GMR
The Original

A Systematic Review of Telemedicine Applications and Outcomes in Emergency Department Settings

Shoug Zeid T Alenezi[1]*, Fadiyah Dhami S Alanazi[2], Suzan Sameer Alaqeel[2], Najwa Ahmad M Alqurashi[2], Sarah Zakaria Aldossary[2], Taif Khalaf K Alanazi[3],

1 Emergency Consultant, Emergency Department, North Medical Tower, Ar'ar city, Saudi Arabia
2 Emergency Medicine Resident, Emergency Department, King Saud Medical City, Riyadh, Saudi Arabia
3 Emergency Resident, Emergency Department, King Fahad Medical City, Riyadh, Saudi Arabia

*Corresponding Author: E-mail shz@hotmail.com

ABSTRACT

Background: Telemedicine has emerged as a strategic tool to address emergency department (ED) overcrowding and operational challenges, particularly following accelerated adoption during the COVID-19 pandemic. Aim: This systematic review synthesizes recent evidence on telemedicine applications and outcomes in ED settings, following PRISMA guidelines. Methods: Twelve studies were included, encompassing diverse designs (e.g., simulation trials, observational studies, qualitative interviews) and geographies. Results: Findings highlight three key themes: (1) telemedicine as an operational tool to improve patient flow, with evidence supporting its role in reducing low-acuity ED visits and optimizing resource use; (2) telemedicine as a means to enhance care processes, with high user satisfaction among patients and providers, though dependent on training and workflow-integrated design; and (3) telemedicine as a platform for innovation, including augmented reality and artificial intelligence for advanced diagnostics and consultation. Conclusion: While telemedicine demonstrates promise in improving efficiency and access, the evidence remains heterogeneous, with a need for more randomized controlled trials focusing on clinical outcomes. Future implementation must address sustainability, equity, and integration into health systems to realize telemedicine's potential in reshaping emergency care.

Keywords: *Telemedicine; Emergency Department; Systematic Review; Patient Flow; Operational Efficiency; Telehealth; Digital Health; Care Delivery*

INTRODUCTION

Emergency Departments (EDs) globally function as the critical frontline of healthcare systems, designed to manage acute illness and injury. However, these vital units are increasingly besieged by systemic pressures, including rising patient volumes, staffing shortages, and hospital capacity constraints, leading to pervasive overcrowding [1]. This state of overcrowding is not merely an operational inefficiency; it is a significant public health concern associated with detrimental outcomes, including prolonged patient wait times, delays in critical interventions, increased medical errors, reduced patient satisfaction, and higher mortality rates [2]. The traditional paradigm of relying solely on physical infrastructure expansion and linear workflow optimization has proven insufficient to address this multifaceted crisis, necessitating innovative approaches to care delivery.

Telemedicine, defined broadly as the use of telecommunications technology to provide healthcare at a distance, has emerged as a transformative tool with the potential to reshape acute care delivery [3]. Its application in emergency medicine is not novel; foundational work, particularly in the field of telestroke, has established robust evidence for its efficacy in improving access to time-sensitive specialty care, especially in underserved regions [4]. For decades, these applications demonstrated that remote evaluation and consultation could maintain or even enhance the quality of care for specific conditions. The COVID-19 pandemic served as an unprecedented catalyst, forcibly accelerating the adoption of telemedicine across all medical domains, including the ED [5]. This rapid integration was initially a pragmatic response to infection control and physical distancing requirements, but it has subsequently prompted a more permanent reevaluation of how digital tools can be woven into the fabric of emergency care.

The post-pandemic landscape presents a pivotal moment to critically assess the evolving role of telemedicine beyond crisis response. Current applications extend far beyond stroke and include direct-to-consumer triage, post-discharge follow-up, inpatient boarding management, and remote specialist consultation for a wide array of conditions [6]. Potential benefits are multifactorial, targeting key pressure points in ED operations: reducing unnecessary visits through pre-consultation, accelerating throughput by facilitating faster specialist input, improving patient flow for boarded admissions, and enhancing care continuity after discharge [7]. Furthermore, technological advancements in artificial intelligence, augmented reality, and high-fidelity remote monitoring are continually expanding the possible scope of telemedical interventions. Despite this momentum, the evidence base remains heterogeneous and fragmented. Existing literature reviews often focus on specific technologies (e.g., video visits), particular patient subgroups (e.g., pediatric or geriatric), or single disease processes [8]. There is a conspicuous need for a synthesized, contemporary overview that examines telemedicine's applications and outcomes across the general ED setting, distinguishing its role from pandemic-specific deployments. This systematic review therefore, aims to identify, evaluate, and synthesize the most recent evidence on the applications and outcomes of telemedicine within emergency department settings.

Methodology

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9] to ensure a transparent and reproducible process. The primary objective was to systematically identify, appraise, and synthesize the available literature on the applications and outcomes of telemedicine within emergency department (ED) settings, with a focus on recent evidence. The methodology was structured around five key phases: a comprehensive literature search, a multi-stage study selection process, systematic data extraction, quality assessment, and a narrative synthesis of findings.

Search Strategy

A comprehensive and systematic search of the literature was performed to identify all relevant studies published within the last three years, from January 2023 to December 2025. This timeframe was selected to capture the most contemporary evolution of telemedicine in emergency care, particularly developments during and following the COVID-19 pandemic, while aligning with the review's focus on recent evidence. The search was executed across four major electronic bibliographic databases: PubMed/MEDLINE, Scopus, Web of Science, and CINAHL. These databases were chosen for their extensive coverage of biomedical, interdisciplinary, and nursing/allied health literature. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and free-text keywords related to three core concepts: (1) Telemedicine (e.g., "telemedicine", "telehealth", "remote consultation", "mhealth"), (2) Emergency Care (e.g., "emergency service, hospital", "emergency department", "accident and emergency"), and (3) Application/Outcome (e.g., "utilization", "triage", "patient satisfaction", "length of stay"). Boolean operators (AND, OR) were used to combine these concepts. The full search strategy for PubMed is provided as an example: (("Telemedicine"[Mesh] OR telehealth OR "remote consultation")

AND ("Emergency Service, Hospital"[MeSH] OR "emergency department" OR "ED") AND ("outcome" OR "utilization" OR "efficacy"). No language filters were initially applied, but the final synthesis was restricted to studies published in English. Reference lists of key included articles and relevant review papers were also hand-searched to identify any additional studies not captured by the database searches [10].

Study Selection (Screening)

The study selection process was managed using the Rayyan web application, a platform designed for systematic review screening that facilitates blinded collaboration and conflict resolution among reviewers [11]. All records identified through the database searches were imported into Rayyan, and duplicates were removed automatically by the software and verified manually. The screening was conducted in two sequential stages by two independent reviewers. In the first stage, titles and abstracts were screened against predefined eligibility criteria. Studies were included if they: (1) primarily involved the application of telemedicine (including synchronous video/audio, asynchronous, or hybrid models) in an ED or directly related to ED patient flow (e.g., pre-hospital triage to ED, post-ED discharge follow-up); (2) reported on outcomes such as clinical effectiveness, operational efficiency, cost, or user experience; (3) were primary research studies (e.g., randomized trials, observational studies, qualitative studies); and (4) were published between 2023 and 2025. Studies were excluded if they: (1) focused exclusively on the management of the COVID-19 pandemic; (2) were limited to a single specific disease entity (e.g., telestroke-only studies) without broader ED application; (3) were conducted in non-ED settings (e.g., primary care, inpatient wards) without a clear link to ED utilization or processes; (4) were review articles, editorials, commentaries, or conference abstracts without full data; or (5) were published prior to 2023. Following the title/abstract screening, the full texts of potentially eligible articles were retrieved and assessed independently by the same two reviewers against the same criteria. At both screening stages, any discrepancies between reviewers regarding inclusion or exclusion were resolved through discussion and consensus, with a third senior researcher available for arbitration if needed. This process yielded the final list of 12 studies included in the review [11].

Data Extraction

A standardized, pre-piloted data extraction form was developed in Microsoft Excel to ensure consistency and capture all relevant information from the included studies. Data extraction was performed independently by two reviewers, and the extracted data were then cross-checked for accuracy and completeness. Any discrepancies were resolved by referring back to the original article and reaching a consensus. The extracted data were organized into two main tables. Table 1 captured descriptive and methodological characteristics, including: study authors and year; country and setting; study design (e.g., randomized trial, cohort, cross-sectional, qualitative); sample size; description of the study population (e.g., patients, healthcare providers); and key demographic details (e.g., age, sex) when reported. Table 2 focused on the study objectives, interventions, and outcomes, detailing: the primary aim of the study; a description of the telemedicine intervention or application; the key outcomes measured (e.g., ED referral rates, satisfaction scores, process times); and the main findings and conclusions as reported by the study authors. For data not explicitly mentioned in the abstract or main text (e.g., specific demographic details in a simulation study), the field was marked as "Not Mentioned (NM)" to maintain accuracy and transparency [12].

Quality Assessment (Risk of Bias)

The methodological quality and risk of bias of the included studies were critically appraised using the Mixed Methods Appraisal Tool (MMAT), version 2018 [12]. The MMAT was selected due to its suitability for appraising studies of diverse designs—including qualitative, quantitative (randomized, non-randomized, descriptive), and mixed-methods research—which was essential given the heterogeneity of the included evidence. The appraisal was conducted independently by two reviewers. For each study, the reviewers first answered two screening questions concerning the clarity of the research questions and the appropriateness

of the data to address them. Subsequently, depending on the study design category, five specific methodological criteria were rated as "Yes," "No," or "Can't tell." The criteria addressed aspects such as sampling strategy, data collection methods, appropriateness of measurements, risk of non-response bias, integration of mixed-methods components, and substantiation of findings. The results of this appraisal were summarized narratively and presented in Table 3, providing a clear overview of the strengths and limitations across the body of evidence and informing the interpretation of the synthesis.

Data Synthesis

Given the significant heterogeneity in study designs, populations, interventions, and outcome measures among the included studies, a quantitative meta-analysis was deemed inappropriate. Therefore, a narrative synthesis approach was adopted to analyze and summarize the findings [13]. The extracted data from Tables 1 and 2 were analyzed thematically. Key themes and patterns related to telemedicine applications and outcomes in the ED were identified, compared, and contrasted across the studies. The synthesis was structured to address the review's aims, first describing the landscape of recent research (designs, settings) and then integrating findings into coherent thematic areas such as operational impact on ED utilization, care process enhancement, and innovative applications. The findings from the quality assessment (Table 3) were integrated into the narrative to contextualize the strength of the evidence supporting each theme. This approach allowed for a comprehensive and critical summary of the current state of knowledge, highlighting consistencies, contradictions, and gaps in the literature [13].

Results:

The study selection process is summarized in the PRISMA flow diagram (Figure 1). A total of 214 records were initially identified from database searches. Following the removal of 98 duplicates, 116 unique records underwent title and abstract screening, resulting in the exclusion of 55 records. The full texts of 61 reports were sought for retrieval, with 11 being unavailable, leaving 50 reports for full-text eligibility assessment. Of these, 38 were excluded: 7 for wrong outcome, 13 for wrong population, and 18 for being conference abstracts only. Consequently, 12 studies met all criteria and were included in the final systematic review.

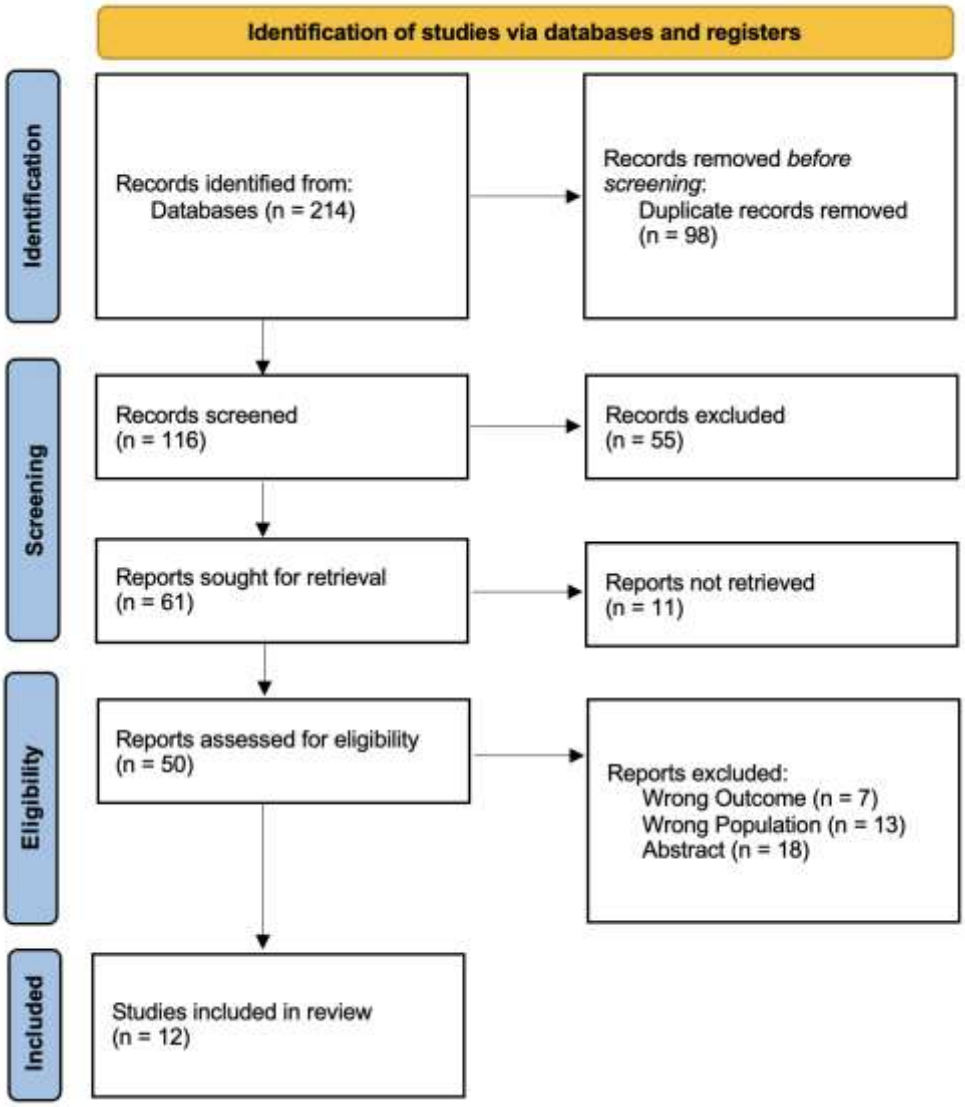

Figure 1: PRISMA Flow Diagram of Study Selection

The twelve studies selected for inclusion, as detailed in Table 1, encompass a diverse range of geographies and methodological approaches, reflecting the global and multifaceted nature of telemedicine research in emergency settings. Studies were conducted across several countries, including Brazil [17, 18], Austria [19, 20], Saudi Arabia [15], the United States [25], and Australia [23], with others not specifying a location. The research designs are equally varied, incorporating simulation trials [14], cross-sectional surveys [15], mixed-methods pilots [16], retrospective and prospective observational studies [17, 18], qualitative interviews [25], modelling analyses [23, 24], and participatory design studies [20, 21]. This heterogeneity in design is matched by a wide spectrum in sample size and type, ranging from large-scale analyses of over 230,000 patient encounters [17] and surveys of the general public [15] to smaller, focused groups such as healthcare professionals in workshops [20], resident physicians [18], and emergency providers in interviews [25]. This demographic and methodological diversity strengthens the review's ability to capture different

perspectives on telemedicine implementation, from systemic-level data analysis to deep, qualitative insights into user experience and workflow integration.

The primary objectives and findings of these studies, synthesized in Table 2, reveal two predominant thematic streams within the current literature. The first stream focuses on evaluating the processes, perceptions, and practical implementation of telemedicine systems. Several studies [14, 16, 19, 25] directly assess the user experience, finding generally positive perceptions among physicians, paramedics, and patients, while also identifying critical technical and human-factor barriers such as the need for user-friendly technology and dedicated training. Complementary to this, another group of studies [17, 20, 21, 24] delves into the design and operational optimization of these systems, investigating adherence to clinical guidelines [17], developing co-design methodologies [20], creating new applications for pre-hospital communication [21], and solving complex scheduling problems for telemedicine hubs [24]. These studies provide crucial insights into the foundational elements required for successful and safe integration of telemedicine into emergency care pathways, emphasizing structured protocols, stakeholder involvement, and efficient resource management.

The second major thematic stream concerns the potential impact and theoretical role of telemedicine on emergency department operations and patient flow. Studies like those by Alshurtan et al. [15] and Hassan [22] address the macro-level hypothesis that telemedicine can reduce unnecessary ED visits and alleviate system overcrowding by providing alternative care pathways and enhancing intra-departmental efficiency. Supporting this, modelling studies by Ferenczi & Perényi [23] and Olanrewaju & Erkoc [24] provide theoretical frameworks and operational models that demonstrate how telemedicine, through pre-hospital triage and optimized specialist coverage, could improve outcomes and reduce burdens on physical ED resources. Furthermore, specialized investigations into training [18] and advanced technologies like Augmented Reality [25] explore how telemedicine can enhance education for future practitioners and expand the scope and quality of remote diagnostics and consultation, pointing toward its evolving future applications beyond basic video consultation.

Table 1: Demographic and Methodological Characteristics of Included Studies

Study Name (Author(s) & Year) [Ref]	Country / Setting	Study Design	Sample Size (N)	Sample Type / Population	Age (Mean/Median or Range)	Sex (% Female)	Other Relevant Demographics
O'Sullivan & Schneider (2023) [14]	Simulation setting (Country NM)	Randomized simulation trial	141 scenarios (129 used ETA)	Certified paramedics & emergency physicians	NM	NM	Participants: Paramedics as ambulance crews, EPs as Tele-Emergency Physicians (TEPs)
Alshurtan et al. (2024) [15]	Saudi Arabia (National population)	Cross-sectional survey	1140 participants	General public survey respondents	46.8% in 18-25 age group	56.8%	Nationality: 95.2% Saudi. Education: 60.7%

							bachelor's degree.
Mateus et al. (2023) [16]	NM (Pediatric ED Telemedicine Network)	Sequential explanatory mixed-methods	Survey: NM; Interviews: Physicians & Parents	ED physicians & parents/guardians of pediatric patients	NM (Pediatric patients)	NM	Population: Critically ill pediatric patients treated via telemedicine program.
Accorsi et al. (2024) [17]	Brazil (Direct-to-consumer telemedicine center)	Retrospective observational	232,197 patient encounters (14,051 referred to ED)	Acutely ill patients seeking virtual urgent care	NM	NM	Encounters analyzed for referral patterns to ED.
Severini et al. (2023) [18]	Brazil (Tertiary university pediatric hospital)	Descriptive prospective study (pre & post)	40 resident physicians	First-year pediatric residents	NM	NM	Focus: Resident physicians in pediatric emergency rotation training.
Klager et al. (2024) [19]	Austria (Rural region of Burgenland)	Mixed-methods (Focus groups & survey)	Focus groups: 13; Survey: 99	Healthcare professionals & volunteers in prehospital EMS	NM	NM	Stakeholders: Healthcare professionals in local emergency medical service.
Klager et al. (2024) [20]	Austria (Rural region of Burgenland)	Descriptive co-design study	17 participants	Healthcare professionals, EMTs, academics	NM	NM	Participants in co-design workshops for telemedicine solution development.
Bai et al. (2024) [21]	NM (Pre-hospital to ED context)	Participatory / User-centered design study	NM (Design study)	Emergency care providers (pre-hospital & hospital)	NM	NM	Users: Pre-hospital and hospital-based emergency providers for system design.
Hassan (2025) [22]	NM (Theoretical/Review context)	Narrative / Review Article	NM (Not applicable)	N/A (Literature and conceptual analysis)	N/A	N/A	Focus: Synthesis of telemedicine's role in ED patient flow.
Ferenczi & Perényi	Australia (Victoria - Ambulance services)	Methodical analysis & Modelling study	NM (Analysis of statistics)	N/A (Analysis of ambulance data &	N/A	N/A	Data Source: Victorian ambulance

(2023) [23]				technology models)			statistics for modelling.
Olanrewaju & Erkoc (2023) [24]	NM (Multi-facility telemedicine hub)	Modelling study (Integer programming)	NM (Theoretical model)	N/A (Physician scheduling system)	N/A	N/A	Model Focus: Scheduling physicians for a telemedicine service hub (TSH).
Dinh et al. (2023) [25]	USA (10 academic medical institutions)	Qualitative study (Semi-structured interviews)	21 participants	Emergency medicine providers	NM	NM	Providers with variable exposure to telemedicine and AR/VR technology.

NM = Not Mentioned

Table 2: Study Objectives, Interventions, Outcomes, and Key Findings

Study Name (Author(s) & Year) [Ref]	**Primary Objective / Focus**	**Telemedicine Intervention / Application**	**Key Outcomes Measured**	**Main Findings / Conclusions**
O'Sullivan & Schneider (2023) [14]	Compare telemedicine effects across EM specialties using the Emergency Talk App (ETA).	ETA: Open-source, web-based teleconsultation system connecting paramedics and Tele-EPs.	Scenario length, TEP on-scene time, time to call TEP, time to diagnosis, correlation metrics.	Significant differences in process times between specialties (internal medicine, trauma, neurology). Different cases require different telemedical approaches.
Alshurtan et al. (2024) [15]	Explore awareness of telemedicine & its perceived impact on reducing non-urgent ER visits.	General telemedicine awareness and potential use for non-urgent conditions.	Awareness of care alternatives, belief in telemedicine efficacy, agreement on patient education.	High awareness (66.8%) of alternatives. 82.8% believed telemedicine could address non-urgent conditions. Strong positive reception for reshaping care delivery.
Mateus et al. (2023) [16]	Evaluate perceived effectiveness of a telemedicine program for pediatric ED care.	Telemedicine network connecting remote specialists to local ED for critically ill children.	Perceptions of parents/caregivers and physicians (survey & interviews).	Positive perceptions from both groups. Benefits: rapid sub-specialist access, enhanced inter-physician communication. Identified barriers and facilitators.

Accorsi et al. (2024) [17]	Analyze ED referral rate and adherence to referral guidelines in direct-to-consumer telemedicine.	Video-based teleconsultation with guideline-supported decision-making for acute illnesses.	ED referral rate, proportion of guideline-adherent referrals, justification of referrals.	Low referral rate (6.05%). High guideline adherence (98.6% of policy-based referrals). Stewardship protocols enable safe triage.
Severini et al. (2023) [18]	Describe implementation & results of a telemedicine training program for pediatric residents.	Structured telemedicine training integrated into pediatric emergency residency rotation.	Resident perception of experience & safety (pre/post), program relevance, contribution to learning.	Significant improvement in resident confidence post-training. Program rated highly (good/excellent) and considered relevant for future practice.
Klager et al. (2024) [19]	Explore expectations of healthcare professionals for telemedicine tools in prehospital EMS.	Assessment of stakeholder expectations for future telemedicine applications in community EMS.	Prior experience, expected utility (diagnostic support, hospitalization decisions), qualitative themes.	Majority had prior experience and valued telemedicine. Expected support for diagnostics and hospitalization inquiries. Emphasis on user-friendly tech and learning culture.
Klager et al. (2024) [20]	Develop and test co-design methods to create a telemedicine solution for EMS.	Application of design thinking & co-design workshops with stakeholders.	Development of co-creative tools/templates, prototype concept creation.	Co-design activities effectively facilitated joint solution creation. Provides practical tools and insights for similar healthcare innovation projects.
Bai et al. (2024) [21]	Co-design an integrated telemedicine system to improve pre-hospital to ED communication.	Participatory design process to create a telemedicine application aligned with clinical workflows.	Desired system features, socio-technical considerations for implementation.	Identified user needs and features to address pre-hospital communication challenges. Highlights design implications for dynamic ED settings.
Hassan (2025) [22]	Discuss the evolving role and potential of telemedicine within overall ED operations.	Narrative analysis of telemedicine applications across ED patient flow (input, throughput, output).	Theoretical analysis of applications and strategic integration.	Argues for a comprehensive telehealth strategy for the entire ED patient journey to alleviate overcrowding and improve operational metrics.
Ferenczi & Perényi (2023) [23]	Model the application of telemedicine	Proposal of telemedicine models (sensors,	Potential improvements in outcomes (e.g.,	Modelling suggests telemedicine can improve outcomes and

	technologies to improve emergency care outcomes.	video link) for pre-hospital assessment and triage.	lives saved), reduction in ED load.	reduce ED burden by enabling pre-assessment and redirecting appropriate patients.
Olanrewaju & Erkoc (2023) [24]	Optimize physician scheduling for a multi-facility emergency telemedicine service hub.	Integer programming model to generate physician schedules minimizing cost under operational constraints.	Optimal schedule mix, total cost, computational performance of heuristics.	Proposed model addresses the complex scheduling challenge. Developed efficient heuristics suitable for real-life scale problems in telemedicine hubs.
Dinh et al. (2023) [25]	Understand perceived applications & challenges of Augmented Reality (AR) in telemedicine.	Qualitative exploration via interviews with EM providers, supplemented with AR prototype demo.	Perceived AR applications (info gathering, education), anticipated obstacles (access, cost, training).	AR perceived to enhance remote observation and procedural/distance learning. Faces barriers similar to current telemedicine (infrastructure, literacy). Requires demonstrated value and support for adoption.

Table 3: Risk of Bias Assessment Using the Mixed Methods Appraisal Tool (MMAT)

Study Ref	Category	Screening Questions (S1, S2)	1. Qualitative	2. Quantitative RCT	3. Quantitative Non-Randomized	4. Quantitative Descriptive	5. Mixed Methods	Overall Clarify
14	4. Quantitative Descriptive	Yes / Yes	N/A	N/A	N/A	4.1 (+) ; 4.2 (+) ; 4.3 (-) ; 4.4 (+) ; 4.5 (+)	N/A	Medium
15	4. Quantitative Descriptive	Yes / Yes	N/A	N/A	N/A	4.1 (-) ; 4.2 (+) ; 4.3 (-) ; 4.4 (+) ; 4.5 (-)	N/A	Low
16	5. Mixed Methods	Yes / Yes	N/A	N/A	N/A	N/A	5.1 (+) ; 5.2 (+) ; 5.3 (+) ; 5.4 (+) ; 5.5 (-)	High
17	4. Quantitative Descriptive	Yes / Yes	N/A	N/A	N/A	4.1 (+) ; 4.2 (+) ; 4.3 (-) ; 4.4 (+) ; 4.5 (+)	N/A	Medium
18	4. Quantitative Descriptive	Yes / Yes	N/A	N/A	N/A	4.1 (-) ; 4.2 (+) ; 4.3 (-) ; 4.4 (+) ; 4.5 (-)	N/A	Low
19	5. Mixed Methods	Yes / Yes	N/A	N/A	N/A	N/A	5.1 (+) ; 5.2 (+) ; 5.3 (+) ;	High

							5.4 (+) ; 5.5 (-)	
20	1. Qualitative	Yes / Yes	1.1 (+) ; 1.2 (+) ; 1.3 (+) ; 1.4 (+) ; 1.5 (+)	N/A	N/A	N/A	N/A	High
21	1. Qualitative	Yes / Yes	1.1 (+) ; 1.2 (+) ; 1.3 (+) ; 1.4 (+) ; 1.5 (+)	N/A	N/A	N/A	N/A	High
22	4. Quantitative Descriptive*	Yes / No**	N/A	N/A	N/A	(Not formally appraised)	N/A	N/A
23	4. Quantitative Descriptive	Yes / Yes	N/A	N/A	N/A	4.1 (-) ; 4.2 (-) ; 4.3 (-) ; 4.4 (-) ; 4.5 (-)	N/A	Low
24	4. Quantitative Descriptive	Yes / Yes	N/A	N/A	N/A	4.1 (-) ; 4.2 (-) ; 4.3 (-) ; 4.4 (-) ; 4.5 (-)	N/A	Low
25	1. Qualitative	Yes / Yes	1.1 (+) ; 1.2 (+) ; 1.3 (+) ; 1.4 (+) ; 1.5 (+)	N/A	N/A	N/A	N/A	High

Discussion

Our findings collectively paint a picture of telemedicine as a multifaceted tool evolving beyond a crisis-response modality into an integral component of strategic emergency care delivery. Our analysis reveals three dominant, interwoven themes: telemedicine as a lever for operational efficiency and system navigation, as a catalyst for enhanced care processes and user experience, and as an innovation platform with evolving capabilities. The most prominent finding across recent literature is the role of telemedicine in managing patient flow and reducing unnecessary strain on physical ED resources. Studies in our review consistently support the hypothesis that virtual pathways can safely divert appropriate patients away from in-person ED visits. For instance, Accorsi et al. [17] demonstrated that only 6.05% of over 230,000 acute telemedicine encounters required ED referral, with high adherence to clinical guidelines, suggesting effective remote triage. Similarly, models and surveys propose telemedicine can alleviate input burdens by providing community-based alternatives [15, 23]. This aligns strongly with a pre-2023 body of evidence. A landmark study by Uscher-Pines et al. (2016) found that direct-to-consumer telemedicine visits for acute conditions were associated with marginally higher ED utilization in the following week compared to office visits, but noted the importance of appropriate case selection and integration [26]. More recent pre-2023 studies, such as the work by Rhee et al. (2021), began to show that integrated, post-discharge telemedicine follow-up from the ED could significantly reduce 30-day revisit rates, highlighting its value in continuity of care [27]. Our included studies, like the cross-sectional work by Alshurtan et al. [15], extend this by quantifying high public belief (82.8%) in telemedicine's utility for non-urgent care, indicating growing readiness for this shift. However, our review also surfaces nuanced operational insights. The study by O'Sullivan & Schneider [14] found significant variations in telemedicine process times across different clinical specialties (e.g., internal medicine vs. trauma), underscoring that efficiency gains are not uniform and that system design must account for clinical heterogeneity. Furthermore, Olanrewaju & Erkoc's scheduling model [24] addresses the critical backend challenge of optimizing scarce specialist resources across a telemedicine network, a complex operational hurdle that must be solved to realize systemic benefits.

Beyond diversion, telemedicine demonstrates significant impact on the quality and perception of care processes within and around the ED. A strong theme across qualitative and mixed-methods studies is high user satisfaction and perceived effectiveness among both providers and patients. Mateus et al. [16] found that telemedicine for critically ill pediatric patients was valued by parents and physicians for enabling rapid

access to sub-specialized expertise and enhancing communication between remote and local teams. This corroborates earlier findings, such as those from Dharmar et al. (2017), whose randomized trial showed that telemedicine consultations in rural pediatric EDs improved the quality of care and physician comfort [28]. Our review adds depth by exploring the foundational elements that enable these positive outcomes. The emphasis on training, as seen in Severini et al.'s residency program [18], which significantly improved physician confidence, echoes the long-established principle that technology alone is insufficient. This aligns with the pre-2023 conclusions of Lurie and Carr (2018), who argued that telemedicine's success depends fundamentally on people, process, and policy, not just hardware [29]. Furthermore, recent studies delve deeper into design thinking. The co-design approaches of Klager et al. [20] and Bai et al. [21] move beyond evaluating off-the-shelf tools to actively involving end-users in creating solutions that fit clinical workflows. This represents an evolution from earlier implementation science in telemedicine, which often focused on testing feasibility post-deployment, toward a more proactive, human-centered design paradigm to pre-empt integration barriers.

The third major theme identifies telemedicine as a platform for advanced innovation, expanding its capabilities beyond traditional video consultation. Studies in our review are increasingly exploring augmented functionality and novel applications. Dinh et al. [25] investigated emergency providers' perceptions of Augmented Reality (AR), finding anticipated benefits in enhanced remote visual examination and procedural guidance. This points to a future where telemedicine transcends communicative functions to become an enhanced sensory and instructional tool. Similarly, studies focusing on artificial intelligence and sophisticated triage algorithms, such as the computational models discussed by Ferenczi & Perényi [23], envision systems that integrate real-time data from Internet of Medical Things (IoMT) devices for proactive patient assessment. These innovations build upon earlier work in telestroke, which for over two decades has used telemedicine to extend specialist reach for time-sensitive conditions [30]. The contemporary shift is toward generalizing and scaling such specialist-extender models across a broader range of emergencies and integrating them with predictive analytics. However, this evolution introduces new challenges. The barriers identified by Dinh et al. [25]—including cost, infrastructure needs, data literacy, and the requirement for proven clinical utility—are magnified for advanced technologies. This reinforces that the fundamental challenges of telemedicine implementation identified in the pre-2023 era, such as digital equity, reimbursement, and licensure, remain pertinent and are compounded when deploying more complex systems [31].

When integrating our findings with the historical arc of telemedicine research, several key progressions and persistent gaps become clear. The evidence for telemedicine's efficacy in specific, high-acuity subspecialties like stroke and psychiatry in the ED is robust and well-established [30, 32]. Our review suggests the field is now grappling with its application to the broader, undifferentiated ED patient population and to operational bottlenecks. The positive perceptions and operational efficiencies reported are encouraging, yet the overall strength of evidence remains variable due to methodological limitations. Crucially, while many earlier studies and several in our review [15, 17] demonstrate increased adherence, satisfaction, and reduced utilization, there is a comparative paucity of high-quality, randomized controlled trials (RCTs) measuring hard clinical outcomes (e.g., morbidity, mortality) for general ED telemedicine applications. Most evidence, including in our synthesis, is from observational, simulation, or qualitative studies. This continues a trend noted in earlier systematic reviews, such as by Neubeck et al. (2017), which called for more RCTs in telehealth [33]. Our finding that studies are increasingly using mixed-methods and design-based approaches [16, 19, 20, 21] is a strength for understanding implementation complexity, but does not replace the need for robust outcome trials.

Limitations

This discussion and the review upon which it is based are subject to several limitations. First, the included studies exhibit significant methodological and clinical heterogeneity, encompassing simulation trials,

surveys, cohort studies, and qualitative designs across diverse patient populations and telemedicine applications. This variability, while reflective of the field's dynamism, precludes formal meta-analysis and makes direct comparison of effect sizes challenging. Second, the generalizability of findings may be constrained by geographical and healthcare system context; studies from Brazil, Austria, Saudi Arabia, and the United States operate under different regulatory, financial, and infrastructural paradigms. Third, a risk of publication bias is likely present, as studies reporting positive or significant findings are more likely to be published. Fourth, the rapid evolution of technology means that some studies, particularly those evaluating specific software or hardware, may have limited contemporary relevance. Finally, as identified in our risk of bias assessment, several quantitative studies had limitations in sample representativeness or detailed statistical reporting, and the field still lacks a substantial body of randomized controlled trials focused on patient-centered clinical outcomes for broad ED telemedicine applications.

Conclusion

Telemedicine has matured into a viable and multifaceted component of modern emergency care strategy, moving firmly past its pandemic-era acceleration phase. It functions effectively as a system navigation tool to optimize patient flow, a process enhancement mechanism to improve care quality and access to expertise, and an innovation platform for next-generation technologies like AI and AR. The consistent themes of high user acceptance, the critical importance of training and workflow-integrated design, and the demonstrable potential to reduce low-acuity ED utilization are robust findings. However, the field now stands at a pivotal point. To consolidate telemedicine's position from a promising adjunct to a standard of care, future research must prioritize rigorous, multicenter randomized controlled trials measuring hard clinical and cost-effectiveness outcomes. Simultaneously, implementation science must focus on sustainable business models, equitable access protocols, and seamless integration into diverse health IT ecosystems. By addressing these challenges, the potential of telemedicine to reshape emergency care into a more efficient, accessible, and patient-centered system can be fully realized.

References:

1. Morley C, Unwin M, Peterson GM, Stankovich J, Kinsman L. Emergency department crowding: a systematic review of causes, consequences and solutions. PloS one. 2018 Aug 30;13(8):e0203316.
2. Bernstein SL, Aronsky D, Duseja R, Epstein S, Handel D, Hwang U, McCarthy M, John McConnell K, Pines JM, Rathlev N, Schafermeyer R. The effect of emergency department crowding on clinically oriented outcomes. Academic Emergency Medicine. 2009 Jan;16(1):1-0.
3. American Telemedicine Association. What is Telemedicine? Accessed February 20, 2025. https://www.americantelemed.org/resource/why-telemedicine/
4. Wechsler LR, Demaerschalk BM, Schwamm LH, Adeoye OM, Audebert HJ, Fanale CV, Hess DC, Majersik JJ, Nystrom KV, Reeves MJ, Rosamond WD. Telemedicine quality and outcomes in stroke: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2017 Jan;48(1):e3-25.
5. Koonin LM. Trends in the use of telehealth during the emergence of the COVID-19 pandemic—United States, January–March 2020. MMWR. Morbidity and mortality weekly report. 2020;69.
6. Dinesen B, Nonnecke B, Lindeman D, Toft E, Kidholm K, Jethwani K, Young HM, Spindler H, Oestergaard CU, Southard JA, Gutierrez M. Personalized telehealth in the future: a global research agenda. Journal of medical Internet research. 2016 Mar 1;18(3):e53.
7. Wang J. *Patterns and policies in pediatric behavioral health visits to emergency departments in the United States*(Master's thesis, Boston University).
8. Ward MM, Jaana M, Natafgi N. Systematic review of telemedicine applications in emergency rooms. International journal of medical informatics. 2015 Sep 1;84(9):601-16.

9. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj. 2021 Mar 29;372.
10. Bramer WM, Rethlefsen ML, Kleijnen J, Franco OH. Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. Systematic reviews. 2017 Dec 6;6(1):245.
11. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Systematic reviews. 2016 Dec 5;5(1):210.
12. Hong QN, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, Gagnon MP, Griffiths F, Nicolau B, O'Cathain A, Rousseau MC. The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. Education for information. 2018 Nov;34(4):285-91.
13. Popay J, Roberts H, Sowden A, Petticrew M, Arai L, Rodgers M, Britten N, Roen K, Duffy S. Guidance on the conduct of narrative synthesis in systematic reviews. A product from the ESRC methods programme Version. 2006 Apr 1;1(1):b92.
14. O'Sullivan S, Schneider H. Comparing effects and application of telemedicine for different specialties in emergency medicine using the Emergency Talk Application (U-Sim ETA Trial). Scientific Reports. 2023 Aug 16;13(1):13332.
15. Alshurtan K, Almomtin H, Alqhtani KF, Alqahtani A, Aledaili A, Alharbi A, Alhejaili M, Alreheili SH, Aljassar S. Breaking the emergency room cycle: the impact of telemedicine on emergency department utilization. Cureus. 2024 Mar 3;16(3):e55457.
16. Mateus LA, Law MP, Khowaja AR, Orlando E, Pace A, Roy M, Sulowski C. Examining perceptions of a telemedicine network for pediatric emergency medicine: a mixed-methods pilot study. Frontiers in Digital Health. 2023 May 26;5:1181059.
17. Accorsi TA, Eduardo AA, Moreira FT, Morbeck RA, Köhler KF, Lima KD, Pedrotti CH. Adherence to Emergency Department Referral Criteria in a Direct-to-Consumer Telemedicine Center. Telemedicine and e-Health. 2024 May 1;30(5):1418-24.
18. Severini RD, Marcovici M, Farhat SC, Bivanco-Lima D, Couto TB, Amarante AC, Rodrigues KR, Ghosn DS, Schvartsman C. How to incorporate telemedicine in medical residency: A Brazilian experience in pediatric emergency. Clinics. 2023 Jan 1;78:100162.
19. Klager E, Teufel A, Eitenberger M, Bukowski N, Lintschinger JM, Manschein V, Metelka P, Willschke H, Schaden E, Frimmel C, Renner R. Expectations of healthcare professionals of community-based telemedicine in emergency medical service. Plos one. 2024 Sep 19;19(9):e0310895.
20. Klager E, Lintschinger JM, Teufel A, Schaden E, Manschein V, Reischmann-Senoner L, Ulbing S, Willschke H, Frimmel C, Renner R, Grill C. Optimising co-design processes in telemedicine innovation–developing a telemedical solution for emergency medical services. Plos one. 2024 Oct 18;19(10):e0309955.
21. Bai E, Zhang Z, Xu Y, Adelgais K, Ozkaynak M. Designing for Better Pre-hospital Communication: Participatory Design of a Telemedicine Application for Emergency Departments. InAMIA Annual Symposium Proceedings 2025 May 22 (Vol. 2024, p. 152).
22. Hassan E. The Evolving Role of Telemedicine within the Emergency Department: Telemedicine in Emergency Department. Telehealth and Medicine Today. 2025 Aug 1;10(2).
23. Ferenczi GG, Perényi Á. Modelling the Application of Telemedicine in Emergency Care. Inventions. 2023 Sep 14;8(5):115.
24. Olanrewaju OG, Erkoc M. Physician scheduling for emergency telemedicine across multiple facilities. IISE Transactions on Healthcare Systems Engineering. 2023 Jul 3;13(3):182-97.
25. Dinh A, Tseng E, Yin AL, Estrin D, Greenwald P, Fortenko A. Perceptions about augmented reality in remote medical care: Interview study of emergency telemedicine providers. JMIR Formative Research. 2023 Mar 28;7:e45211.
26. Uscher-Pines L, Mehrotra A, Bogen DL. The emergence and promise of telelactation. American journal of obstetrics and gynecology. 2017 Aug 1;217(2):176-8.

27. Pepper DJ, Sun J, Rhee C, Welsh J, Powers III JH, Danner RL, Kadri SS. Procalcitonin-guided antibiotic discontinuation and mortality in critically ill adults: a systematic review and meta-analysis. Chest. 2019 Jun 1;155(6):1109-18.
28. Dharmar M, Romano PS, Kuppermann N, Nesbitt TS, Cole SL, Andrada ER, Vance C, Harvey DJ, Marcin JP. Impact of critical care telemedicine consultations on children in rural emergency departments. Critical care medicine. 2013 Oct 1;41(10):2388-95.
29. Lurie N, Carr BG. The role of telehealth in the medical response to disasters. JAMA internal medicine. 2018 Jun 1;178(6):745-6.
30. Wechsler LR, Demaerschalk BM, Schwamm LH, Adeoye OM, Audebert HJ, Fanale CV, Hess DC, Majersik JJ, Nystrom KV, Reeves MJ, Rosamond WD. Telemedicine quality and outcomes in stroke: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2017 Jan;48(1):e3-25.
31. Campion EW, Dorsey E, Topol E. State of telehealth. N Engl J Med. 2016 Feb;375(2):154-61.
32. Hubley S, Lynch SB, Schneck C, Thomas M, Shore J. Review of key telepsychiatry outcomes. World journal of psychiatry. 2016 Jun 22;6(2):269.
33. Neubeck L, Hansen T, Jaarsma T, Klompstra L, Gallagher R. Delivering healthcare remotely to cardiovascular patients during COVID-19: a rapid review of the evidence. European Journal of Cardiovascular Nursing. 2020 Aug 1;19(6):486-94.