed a real-time CDSS aimed at predicting the onset of life-threatening conditions like aortic dissection (Liao et al., 2024). As these AI technologies evolve, they promise to revolutionize emergency medicine, offering more efficient, data-driven, and personalized care (Santos et al., 2014; Wright & Robicsek, 2015; Pereira et al., 2018).

7.2. Triage and resource allocation

Optimizing triage and resource allocation is another key application of AI in emergency medicine. AI-powered triage systems have been successful in accurately categorizing patients based on the severity of their conditions, leading to more efficient use of limited medical resources (Shafaf & Malek, 2019). Optimizing triage and resource allocation is another key application of AI in emergency medicine. AI-powered triage systems have been successful in accurately categorizing patients based on the severity of their conditions, leading to more efficient use of limited medical resources (Petrella, 2024). Additionally, AI-based tools can assist in dynamically allocating resources such as staff, equipment, and beds during emergencies. This allows healthcare providers to prioritize the most urgent cases, improving patient outcomes and optimizing the use of limited resources (Raita et al., 2019).

7.3. AI in cardiac emergencies

7.3.1. AI in predicting cardiac arrest

Recent studies suggest that artificial intelligence (AI) is playing an increasingly important role in predicting cardiac arrest. A scoping review identified 47 studies on the use of AI in this area. Of these, 55% focused on predicting cardiac arrest based on specific patient parameters, while 34% developed AI-based warning systems (Toy et al., 2023). Recent studies suggest that artificial intelligence (AI) is playing an increasingly important role in predicting cardiac arrest. A scoping review identified 47 studies on the use of AI in this area. Of these, 55% focused on predicting cardiac arrest based on specific patient parameters, while 34% developed AI-based warning systems (Sun et al., 2023). Recent studies suggest that artificial intelligence (AI) is playing an increasingly important role in predicting cardiac arrest. A scoping review identified 47 studies on the use of AI in this area. Of these, 55% focused on predicting cardiac arrest based on specific patient parameters, while 34% developed AI-based warning systems (Alamgir et al., 2021).

7.3.2. AI tools for risk assessment in chest pain patients

Recent investigative efforts by the University of Oxford have demonstrated the profound utility of artificial intelligence mechanisms in prognosticating the likelihood of myocardial infarctions in individuals experiencing thoracic discomfort. Within the ambit of a comprehensive study, encompassing over 40,000 participants subjected to cardiac computed tomography (CT) imaging, a striking revelation emerged: a significant cohort of patients devoid of pronounced coronary artery obstruction were, paradoxically, still predisposed to elevated future cardiac event risks. The AI apparatus, meticulously developed by the research cohort, exhibited remarkable precision in forecasting risk by scrutinizing subtle alterations in the adipose tissue encircling inflamed arterial segments, alongside other pertinent clinical determinants. This breakthrough harbors the potential to avert numerous fatalities linked to myocardial infarction on an annual basis, by augmenting the precision of clinician judgment within the National Health Service (NHS) framework in the United Kingdom (He et al., 2020; Skinner et al., 2010; Scott et al., 2017).

7.3.3. AI applications in echocardiograms

The application of artificial intelligence (AI) in refining echocardiographic evaluations has yielded remarkable progress. In a significant investigation, a deep convolutional neural network (DCNN) was meticulously trained to forecast anomalies in myocardial wall kinetics, achieving an area under the curve (AUC) score of 0.99—remarkably aligning with the performance of seasoned cardiologists (Sun et al., 2023). This development not only underscores AI's burgeoning role in elevating diagnostic accuracy but also empowers clinicians, even those with limited computational proficiency, to seamlessly integrate AI-driven algorithms into routine clinical workflows. These case studies collectively illustrate the burgeoning promise of AI across a spectrum of cardiac emergency interventions—spanning from predictive capabilities to risk stratification and enhanced diagnostic precision (Mehta & Lingayat, 2008). In its entirety, AI demonstrates the capacity to analyze a comprehensive range of cardiovascular anomalies. Its utility, particularly in the real-time detection of elusive irregularities during electrocardiographic (ECG) surveillance, renders it an indispensable asset in elevating diagnostic methodologies (Haq et al., 2022).

7.4. AI in trauma care

The deployment of artificial intelligence within trauma care has garnered considerable scholarly attention. A prominent instance is the advancement of an AI-enhanced decision support mechanism tailored for the triage and management of trauma victims. As elucidated in a study published in *Annals of Trauma and Acute Care Surgery*, researchers developed a machine learning framework designed to scrutinize patient data—ranging from vital signs and injury patterns to laboratory analyses—in order to forecast mortality risks among trauma patients. The model, demonstrating an impressive area under the curve (AUC) score of 0.91, surpassed conventional triage approaches grounded in the Injury Severity Score (Woodford et al., 2012). Such AI-driven innovations facilitate clinicians in rendering more discerning decisions, thereby ensuring that the gravest cases receive timely, precise care, culminating in improved patient survival rates. Further, AI's utility has been probed for its capacity

to forecast the likelihood of complications and adverse outcomes in trauma settings. Research featured in the *Journal of the American College of Surgeons* unveiled a deep learning algorithm capable of anticipating the risk of acute respiratory distress syndrome (ARDS) in individuals suffering traumatic injuries (Courville et al., 2023). By precisely identifying those at elevated risk, healthcare providers can implement preemptive measures and tailored interventions, thereby potentially diminishing the prevalence of this perilous complication. The integration of AI into trauma care extends notably into the realm of image analysis. Investigators have pioneered AI-fueled computer vision systems adept at detecting critical injuries—such as intracranial hemorrhages—via CT scans and radiographs with striking precision. These technological breakthroughs expedite the diagnostic workflow, enabling the rapid commencement of appropriate treatments, an essential advantage in trauma cases where the expeditious delivery of care is paramount (Brossard et al., 2021; Gallagher et al., 2007).

7.5. AI in disaster response and mass casualty incidents

The capacity of artificial intelligence to revolutionize disaster response and large-scale casualty management has garnered substantial attention. Sophisticated AI-driven mechanisms are capable of synthesizing vast arrays of data from diverse sources, encompassing real-time sensors, digital platforms, and emergency communication networks, to deliver heightened situational cognizance and bolster decision-making processes in moments of crisis. For instance, cutting-edge AI applications have been developed that can swiftly analyze visual media—images and video feeds—originating from disaster-stricken areas, autonomously identifying and categorizing casualties, structural damage, and other imperative data points. This critical information is subsequently utilized to direct the mobilization of emergency personnel, enhance the allocation of essential resources, and synchronize relief operations with greater precision (Saqib et al., 2023)

Moreover, artificial intelligence has been harnessed for predictive capabilities, notably in forecasting the ramifications of natural disasters and simulating the transmission dynamics of infectious diseases. By scrutinizing historical datasets, meteorological trends, and an array of pertinent variables, AI-driven models can yield more precise prognostications and scenario-based projections, thus empowering emergency management bodies to better anticipate and orchestrate their responses to such calamitous events (Goswami et al., 2016).

7.6. AI in neurology

Recent strides in artificial intelligence have substantially impacted neurology, notably in neuroimaging analysis and the preemptive identification of neurological pathologies. Specifically, AI-driven methodologies now empower the examination of MRI and CT brain scans to discern nascent indicators of neurodegenerative ailments, including Alzheimer's and Parkinson's diseases, among others (Gao & Lima, 2021). These advanced algorithms can detect imperceptible shifts in cerebral structure and functionality, thus equipping medical practitioners with tools for more precise, earlier diagnoses. This capability enhances the opportunity for timely medical interventions, potentially mitigating the progression of these incapacitating conditions (Tangsrivimol et al., 2023).

Furthermore, beyond diagnostics, AI is being actively evaluated for its potential to revolutionize personalized therapeutic approaches to neurological disorders. By aggregating and analyzing diverse data points—ranging from genetic profiles and neuroimaging results to comprehensive clinical histories. AI systems can propose tailored treatment plans that align with a patient's specific physiological attributes and disease trajectory. This paradigm of bespoke treatment offers the possibility of optimizing outcomes by refining therapeutic interventions according to the individual's unique biological and clinical landscape (Tran et al., 2019).

7.7. AI in stroke

The advent of artificial intelligence has heralded a remarkable transformation in stroke management, especially in the realms of diagnosis, prognosis, and therapeutic strategy formulation. A persistent obstacle in stroke care remains the expeditious identification of stroke subtypes, accompanied by the swift administration of the correct treatment. AI-driven computer vision systems have shown great potential in precisely discerning and categorizing various stroke types—such as ischemic or hemorrhagic strokes—through the analysis of intricate medical imaging datasets. Moreover, advanced AI models have been created to forecast stroke risk and anticipate favorable clinical outcomes (Varnosfaderani & Forouzanfar, 2024). These models synthesize a multitude of patient data, including clinical history, biomarkers, and other pertinent variables, to identify individuals at elevated risk, thereby informing the selection of optimal therapeutic interventions—ranging from thrombolytic treatments to endovascular techniques.

Beyond diagnostic and predictive functionalities, AI's utility extends to the enhancement of stroke treatment protocols. AI-powered decision support systems are capable of amalgamating real-time patient data with established treatment guidelines and historical outcomes, offering tailored recommendations for acute stroke management. This personalized approach holds the promise of significantly improving patient prognoses while concurrently minimizing the likelihood of adverse events.

7.8. AI in radiology and pathology

AI has great potential in medical imaging, especially radiology and pathology. AI algorithms in radiology have been shown to accurately and efficiently detect and classify a wide range of abnormalities, including tumors, hemorrhages, as well as other pathologies (Létourneau-Guillon et al., 2020). Radiologists could also benefit from AI-based tools; via these devices, radiologists can help detect diseases at earlier stages, in other words, allow for timely interventions and better patient forecasts (Varnosfaderani & Forouzanfar, 2024).

AI has been applied to the analysis of histopathological slides to identify cancer cells and other markers for diseases quickly and at a high accuracy level. The inclusion of AI in these diagnostic fields can reduce the burden on healthcare professionals, increase consistency and accuracy (aided by algorithms), and potentially aid in developing custom treatment plans (Habuzza et al., 2021). AI automates the analysis of medical images (CT, MRI) and histopathological samples, thereby improving the efficiency and accuracy of the diagnosis process, which further drives them to make more informed decisions and deliver customized therapies. AI applied to radiology and pathology can facilitate early disease sensing, allowing for very timely interventions that, in turn, would benefit a patient (Harnessing AI for cancer diagnosis, 2022).

7.9. AI in surgical planning and robotic-assisted procedures

Surgical planning/guidance and robotic-assisted procedures have also leveraged AI techniques. AI algorithms can look at pre-op imaging data, patient history and other pertinent information to make personalized surgical plans which can help create a safe and perform optimally during surgery. These AI-enabled surgical assistance tools can assist surgeons in determining optimal procedures, anticipating potential difficulties and tailoring approaches to individual patients for more efficient interventions (Hashimoto et al., 2018; Ryvlin et al., 2023).

In addition, robot-inspired AI systems have been designed to help surgeons during complex operations by giving them unprecedented levels of precision, dexterity and stability. Well, these robotic AI systems can offer better surgical results by lowering the chances of a human perfectly errorless approach while also extending surgeon expertise without ever turning to invasive procedure solutions. Further, AI completion of the loop with robot-assisted surgery can reduce patient recovery times and extend what healthcare professionals are able to perform by providing them solutions that remove complexity yet aid in surgical delivery-prevision. (Penza et al., 2019; Mithany et al., 2023; Modi et al., 2009).

8. Limitations and Challenges

One of the biggest considerations is whether and how much model training data can be shared. The first and most important aspect is the availability of a good dataset, making it difficult to build a decent AI algorithm. Incomplete or biased datasets can bring a suboptimal performance and hence also result in existing healthcare disparities (Hazarika, 2020). Interpretability/Transparency: Another challenge with AI-powered decision-making is the interpretability and transparency of the process. Both healthcare professionals and patients need to know how a conclusion is reached by AI so that the decision-making procedure can be transparent and reliable (Kiseleva et al., 2022).

Furthermore, the use of AI in emergency medicine comes with ethical issues like resource allocation and whether biases associated with machine-driven treatment recommendations will become a problem for patients/ or have negative effects on patient privacy/data security (Challen et al., 2019). Solving these problems will require continued dialogue between AI experts, healthcare stakeholders, and regulators. Tests should be implemented to validate the ability of AI systems and oversight mechanisms for safe, secure integration into emergency medicine departments with an emphasis on patient safety, relevance, autonomy security fair distribution across populations at home.

9. Conclusion

Artificial intelligence (AI) is transforming emergency medicine by offering innovative approaches to enhance patient care and optimize operational efficiency. AI-powered tools are being implemented in various applications, such as triage systems, predictive analytics, automated diagnostic assistance, and resource allocation optimization. AI has shown potential in analyzing diagnostic images, predicting patient outcomes, and supporting clinical documentation. However, the rapid adoption of AI in emergency medicine faces challenges, including data availability and quality, ethical considerations, workforce transition, and the need for regulatory frameworks. Future directions include enhanced predictive analytics, precision diagnostics, personalized patient care, and the integration of AI in remote monitoring and telehealth. Case studies demonstrate the successful application of AI in clinical decision support systems, triage, and resource allocation. AI is also being explored in specific areas such as cardiac emergencies, trauma care, disaster response, neurology, and stroke management. While AI holds great promise, it is essential to address limitations and challenges, such as data sharing, interpretability, and potential biases, to ensure the responsible and effective integration of AI in emergency medicine.

Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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