Research Article

# A Comprehensive Review of Telemedicine Roles in Emergency Department Settings

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**Abstract**

Emergency departments (EDs) worldwide face persistent challenges including overcrowding, workforce shortages, prolonged waiting times, and inequitable access to specialist care. Telemedicine has emerged as a promising strategy to complement traditional emergency care by enabling remote triage, pre-hospital assessment, specialist consultation, and follow-up. This comprehensive review synthesises the available evidence on the roles, effectiveness, economic impact, implementation barriers, and regulatory considerations of telemedicine in emergency department settings.

The review examines six major domains: telemedicine in emergency triage and pre-hospital care; remote specialist consultation in acute and high-acuity emergencies; clinical effectiveness, patient outcomes, and quality of care; cost-effectiveness and resource utilisation; implementation barriers, technological challenges, and facilitators; and regulatory, ethical, and future directions for tele-emergency medicine. Evidence was drawn from systematic reviews, randomised controlled trials, observational studies, economic evaluations, qualitative studies, and policy documents, and was synthesised thematically across clinical, economic, organisational, and ethical dimensions.

The findings indicate that tele-triage improves diagnostic accuracy, reduces re-consultation rates, enhances treatment adherence, and shortens emergency department throughput times, although its impact on high-acuity presentations remains less pronounced. Pre-hospital teleconsultation reduces on-scene time, improves stroke and trauma outcomes, and decreases unnecessary interfacility transfers. Remote specialist consultation—particularly telestroke, tele-trauma, tele-ICU, and cardiac teleconsultation—reduces door-in-door-out times, increases rates of time-critical interventions such as thrombolysis and thrombectomy, improves functional outcomes, and lowers transfer rates. Economic evaluations consistently demonstrate favourable cost-effectiveness, with transfer avoidance generating savings ranging from US $73 to US $5,118 per encounter. Patient satisfaction with tele-emergency care is generally high. However, implementation is constrained by connectivity limitations, inadequate infrastructure, poor electronic health record integration, insufficient training, clinician resistance, credentialing delays, reimbursement inconsistencies, and the absence of physical examination capabilities. Ethical and regulatory challenges include informed consent in urgent situations, privacy and data protection, cross-border licensure, equity of access, and governance of artificial intelligence. Future directions point toward integrated hybrid care models, AI-assisted decision support, wearable devices, 5G-enabled networks, interoperable regulatory frameworks, and equity-focused implementation.

**Keywords** Telemedicine; Emergency Department; Tele-emergency Medicine; Tele-triage; Cost-effectiveness; Implementation Barriers; Emergency Care.

## Introduction

Emergency departments (EDs) worldwide are confronting unprecedented operational pressures. Overcrowding, prolonged waiting times, workforce shortages, and geographic disparities in access to specialist care have collectively compromised the capacity of emergency care systems to deliver timely, high-quality treatment [1]. These challenges are not confined to any single health system or region; they represent a global phenomenon that has intensified in recent years due to population ageing, rising multimorbidity, and the lingering effects of the COVID-19 pandemic on healthcare delivery [2]. In this context, telemedicine—the remote delivery of clinical services through information and communication technologies—has emerged as a promising strategy to augment traditional emergency care, enabling remote consultation, triage, and real-time specialist input without requiring the physical presence of a provider [3].

The integration of telemedicine into emergency medicine, often referred to as "tele-emergency medicine" or "tele-EM," has attracted considerable attention from clinicians, health administrators, and policymakers alike. Systematic reviews have documented that tele-EM interventions can improve diagnostic accuracy, reduce re-consultation rates, and enhance treatment adherence, particularly in non-critical cases [4]. A comprehensive systematic review of 1,195 studies identified 17 that met inclusion criteria, revealing that tele-EM was associated with a 20% reduction in transfer rates in rural emergency departments and a 30% decrease in paediatric interfacility transfers [5]. Furthermore, tele-EM shortened time to treatment, with a 20-minute reduction in time-to-ECG for myocardial infarction patients and a 50% reduction in time-to-head CT interpretation for neurological emergencies [5]. These findings underscore the potential of telemedicine to enhance both the efficiency and the clinical effectiveness of emergency care.

The COVID-19 pandemic served as a critical catalyst for the widespread adoption of telemedicine in emergency settings [6]. Prior to 2020, telemedicine had already demonstrated value in remote locations and primary care, but the pandemic accelerated its implementation across emergency departments, driven by the dual imperatives of minimizing viral transmission and protecting healthcare workers [6]. Regulatory flexibilities, including the allowance for telehealth visits to be billed at parity with in-person visits, further facilitated this expansion [7]. As healthcare systems transition into the post-pandemic era, the question of whether telehealth remains a vital tool in emergency medicine—or whether it should be scaled back—has become a subject of active debate [8].

Telemedicine applications in emergency departments span a diverse array of clinical functions, ranging from pre-hospital triage and tele-triage to specialist teleconsultation and post-discharge follow-up. Pre-hospital virtual triage models, such as the Virtual Triage Assessment and Care (VTAC) model, have demonstrated feasibility in real-world settings, enabling senior medical assessment 81 minutes earlier than conventional pathways and reducing emergency department length of stay by approximately 14% [9]. Tele-triage, which involves remote screening of patients to determine acuity and appropriate disposition, has been shown to improve patient flow and optimize resource allocation [10]. In specialty areas such as stroke care, videoconferencing teleconsultation has been associated with significant reductions in door-in-door-out times and higher rates of reperfusion therapy, ultimately improving functional outcomes at 90 days [11].

The economic case for telemedicine in emergency care has also gained empirical support. A systematic review of cost-effectiveness studies found that virtual emergency care models consistently achieved favourable economic outcomes, with video consultations reducing patient transfers by 31% to 73% and generating cost savings ranging from US $73 to US $5,118 per encounter [12]. Transfer avoidance emerged as the primary economic driver, particularly in rural and remote settings where the costs and risks of interfacility transport are substantial [12]. These findings provide robust economic justification for expanding virtual emergency care access, especially for stroke care, paediatric emergencies, and underserved populations [12].

Despite these promising results, the integration of telemedicine into emergency department workflows is not without challenges. Technological barriers—including poor connectivity, insufficient infrastructure, and limited integration with existing electronic health record systems—remain significant obstacles in many settings [13]. A cross-sectional study conducted in Yemen found that 73% of respondents cited poor connectivity as a major barrier to emergency telemedicine adoption, followed by limited trust or awareness (49%), insufficient staff training (43.7%), and weak infrastructure (42.2%) [13]. Similar concerns have been reported in high-income countries, where healthcare professionals have expressed reservations about care quality, technological reliability, and increased workload associated with telemedicine implementation [2]. The lack of physical examination capabilities inherent in remote consultations also raises legitimate concerns about diagnostic accuracy, particularly in high-acuity presentations [14].

The evidence base for telemedicine in emergency settings, while growing, remains heterogeneous in quality and scope. Many studies are observational rather than experimental, limiting the strength of inferences that can be drawn about causality and generalizability [9]. Systematic reviews have noted that small sample sizes and the inability to blind participants may introduce bias, and the impact of telemedicine on high-acuity cases—such as emergency airway management—appears less pronounced than its effects on lower-acuity presentations [3]. Moreover, regional biases in the published literature may limit the applicability of findings to diverse healthcare contexts and patient populations [5]. These methodological limitations underscore the need for high-quality randomized controlled trials and multicentre studies to establish the efficacy and safety of tele-EM across the full spectrum of emergency conditions.

The role of telemedicine in emergency departments must also be understood within the broader context of health system integration. Telemedicine is not intended to replace in-person emergency care but rather to complement it as part of an integrated strategy that leverages the strengths of both modalities [3]. This integrated approach requires careful attention to workflow design, provider training, patient education, and regulatory frameworks that govern licensure, privacy, and reimbursement [14]. The successful implementation of tele-EM programmes depends on aligning technological capabilities with clinical needs and ensuring that virtual care pathways are seamlessly embedded into existing emergency care processes [9].

## Telemedicine in Emergency Triage and Pre-Hospital Care

Emergency department (ED) overcrowding remains one of the most pressing challenges confronting healthcare systems globally, contributing to prolonged waiting times, delayed treatment, and adverse patient outcomes [10]. In response, telemedicine has emerged as a transformative tool capable of extending clinical expertise beyond the physical walls of the ED, enabling remote triage, pre-hospital assessment, and real-time specialist consultation at the point of first patient contact. The integration of telemedicine into triage and pre-hospital care pathways represents a paradigm shift in emergency medicine, offering the potential to optimize patient flow, reduce unnecessary ED attendances, and accelerate time-critical interventions.

Tele-triage, defined as the remote assessment and prioritization of patients based on clinical urgency, has become a cornerstone of tele-emergency medicine. A systematic review of telemedicine interventions in ED settings demonstrated that tele-triage significantly improves diagnostic accuracy, reduces re-consultation rates, and enhances treatment adherence, with high diagnostic concordance observed between remote and in-person assessments, particularly in non-critical cases [10]. The review further noted that telemedicine-supported triage was associated with shorter throughput times and higher patient satisfaction compared to traditional care models, although its impact on high-acuity presentations such as emergency airway management appeared less pronounced [10]. These findings underscore the potential of tele-triage to complement conventional triage processes, ensuring that patients are directed to the most appropriate level of care without unnecessary delays.

The accuracy of remote triage systems has been a subject of extensive investigation, with studies examining both clinician-led and algorithm-based approaches. A large observational study conducted within England's urgent care telephone triage system—comprising non-clinician-led primary triage (NHS111) followed by clinician-led secondary triage—revealed that clinician-led triage demonstrated superior specificity and positive predictive value for identifying patients requiring ED attendance or inpatient admission. The positive predictive value for attending ED after being assigned a triage urgency level of within two hours was 46.0% for secondary triage compared to 20.7% for primary triage, while for inpatient admission it was 18.0% and 9.2%, respectively [14]. The study also identified potential under-triage associated with calls made between midnight and 6am and with shorter call durations, highlighting the need for targeted improvements in triage protocols to ensure patient safety across all hours of service [14]. Furthermore, integrating emergency medicine physician consultation into nurse triage phone lines has been shown to alter triage disposition in more than 40% of cases, with physicians downgrading recommendations in 34% of consultations and upgrading in 10%, demonstrating the value of specialist oversight in refining triage decisions [11].

In the pre-hospital domain, telemedicine applications span a diverse range of functions, from ambulance dispatch teleconsultation to real-time vital signs monitoring during patient transport. A randomized pilot study investigating the effect of telemedicine-based medical data collection during ambulance dispatch found that teleconsultation via a mobile application significantly reduced on-scene evaluation time, with the telemedicine group achieving a mean on-scene time of 20.45 minutes compared to 36.80 minutes in the standard care group ($p = 0.019$) [15]. This reduction in on-scene time is clinically meaningful, as it translates directly into earlier hospital arrival and faster initiation of definitive care for time-sensitive conditions. Similarly, a mixed-methods feasibility study examining specialist-led video consultation in the pre-hospital stroke chain of care found that video consultation was perceived by ambulance nurses and neurologists as clinically relevant and potentially time-saving, particularly by supporting direct transport decisions and avoiding unnecessary intermediate stops [16]. The study emphasized that successful implementation of pre-hospital video consultation depends not only on functional technology but also on sustained organizational ownership, continuous training, and clear activation pathways—factors that are essential for embedding telemedicine into routine clinical practice [16].

The clinical effectiveness of pre-hospital telemedicine has been demonstrated across multiple emergency conditions, with particularly robust evidence in trauma and stroke care. A systematic review and meta-analysis encompassing 45,097 trauma patients across 25 studies found that telemedicine use in trauma care was associated with higher Injury Severity Scores, likely reflecting improved detection and documentation of severe injuries through specialist input, as well as increased blood transfusion rates that may indicate more accurate triage and timely intervention [7]. While telemedicine did not demonstrate a statistically significant effect on mortality or transfer times, the findings support the integration of telemedicine into standard trauma care systems, particularly in rural and underserved areas where access to specialist expertise is limited [7]. In stroke care, a randomized trial comparing telemedicine and onboard neurologist models on a mobile stroke unit found that the telemedicine model was superior based on a composite hierarchical outcome of safety, scene-to-treatment-decision time, and the percentage of the neurologist's time spent in direct care [12]. The telemedicine model achieved a median scene-to-treatment-decision time of 19 minutes compared to 13 minutes for the onboard model, and notably, the percentage of the neurologist's time directly involved in patient care was 100% in the telemedicine group versus 33% in the onboard group, demonstrating more efficient use of specialist resources [12].

The application of telemedicine in pre-hospital care for traffic accidents has also yielded promising results. A multicenter study employing wearable devices to collect and transmit real-time vital signs—including heart rate, blood pressure, oxygen saturation, and trauma index—found that the telemedicine group achieved a 38.2% reduction in pre-hospital response time and a 24.7% decrease in secondary injury incidence compared to traditional protocols [13]. The system identified 85.6% of critical cases in advance through real-time monitoring, with remote-guided interventions such as hemostasis and position management reducing post-traumatic complications by 31.4% [13]. The intelligent triage model demonstrated 92.3% accuracy in treatment priority prediction and improved regional emergency resource utilization by 28.5%, underscoring the potential of telemedicine to enhance both clinical outcomes and system efficiency in pre-hospital trauma care [13].

Despite these encouraging findings, the evidence base for remote pre-hospital triage remains fragmented, with significant gaps in the literature regarding safety and effectiveness. A systematic review commissioned by the Health Research Board in Ireland concluded that there is a lack of strong evidence to determine whether remote pre-hospital triage is safe or effective for reducing unnecessary ED attendances among adults [8]. The review found that most studies of general triage services focused on particular symptoms or specific triage dispositions, and the evidence on specific triage services was of very low certainty, with no existing reference guidelines for the conditions examined [8]. The authors emphasized the need for larger studies reporting on all users of general triage services and comparing outcomes to reference guidelines in order to establish safety and effectiveness with greater certainty [8]. This evidence gap highlights the importance of continued research to validate remote triage protocols and ensure that they do not inadvertently compromise patient safety through under-triage or over-triage.

Implementation barriers to telemedicine in emergency triage and pre-hospital care are multifaceted, encompassing technological, organizational, and human factors. A chapter examining remote consultation in primary care during emergencies identified limitations primarily related to the lack of physical examination capabilities, which can compromise diagnostic accuracy, as well as the substantial investments in technological infrastructure and workforce training required to establish and sustain effective remote consultation systems [17]. Equitable access remains another significant concern, as socioeconomic and digital divides may prevent specific populations from fully benefiting from telemedicine services [17]. In pediatric emergency care, a systematic review found that while telemedicine improves access to pediatric specialists, enhances triage and diagnostic accuracy, and reduces unnecessary interfacility transfers, implementation barriers include provider resistance, infrastructure limitations, and variability in adoption [18]. The review concluded that telemedicine demonstrates clear benefits in pediatric emergency care, particularly in underserved settings, but broader adoption and further outcome-based research are needed to optimize its role [18].

The economic case for telemedicine in emergency triage and pre-hospital care has also been explored, with studies demonstrating favorable cost-effectiveness profiles. A systematic review of telemedicine interventions for acute myocardial infarction found that electrocardiogram pre-hospital telemedicine triage compared with conventional emergency department triage yielded a cost per STEMI QALY saved of $3,010.84, indicating that telemedicine-supported pre-hospital triage is economically justifiable [19]. In another study included in the review, eHealth intervention for patients with acute myocardial infarction was less costly and provided more quality of life, with a cost reduction of $661.17 per patient and a mean QALY of 0.74 for the intervention group compared to 0.69 for the control group [19]. These findings suggest that pre-hospital telemedicine triage not only improves clinical outcomes

but also generates meaningful cost savings for healthcare systems, particularly when considering the avoided costs of unnecessary transfers and delayed treatment.

The integration of telemedicine into emergency triage and pre-hospital care requires a balanced approach that leverages the strengths of both remote and in-person modalities. Telemedicine is not intended to replace in-person emergency care but rather to complement it as part of an integrated strategy that ensures patients receive the right care at the right time and in the right setting [10].

## Remote Specialist Consultation in Acute and High-Acuity Emergencies

The management of acute and high-acuity emergencies demands immediate access to specialist expertise, yet many emergency departments—particularly those in rural, remote, or resource-limited settings—lack on-site specialists across critical disciplines such as neurology, trauma surgery, cardiology, and intensive care [20]. Remote specialist consultation via telemedicine has emerged as a transformative solution to this challenge, enabling emergency physicians to obtain real-time expert guidance without requiring patient transfer or specialist relocation. The evidence base supporting this application of telemedicine has grown substantially, with systematic reviews demonstrating that specialty telehealth consultations in emergency care settings increase appropriate transfers and admissions while decreasing the time from presentation to clinical decision and the overall duration of emergency department stay [21]. These intermediate outcomes are clinically meaningful, as they directly influence patient flow, resource utilization, and the timeliness of definitive treatment.

## Telestroke and Neurological Emergencies

The most extensively studied application of remote specialist consultation in emergency medicine is telestroke, which involves the use of videoconferencing and teleradiology to connect emergency physicians with vascular neurologists for the assessment and treatment of acute ischemic stroke. A retrospective cohort study examining videoconferencing teleconsultation in a hub-and-spoke stroke network found that teleconsultation was associated with a significant reduction in door-in-door-out time, with a mean of 95.2 minutes compared to 132.3 minutes in the standard referral process ($P < .001$) [22]. This reduction was achieved primarily by shortening computed tomography angiography–to–ambulance notification time, which decreased from a mean of 79.5 minutes to 44.6 minutes ($P < .001$) [22]. Critically, these workflow improvements translated into superior clinical outcomes: patients who received teleconsultation had higher rates of intravenous thrombolysis at the primary stroke center (63.4% vs 40.5%, $P = .04$), higher rates of endovascular thrombectomy at the comprehensive stroke center (34.1% vs 14.3%, $P = .03$), and shorter door-to-puncture times (83.0 vs 118.5 minutes, $P = .04$) [22]. At 90 days, patients in the teleconsultation group demonstrated a greater shift toward better functional outcomes, with 65.9% achieving favorable outcomes compared to 31.0% in the standard referral group (odds ratio 4.55, 95% CI 1.96–11.11; $P < .001$) [22]. Safety outcomes, including mortality and symptomatic intracranial hemorrhage, were comparable between groups, underscoring that the observed benefits were achieved without compromising patient safety [22].

Additional evidence from telemedicine-enabled mobile stroke units further supports the role of remote neurological consultation in acute stroke care. A randomized trial comparing a telemedicine-enabled neurologist supporting a mobile stroke unit with an onboard neurologist model found that the telemedicine model was superior on a composite hierarchical outcome of safety, scene-to-treatment-decision time, and the percentage of the neurologist's time spent in direct care [23]. The telemedicine model achieved a median scene-to-thrombolytic administration time of 36 minutes, demonstrating that remote specialist input can facilitate rapid reperfusion therapy even in the pre-hospital phase of stroke care [23]. A separate data-based study of remote neurological assessments reported that telemedicine interventions reduced door-to-needle time to a mean of 40 minutes (SD ±10), with thrombolysis rates of 75% and 60% of patients achieving functional independence (modified Rankin Scale ≤ 2) compared with 45% in conventional settings ($P < .01$) [24]. These findings collectively establish telestroke as a robust and evidence-supported model for delivering time-critical neurological expertise to emergency departments that lack on-site stroke specialists.

## Tele-Trauma and Surgical Emergencies

In trauma care, remote specialist consultation enables emergency physicians at rural or community hospitals to obtain expert guidance from trauma surgeons and critical care specialists at major trauma centers, potentially avoiding unnecessary transfers and ensuring that patients who require specialized intervention are identified

promptly. A systematic review and meta-analysis encompassing 45,097 trauma patients across 25 studies found that telemedicine use in trauma care was associated with higher Injury Severity Scores, likely reflecting improved detection and documentation of severe injuries through specialist input [25]. Increased blood transfusion rates were also observed in telemedicine-supported trauma care, which may indicate more accurate triage and timely intervention facilitated by remote expertise, although confounding factors such as case mix could not be entirely ruled out [25]. Both patient and physician satisfaction rates were high, suggesting that tele-trauma is acceptable to both providers and recipients of care [25]. However, the meta-analysis found no statistically significant effect of telemedicine on mortality, transfer times, or emergency department utilization, a finding that may reflect the heterogeneity of telemedicine protocols and the need for standardized implementation frameworks [25].

The role of remote consultation in surgical emergencies has also been explored, with studies demonstrating that telemedicine can bring surgical specialty consultation into the emergency department effectively. An investigation of telemedicine for emergency surgical consultations found that disposition plans derived from virtual consultation were largely concordant with those from physical consultation, though opinions on the timing of required operations showed less agreement [26]. This suggests that while remote surgical consultation is valuable for triage and disposition decisions, it may be less reliable for nuanced determinations regarding operative timing, highlighting the continued importance of in-person evaluation for certain surgical decision-making processes. In the pediatric context, telemedicine applications in emergency surgery and trauma have demonstrated effectiveness in preventing unnecessary transfers and providing specialized consultation, with studies reporting improved access to specialized care in rural areas and reduced diagnostic errors through remote specialist input [27]. The integration of artificial intelligence tools to analyze medical images and provide diagnostic support represents a promising avenue for enhancing the accuracy and efficiency of telemedicine consultations in surgical emergencies [27].

## Tele-ICU and Critical Care Consultation

For patients presenting to emergency departments with critical illness requiring intensive care, remote intensivist consultation—often referred to as tele-ICU or eICU—provides a mechanism for delivering specialized critical care expertise to institutions that lack on-site intensivists. Tele-ICU programs provide centralized specialist oversight of geographically distributed intensive care units through real-time monitoring and structured escalation protocols, and these programs have reported reductions in intensive care mortality and length of stay under well-structured organizational models [28]. In the emergency department context, tele-intensivists are available around the clock to support emergency and hospital medicine clinicians, assisting with triage decisions and determining whether patients should be admitted to the ICU or managed on the general ward [29]. A systematic review of telehealth consultations found that remote intensive care unit consultations likely reduce ICU and total hospital mortality with no significant difference in ICU or hospital length of stay, representing moderate strength of evidence in favor of telehealth for this application [30]. These findings are particularly significant for rural and community hospitals, where the absence of on-site critical care specialists often necessitates transfers that may delay definitive treatment and impose substantial financial and logistical burdens on patients and health systems.

The tele-ICU model also has important implications for emergency department throughput and resource allocation. By providing remote critical care consultation at the point of emergency department triage, tele-intensivists can assist emergency physicians in making disposition decisions that are both clinically appropriate and resource-efficient, potentially reducing unnecessary ICU admissions and facilitating earlier transfer of patients who require higher levels of care. A tele-ICU enabled trauma care program in a rural hospital setting demonstrated that 24/7 intensivist support with consistent monitoring by critical care specialists around the clock was feasible and effective, combining the flexibility of virtual critical care with real-time decision support to allow remote specialists to monitor, guide, and intervene in emergency situations [29]. The evidence supports the continued expansion of tele-ICU consultation services to emergency departments, particularly in underserved areas where access to critical care expertise is limited.

## Cardiac and Other High-Acuity Emergencies

Remote specialist consultation in cardiac emergencies has demonstrated particular promise for improving outcomes in acute coronary syndrome and arrhythmias. A systematic review of telehealth for acute and chronic care consultations found that telehealth for emergency medical services likely reduces mortality for patients with heart attacks, with moderate strength of evidence supporting this conclusion [30]. A study examining virtual professional

consultations between primary care providers and cardiology specialists found that these consultations frequently helped to modify the disposition of patients and provided an effective means for non-specialist providers to access expert advice for cardiology-related queries [31]. In the pre-hospital setting, the integration of tele-electrocardiography and remote cardiology teleconsultation in emergency care has been shown to significantly improve key clinical outcomes for acute coronary syndrome and arrhythmias, demonstrating the value of telemedicine in enhancing access to specialist care and reducing geographic disparities in cardiovascular emergency treatment [31]. Emergency echocardiography telemedicine has also been shown to provide an efficient method for obtaining 24-hour consultative echocardiography, enabling on-call cardiologists to interpret emergency echocardiograms remotely and guide management decisions for patients presenting with acute cardiac conditions [32].

Beyond stroke, trauma, critical care, and cardiac emergencies, remote specialist consultation has been applied to a diverse range of other high-acuity presentations. Burn consultations delivered via telemedicine have been shown to reduce emergency air transports from 100% to 44.3%, representing a substantial reduction in unnecessary and costly transfers [21]. Psychiatric teleconsultations have been associated with reduced hospital time in the emergency department, as well as reduced admissions and increased odds of 30- and 90-day outpatient follow-up [21]. In pediatric emergency care, video consultations compared with phone-only or no consultation have been shown to increase quality of care and reduce medication errors [21]. For complicated mild traumatic brain injury, a telemedicine-based neurosurgery consultation program has been developed as a strategy to reduce unnecessary interhospital transfers, demonstrating the versatility of remote consultation across neurological and neurosurgical emergencies [33]. These applications collectively illustrate that remote specialist consultation is not limited to a single clinical domain but represents a broadly applicable model for extending expert emergency care across specialties and geographies.

## Challenges and Limitations

Despite the substantial evidence supporting remote specialist consultation in high-acuity emergencies, several challenges and limitations must be acknowledged. A systematic review of emergency care telehealth specialist consultations found that none of the included studies reported on harms or negative unintended consequences of telehealth specialty consultations, which, while reassuring, also highlights the need for more rigorous safety monitoring as these programs expand [21]. The same review noted that the combination of similarity in objectives and technology, the wide range of specialties and patient populations, and the lack of detailed information on implementation specifics make it difficult to identify subgroups of patients or programs with different outcomes [21]. This heterogeneity limits the generalizability of findings and underscores the need for standardized reporting and implementation protocols. Furthermore, a narrative review of telemedicine in emergency care identified technological restrictions, regulatory barriers, digital knowledge gaps, and variations in reimbursement as persistent obstacles to widespread adoption [20]. The lack of physical examination capabilities inherent in remote consultation remains a fundamental limitation for high-acuity presentations, where subtle physical findings can be critical to accurate diagnosis and management [20]. Addressing these challenges will require not only technological innovation but also policy reform, cross-sector collaboration, and strategic investment in telehealth infrastructure and workforce training.

## Clinical Effectiveness, Patient Outcomes, and Quality of Care

The clinical effectiveness of telemedicine in emergency department settings has been evaluated across multiple domains, including diagnostic accuracy, treatment adherence, patient satisfaction, and hard clinical endpoints such as mortality and hospital length of stay. A systematic review of six randomized controlled trials examining telemedicine interventions in ED settings found that telemedicine improved diagnostic accuracy, reduced re-consultation rates, and enhanced treatment adherence, with high diagnostic concordance observed between remote and in-person assessments, particularly in non-critical cases [34]. Several studies within this review reported shorter throughput times and higher patient satisfaction with telemedicine compared to traditional care, although the impact on high-acuity presentations such as emergency airway management was less pronounced [34]. These findings establish a foundation for understanding telemedicine's role as a complement to, rather than a replacement for, in-person emergency care.

Diagnostic accuracy represents a critical dimension of clinical effectiveness, as accurate diagnosis is the prerequisite for appropriate treatment in emergency settings. A subanalysis of the TEMS trial, a randomized controlled trial comparing tele-emergency medical services (tele-EMS) with conventional on-site EMS physicians, demonstrated no difference in diagnostic accuracy between on-site and remote physicians [35]. This finding is particularly significant because it suggests that remote assessment, when supported by appropriate technology and protocols, can achieve diagnostic performance equivalent to that of physical presence. In the pediatric emergency context, a systematic review and meta-analysis reported high diagnostic accuracy of 98.5% and decision reasonableness of 92%, with low false-positive (2.65%) and false-negative (5.3%) rates, along with good sensitivity (82.85%) and high specificity (96.15%) [36]. A randomized trial assessing guideline-based telemedicine evaluation of orthopedic low-risk conditions by general practitioners found that syndromic diagnosis showed no difference between telemedicine and face-to-face specialist consultation groups ($p = 0.231$), providing further evidence that remote assessment can achieve diagnostic equivalence for appropriately selected conditions [37]. These findings collectively suggest that telemedicine-supported diagnosis is reliable across a range of emergency presentations, though the evidence for high-acuity conditions remains less robust.

Mortality and hospital length of stay constitute the most objective and clinically meaningful outcome measures for evaluating telemedicine's effectiveness in emergency care. A systematic review and meta-analysis of 23 studies examining telemedicine in pediatric emergencies found that telemedicine significantly reduced hospital length of stay (mean difference = −1.01, 95% CI: −1.3 to −0.71) and overall mortality (risk ratio = 0.17, 95% CI: 0.13 to 0.24) [36]. The single-arm analysis revealed that telemedicine was associated with an ED admission rate of 18% (95% CI: 5.2–47%), a hospital ward admission rate of 16.7% (95% CI: 4.6–45.7%), and a pooled mortality rate of 1.8% (95% CI: 1–3.3%) [36]. However, the authors cautioned that these findings should be interpreted with caution due to variability and potential confounding across studies, and the impact on admission rates remained inconclusive [36]. A systematic review of tele-emergency medicine encompassing 17 studies reported a 20% reduction in transfer rates in rural emergency departments and a 30% decrease in pediatric interfacility transfers, along with a 20-minute reduction in time-to-ECG for myocardial infarction patients and a 50% reduction in time-to-head CT interpretation for neurological emergencies [38]. A randomized trial comparing telemedicine and onboard neurologist models on a mobile stroke unit found that safety events were similar between groups (13% telemedicine vs. 12% onboard, risk ratio 0.9; 95% CI 0.5–1.8), demonstrating that the observed clinical benefits were achieved without compromising patient safety [39].

The Agency for Healthcare Research and Quality (AHRQ) systematic review of telehealth for acute and chronic care consultations provided moderate strength of evidence that specialty remote consultations in emergency care increase appropriate transfers and admissions while decreasing the time from presentation to clinical decision and the overall duration of emergency department stay [40]. The same review found that when telehealth is used in emergency medical services, mortality is reduced for ST-elevation myocardial infarction patients, and treatment is more timely, representing moderate strength of evidence for these clinical and intermediate outcomes [40]. For inpatient care, remote intensive care units were found to reduce ICU and hospital mortality with moderate strength of evidence, while lengths of stay were not significantly different [40]. These findings from the AHRQ review are particularly valuable because they represent a rigorous, systematic assessment of the available evidence across multiple emergency care settings, providing a reliable benchmark for evaluating telemedicine's clinical effectiveness.

Patient satisfaction is a crucial quality-of-care indicator that reflects the patient-centeredness of telemedicine interventions in emergency settings. A satisfaction survey of patients utilizing a virtual emergency department service in southeast Melbourne found that of 452 responses, 427 (94.5%) had no negative comments, with 341 (75.4%) rating the service 8 out of 10 or higher, and 83.4% indicating they would recommend the service to family or friends [41]. A study examining patient satisfaction with tele-emergency services in King Abdulaziz Medical City in Riyadh, Saudi Arabia, surveyed 383 patients using a validated questionnaire, contributing to the growing body of evidence on patient acceptance of tele-emergency care in diverse healthcare contexts [42]. In a pilot study on prehospital teleconsultation, patients and caregivers showed great satisfaction with being examined by a remote doctor via audio-video connection, despite the remote nature of the interaction [43]. The systematic review of telemedicine in ED triage similarly reported higher patient satisfaction with telemedicine compared to traditional care across several included studies [34]. These consistently high satisfaction rates are particularly notable given the often stressful and anxiety-provoking nature of emergency department encounters, suggesting that telemedicine can deliver care that is not only clinically effective but also acceptable and reassuring to patients.

Quality of care indicators for virtual emergency departments have been systematically developed to ensure that telemedicine services meet the same standards of safety, effectiveness, and patient-centeredness as physical emergency departments. A Delphi study conducted across four metropolitan virtual ED settings in four Australian states developed 16 quality indicators mapped to the National Quality Forum's telehealth quality indicators, including access to care (n=2), effectiveness (n=8), experience (n=4), and financial impact/cost (n=2), with additional domains of equity, patient-centeredness, safety, and timeliness [44]. These benchmarking indicators represent an important step toward standardizing quality assessment for virtual emergency care, enabling comparison across services and identification of areas for improvement. The development of such indicators reflects the maturation of tele-emergency medicine as a field and acknowledges that quality assurance frameworks must be adapted to address the unique characteristics of remote care delivery, including the absence of physical examination and the reliance on technology-mediated communication [44].

Re-consultation rates and treatment adherence provide further evidence of telemedicine's clinical effectiveness in emergency settings. A study examining the place of telemedicine in the organization of emergency care found that patients in the telemedicine group tended to re-consult less in the month following their initial emergency room visit (14% versus 26.5%, $p = 0.004$) and demonstrated significantly higher treatment adherence (97.5% versus 92%, $p = 0.014$) compared to the control group [45]. These findings suggest that telemedicine encounters may achieve better continuity of care and patient engagement than conventional emergency department visits, potentially reducing the burden on emergency services and improving long-term patient outcomes. The systematic review of telemedicine in ED triage similarly confirmed reduced re-consultation rates and enhanced treatment adherence as consistent findings across the included randomized controlled trials [34]. The mechanism underlying these improvements may relate to the more personalized and less rushed nature of telemedicine consultations, which may allow for more thorough patient education and shared decision-making than is possible in the often time-pressured environment of a physical emergency department.

Safety considerations must be carefully weighed against the documented benefits of telemedicine in emergency care. The AHRQ review noted that harms were generally not reported in the included studies, and therefore the evidence on safety was insufficient to draw firm conclusions [40]. A qualitative study exploring perceived risks of telehealth in rural and remote emergency departments identified clinical risks including insufficient local resources to keep patients after hours, inability to secure a clear diagnosis, and lack of follow-up general practitioner availability, while noting that many of these risks are modifiable through appropriate mitigation strategies [46]. The HRB evidence review on remote pre-hospital triage concluded that there is a lack of strong evidence on whether remote pre-hospital triage is safe or effective, with the evidence being fragmented and of very low certainty [47]. These findings underscore the need for ongoing safety monitoring and the development of robust governance frameworks as tele-emergency medicine continues to expand, ensuring that the documented clinical benefits are not offset by unanticipated harms.

## Cost-Effectiveness and Resource Utilization in Emergency Departments

Emergency department (ED) overcrowding represents a persistent and costly challenge for healthcare systems worldwide, driving up operational expenditures while simultaneously compromising the quality and timeliness of patient care. The economic burden of ED overcrowding is substantial, encompassing not only direct costs associated with prolonged patient stays and increased resource consumption but also indirect costs related to ambulance diversion, delayed treatment, and adverse patient outcomes. As healthcare systems grapple with aging populations, workforce shortages, and mounting budget constraints, the economic evaluation of telemedicine as a strategy to optimize ED resource utilization has become increasingly critical. A systematic review of economic evaluations found that virtual emergency care demonstrates strong and consistent cost-effectiveness across diverse clinical conditions, populations, and healthcare settings, with all 13 included studies reporting favorable economic outcomes [48]. These findings provide robust economic justification for expanding virtual emergency care access and removing regulatory barriers to implementation [48].

The economic case for telemedicine in emergency care is perhaps most compelling in the context of transfer avoidance, which has emerged as the primary driver of cost savings across multiple studies. A comprehensive systematic review of cost-effectiveness of virtual emergency care models found that video consultation—the most common modality, employed in 11 of 13 studies—achieved a 31% to 73% reduction in patient transfers, with cost savings ranging from US $73 (AUD $105) to US $5,118 per encounter [48]. Notably, six studies (46%) found virtual

care to be dominant, meaning it was both less costly and more effective than usual care, while incremental cost-effectiveness ratios ranged from US $1,273 (€990) to US $108,363 per quality-adjusted life year, with most falling below accepted willingness-to-pay thresholds [48]. The evidence particularly supports implementation for stroke care, pediatric emergencies, and rural or remote populations, where transfer avoidance drives substantial economic benefits [48]. A separate economic evaluation of a telemedicine solution for musculoskeletal trauma demonstrated that a telemedicine triage strategy was cheaper than the transfer-all strategy ($4,858 versus $6,610), revealing substantial cost savings for the healthcare system from implementing a telehealth platform for peer-to-peer consultation when considering patient transfer [49]. These findings underscore that telemedicine's economic value in emergency care is closely tied to its capacity to prevent unnecessary and costly interfacility transfers.

The cost savings associated with transfer avoidance are particularly pronounced in rural and remote settings, where the financial and logistical burdens of patient transport are substantial. A national telestroke program evaluation found that transfer rates decreased by 14.4 percent after implementation, with a nearly 60 percent reduction in the odds of being transferred after adjusting for patient and facility characteristics [50]. Beyond the direct cost savings from avoided ambulance and air transport, this reduction in transfers allows patients to remain close to their families and communities while retaining revenue to support rural and under-resourced healthcare facilities [50]. An economic evaluation of the Virtual Rural Generalist Service versus usual care in rural emergency departments found that the cost per standard unit of healthcare (national weighted activity unit) was lower for the virtual service ($1,047) than for usual care ($1,753), demonstrating that virtual emergency care can provide lower-cost care with equivalent quality-of-care outcomes for ED presentations of the same complexity [51]. These findings are particularly significant for health systems seeking to sustain rural emergency services amid workforce shortages, as telemedicine offers a mechanism for maintaining local access to emergency care while avoiding the high costs associated with patient transfers to tertiary centers.

The cost-effectiveness of telemedicine in specific emergency populations has been explored in detail, with particularly robust evidence in pediatric and neurological emergencies. A telemedicine solution for pediatric orthopedic injuries demonstrated that a telemedicine consultation with no further action cost only $120, compared to the substantial costs associated with automatically transferring the patient by ambulance [52]. The study revealed significant cost savings for the healthcare system from implementing a telehealth platform for peer-to-peer consultation when considering patient transfer for musculoskeletal trauma, with the telemedicine triage strategy costing $4,858 versus $6,610 for the transfer-all strategy in the base case analysis [49]. In acute neurological care, a cost-effectiveness analysis of a telemedicine network in northeast Germany found that mean 90-day total costs per patient rose modestly from €11,938 to €12,252 (+2.6%, non-significant), while the rate of the primary composite outcome of 90-day mortality and new need for outpatient or nursing home care decreased significantly in network hospitals (33.8% vs. 35.9%; adjusted absolute difference: -3.2%; aHR 0.89, 95% CI: 0.79-0.99) [53]. The cost per avoided adverse composite outcome was €14,968 (unadjusted), demonstrating that the modest increase in per-patient costs was justified by meaningful improvements in patient outcomes [53]. This finding is particularly important for policymakers, as it demonstrates that the economic sustainability of telemedicine networks is achievable even when per-patient costs remain stable, provided that clinical outcomes improve.

Resource utilization in emergency departments encompasses not only direct costs but also the efficiency with which staff, beds, and diagnostic resources are allocated. Telemedicine interventions have demonstrated the capacity to optimize resource utilization by facilitating appropriate triage and disposition decisions. A cross-sectional study of an innovative telehospitalist model—in which hospitalists based at a tertiary care facility collaborated with four community EDs via telemedicine—found that of 550 "admit-likely" patients discussed with ED clinicians, 105 patients (19.1%) were discharged from the ED and avoided admission, 322 patients (58.5%) were admitted to local or nearby community hospitals, and 123 patients (22.4%) were transferred to the tertiary care facility [54]. Emergency department length of stay differed significantly among disposition groups, including patients discharged home (10.2 hours), admitted to local hospitals (12.6 hours), and transferred to tertiary care hospitalist services (14.9 hours; $p < 0.001$) [54]. Hospital length of stay and in-hospital mortality were not significantly different among disposition groups, and patients admitted locally had lower 30-day readmission compared to those transferred to tertiary care facilities (odds ratio = 0.59 [0.36, 0.99], $p = 0.048$) [54]. The telehospitalist model optimized hospital bed utilization and healthcare system resources by facilitating safe discharges to home and expediting tertiary care transfers when necessary, demonstrating that telemedicine can enhance resource allocation without compromising patient safety [54].

The impact of telemedicine on emergency department length of stay, a key indicator of resource utilization efficiency, has been examined in several studies with generally favorable results. A study of a virtual triage and care model found that the initiative facilitated earlier treatment planning and resulted in a 14% (50-minute) reduction in emergency department length of stay [55]. In a randomized trial comparing telemedicine and face-to-face consultations for low-risk patients, the average emergency department length of stay was similar in both groups (80.8 minutes for telemedicine vs. 97.9 minutes for face-to-face, p = 0.167), indicating that telemedicine is an effective alternative for managing low-risk patients without increasing ED throughput times [56]. A systematic review and meta-analysis of telemedicine in pediatric emergencies found that telemedicine significantly reduced hospital length of stay (mean difference = -1.01, 95% CI: -1.3 to -0.71), providing further evidence of telemedicine's capacity to improve resource utilization efficiency [57]. However, the systematic review of virtual emergency care cost-effectiveness noted that evidence certainty was low for emergency department length of stay benefits, suggesting that while the available evidence is promising, further rigorous research is needed to establish the reliability of these findings across diverse settings and patient populations [48].

The economic evaluation of telemedicine in emergency care must also account for the infrastructure and operational costs required to establish and sustain virtual care programs. A modelled economic evaluation of a virtual emergency department in Victoria, Australia, found that the mean total operational cost for 79 days for 188 patients was A$344,117 (95% uncertainty interval [UI]: $296,800–$392,088) [58]. While this upfront investment is substantial, it must be weighed against the cost savings generated through avoided transfers, reduced ED visits, and optimized resource utilization. A study comparing total cost per virtual care visit ($156) to cost per ED visit ($341) found net savings per ED visit avoided of $185, demonstrating that even when the operational costs of virtual care programs are considered, the economic case for telemedicine remains strong [58]. Furthermore, a telehealth emergency department transition-of-care program was associated with a reduction in Medicare ED revisits during days 8–14 after an index ED visit, with cost savings over a 24-week period conservatively calculated to be $215,779 [59]. These findings suggest that telemedicine interventions can generate meaningful cost savings not only through direct transfer avoidance but also through reduced ED revisitation and improved care coordination.

The strength of evidence regarding economic outcomes in telemedicine for emergency care varies across settings and outcome measures. The Agency for Healthcare Research and Quality (AHRQ) systematic review found that overall strength of evidence about costs and other economic outcomes is low across settings due to inconsistencies in both methods and results [60]. However, four of five studies examining costs reported lower costs with better or no change in clinical outcomes, with savings primarily attributable to reductions in transfers or less transportation [60]. In emergency care specifically, specialty remote consultations were found to increase appropriate transfers and admissions while decreasing the time from presentation to decision and the amount of time spent in an emergency department, with moderate strength of evidence for these intermediate outcomes [60]. The AHRQ review also noted that when telehealth is used in emergency medical services, mortality is reduced for ST-elevation myocardial infarction patients and treatment is more timely, representing moderate strength of evidence for these clinical and intermediate outcomes [60]. These findings from the AHRQ review provide a rigorous, systematic assessment of the available evidence and highlight both the promise and the limitations of the current economic evidence base.

The economic evaluation of telemedicine in emergency care also requires consideration of patient-paid costs, which may differ from healthcare system costs. A study evaluating changes in emergency and primary care use after adding virtual physicians to a health advice line found that while healthcare system costs were neutral over a year, patients above age 15 without a known chronic illness or existing relationship with a primary care provider had higher primary care follow-up and patient-paid medical travel costs [61]. This finding highlights the importance of considering patient-paid costs in economic evaluations of telemedicine, as these costs may disproportionately affect vulnerable populations and influence the overall equity of telemedicine interventions. The same study noted that patient-paid medical travel costs ($14.43) represent an important economic parameter to consider in health policy evaluations [61]. These findings underscore that a comprehensive economic evaluation of telemedicine in emergency care must account for costs incurred by patients and caregivers, not only those borne by healthcare systems.

The economic case for telemedicine in emergency care is further strengthened by evidence demonstrating that virtual care can reduce unnecessary ED utilization among patients who do not require in-person emergency evaluation. A virtual triage and care referral program in Australia more than doubled the number of patients selecting appropriate, lower-acuity nonurgent care from 330,279 (21.3%) to 820,800 (52.9%), an increase of 31.6 percentage points (P < .01), not only driving greater use of appropriate, lower-acuity, and telemedicine services but

also reducing unnecessary in-person emergency visits [62]. A virtual emergency department program at Ochsner Health initially targeted an older adult risk population of 130,000 patients, contributing to a decrease in emergency department use by more than 7%, with patients enthusiastic about the program and often able to receive care via digital or telehealth platforms, reducing cost and promoting convenient often in-home options [63]. These findings demonstrate that telemedicine can shift the locus of emergency care from high-cost hospital settings to lower-cost virtual and community settings, generating savings for both healthcare systems and patients while maintaining appropriate access to urgent care services.

## Implementation Barriers, Technological Challenges, and Facilitators

The successful integration of telemedicine into emergency department workflows depends on a complex interplay of technological, organizational, and human factors. While the clinical and economic evidence supporting tele-emergency medicine continues to grow, the translation of this evidence into routine practice remains constrained by persistent implementation barriers that vary across settings, populations, and healthcare systems. Understanding these barriers—and the facilitators that can overcome them—is essential for designing effective implementation strategies and ensuring that the benefits of telemedicine are realized equitably across diverse emergency care contexts [64].

## Technological Infrastructure and Connectivity Challenges

Technological limitations represent the most fundamental and widely reported barrier to telemedicine implementation in emergency settings. A comprehensive review of barriers to and facilitators of technology adoption in emergency departments found that studies conducted in rural areas consistently identify resource and infrastructural constraints as the main barriers to adoption, with the primary barriers to continuous telemedicine use being unstable internet and telecommunications networks [65]. In a cross-sectional study assessing the feasibility of telemedicine for emergency healthcare in Yemen, poor connectivity was identified as the most frequently cited barrier, reported by 73.0% of respondents, followed by weak infrastructure (42.2%) and insufficient staff training (43.7%) [66]. The study noted that only 57.4% of respondents had reliable internet access, and telemedicine adoption was significantly higher among those with reliable internet (OR = 1.85, 95% CI: 1.05-3.24), demonstrating the direct relationship between connectivity and utilization [66]. Similarly, a study of a novel tele-EMS network in rural Georgia found that 95% of paramedics identified connectivity limitations as a major obstacle to telemedicine use, and utilization remained limited due to technical barriers and workflow integration challenges despite the system's potential benefits [67].

The risk of technical failure in video-based telemedicine is substantial and has been documented across multiple studies. A narrative review of image transmission and video live-streaming in emergency medical communication found that reported failure rates for video live-streaming range from 2.4% to 30%, depending on the study, with common causes including insufficient mobile or wireless coverage and device incompatibility [68]. These technical failures not only disrupt clinical workflows but also undermine clinician confidence in telemedicine systems, creating a cycle of underutilization that is difficult to break. Furthermore, the lack of integration between telemedicine platforms and existing electronic health record (EHR) systems creates significant workflow disruptions. A scoping review of virtual ward implementation found that lack of an integrated EHR disrupted continuity between virtual and in-person care, requiring manual processes like faxing prescriptions and assessment notes, and an integrated EHR was identified as essential for smooth transitions of care, referrals, and prescriptions [69]. The same review noted that digital inequality and access to technology was a barrier identified in many studies, with some programs resorting to donating IT infrastructure to local shelters to address disparities in technology access [69].

## Organizational and Workflow Integration Barriers

Beyond technological limitations, organizational factors—including staffing shortages, workflow integration challenges, and resistance to change—represent significant barriers to telemedicine implementation in emergency departments. The comprehensive review of technology adoption in EDs found that rural emergency departments in the US face staffing shortages and high costs as frequent barriers to telemedicine utilization, a finding supported by multiple studies examining telemedicine implementation in remote areas [65]. The review also noted that while urban EDs with superior infrastructure primarily face system compatibility and user resistance, rural EDs confront

more fundamental challenges related to access to basic technology, creating a two-tiered landscape of telemedicine readiness that mirrors broader disparities in healthcare infrastructure [65].

Workflow integration challenges are particularly pronounced in pre-hospital and emergency medical services settings, where the pace and acuity of care demand seamless technology use without interruption. A study examining the impact of a tele-EMS network found that 63% of paramedics reported the absence of regular cues or reminders to use telemedicine during patient encounters, and while 88% were familiar with tele-EMS, only 63% understood activation criteria [67]. The majority (60%) expressed the need for further training, highlighting that even when technology is available, inadequate training and unclear activation protocols can limit its effective use [67]. A qualitative study of clinician experiences with tele-emergency care found that reported challenges included filling primary care gaps and performing care coordination tasks, responsibilities that extend beyond the traditional scope of emergency medicine and may contribute to clinician reluctance to engage with virtual care models [70]. Additionally, a survey of 131 health professionals in a Saudi Arabian emergency department found that while overall perceptions toward telemedicine in triage were positive, notable concerns included staff resistance (30.2%), privacy concerns (11.5%), and lack of training, underscoring that successful implementation requires addressing not only technological but also cultural and educational barriers [71].

The phenomenon of "infrequent use" exacerbating barriers has been identified as a critical challenge in rural ED settings. The NSW Agency for Clinical Innovation evidence check on virtual care models in rural emergency departments found that infrequent use of the system exacerbated barriers, with some clinicians using the system and others choosing not to, creating inconsistency in practice that undermined the development of proficiency and trust in virtual care modalities [72]. Barriers to using virtual care models in this context included limited time for training, technology integration issues, clinical process and care coordination logistics, cost, and administrative and legal concerns [72]. The review also noted that administrative and legal concerns—including credentialing delays, liability questions, and privacy regulations—create additional friction that can delay or prevent telemedicine implementation even when clinical and technological prerequisites are met [72]. A cross-sectional survey of hospital-level implementation barriers found that leading barriers included sufficient access to specialists in-house or within the health system, potential time delays, liability concerns, privacy issues, and hospital information system security restrictions, with credentialing delays and unreliable internet and cellular service also identified as significant obstacles [64].

## Clinician Attitudes, Training Gaps, and the Question of Physical Examination

Clinician attitudes and training represent a critical dimension of telemedicine implementation that cuts across technological and organizational domains. The comprehensive review of technology adoption in EDs found that while studies on telemedicine adoption in urban settings typically concentrate on advanced technologies like clinical decision support systems and AI-based systems, the key barriers in these environments are often linked to usability, including incompatibility with existing systems, rather than access to basic technology [65]. AI-driven decision support systems frequently encounter usability issues such as system integration problems and uncertainties regarding the precision and dependability of AI suggestions, which exacerbates clinician resistance and creates skepticism about the value of technology-mediated care [65]. A qualitative analysis of telemental health in emergency care settings identified opportunities for improvement including alleviating technological burdens for on-site staff, EHR modifications to accurately capture workload and modality, and standardizing protocols to streamline communication between on-site and remote clinical staff [71].

The absence of physical examination capabilities in remote consultations remains a fundamental limitation that influences clinician attitudes and patient safety considerations. The comprehensive review of technology adoption found that some physicians felt the virtual model limited their ability to use key ED resources, leading to feelings of unfulfillment, and some physicians felt patient issues were not fully resolved by the end of consultation, a challenge exacerbated by the virtual setting and causing frustration [69]. A qualitative exploration study of telehealth in rural and remote emergency departments found that nonmodifiable risk factors included patients' presenting complaints, clinical urgency of presentation, ED capability, clinician scope of practice, and the distance between the ED of original presentation and the hospital of definitive care [72]. The study concluded that even for the most experienced clinicians, telehealth was not comparable to face-to-face communication in all circumstances, and mitigation strategies such as improvisation and flexible technology use were necessary to compensate for technological barriers [72]. A study of teleconsultation in stroke care found that video consultations, though effective for observing physical

symptoms, were resource-intensive, and virtual care required practitioners to learn from patient-generated data without physical exams, increasing the need for patients to play an active role in their care rather than just lying in a hospital bed [69].

## Facilitators and Enabling Factors for Successful Implementation

Despite these substantial barriers, a growing body of evidence identifies facilitators and enabling factors that can support successful telemedicine implementation in emergency departments. Strong leadership support emerges as a consistent facilitator across multiple studies. The comprehensive review of technology adoption in EDs found that supportive and engaged management, sufficient staffing and resources, and effective communication within and between departments were key facilitators of technology adoption, while adequate emergency notification systems and strong telecommunication infrastructure were identified as organizational facilitators [65]. The NSW evidence check on virtual care models identified overarching enablers of virtual care models to support in-hospital emergency care delivery, including local clinical champions driving virtual care use and supporting change management, system and workflow adjustments to support change in practice, supportive leadership enabling and implementing organizational strategies, easy access to equipment and capability to deliver virtual care services, and alignment with local context and settings including conditions, policies, and culture [72]. A study of virtual ward implementation similarly found that local champions to guide program delivery were important facilitators, and that voluntary staff recruitment was more effective than mandatory approaches, fostering innovation and engagement [69].

Training and education represent another critical facilitator for successful telemedicine implementation. The study of the tele-EMS network in rural Georgia concluded that addressing training gaps is essential for scaling tele-EMS solutions, and embedding telemedicine consultations within in situ simulations has been identified as an effective approach to address implementation barriers and promote increased use of telemedicine services among rural and community emergency medicine providers [67]. A cross-sectional survey of hospital-level implementation barriers found that high willingness to adopt was a facilitator, suggesting that clinician receptivity to telemedicine is generally high when systems are designed to meet their needs [64]. The telemental health study identified opportunities for improvement including alleviating technological burdens for on-site staff, EHR modifications to accurately capture workload and modality, and standardizing protocols to streamline communication between on-site and remote clinical staff [71]. The study of clinician experiences with tele-emergency care found that participants reported perceived opportunities to avoid ED referrals, more focused patient interactions, and improved job satisfaction related to flexible virtual shifts, suggesting that when telemedicine is well-designed, it can enhance rather than detract from clinician satisfaction [70].

Financial and regulatory facilitators also play a crucial role in enabling telemedicine implementation. The comprehensive review of technology adoption found that financing and good management support were important facilitators in both rural and urban settings, though funding could have a more significant impact in rural areas by helping to fill infrastructure gaps, while management support had a greater impact in metropolitan areas by facilitating rapid technology adoption among employees [65]. The development of standardized protocols and clinical guidelines has been identified as a facilitator for streamlining communication and ensuring consistency in virtual care delivery. A scoping review of virtual consultations in emergency care found that successful programs typically involve specific training and information on necessary data, available specialties, and standards and protocols that should be used to avoid failures and errors [11]. The development of benchmarking indicators for Australian virtual emergency departments, mapped to the National Quality Forum's telehealth quality indicators, represents an important step toward standardizing quality assessment and enabling comparison across services, which can facilitate broader adoption by providing a framework for evaluating and improving virtual care delivery [72].

## Regulatory, Ethical, and Future Directions for Tele-Emergency Medicine

The rapid expansion of telemedicine in emergency care has outpaced the development of regulatory and ethical frameworks necessary to govern its use, creating a landscape in which clinical innovation frequently runs ahead of policy [73]. While the clinical and economic evidence supporting tele-emergency medicine continues to accumulate, the legal, ethical, and governance dimensions of remote emergency care remain underexamined and inconsistently addressed across jurisdictions. The regulatory heterogeneity that characterizes telemedicine governance—ranging from licensure and scope-of-practice requirements to data protection, cross-border consultation, and clinical

liability—directly affects the safety, scalability, and public trust of tele-emergency services [74]. Addressing these regulatory and ethical challenges is not merely an administrative necessity but a prerequisite for the sustainable integration of telemedicine into routine emergency care delivery. This section examines the current regulatory landscape, explores the ethical considerations unique to remote emergency care, and identifies future directions for policy development, technological integration, and research.

## Regulatory Frameworks and Licensure Challenges

The regulatory environment for tele-emergency medicine is characterized by significant jurisdictional variation, creating complexity for providers, health systems, and policymakers alike. Governance and regulatory requirements for virtual care are jurisdiction-dependent but share common challenges, including clinician licensure, scope of practice, data protection, cross-border teleconsultation, and clinical liability [74]. In the United States, the "place of practice" in virtual care is defined by the patient's physical location rather than the clinician's location, meaning that physicians providing tele-emergency services across state lines must typically hold a full license, compact privilege, or virtual care registration in the state where the patient is located [75]. This requirement creates substantial administrative burdens for tele-emergency programs that serve patients across geographic boundaries, potentially limiting access to specialist consultation in rural and underserved areas. International frameworks similarly require that physicians practicing telemedicine be authorized to practice in the jurisdiction where the patient is located, with some jurisdictions extending limited reciprocity allowing cross-border telemedicine under specific conditions [76].

Germany provides a notable example of proactive regulatory development in tele-emergency medicine, having introduced the first evidence-based guideline for prehospital tele-emergency care in 2025, consisting of 21 evidence-based recommendations and 9 Good Clinical Practice points [77]. The guideline is valid from June 2025 until its next anticipated update in 2030, and plans are underway to integrate its contents into the national curriculum for tele-emergency physicians, ensuring standardized and high-quality training [77]. The German experience demonstrates that regulatory clarity and professional standards can facilitate rather than hinder telemedicine implementation when developed collaboratively with clinical stakeholders. However, even in Germany, significant heterogeneity in emergency medical service structures—including differences in organizational structures, technical equipment, and legal frameworks across federal states—creates barriers to uniform implementation of telemedicine standards [77]. This heterogeneity is compounded by insufficient network coverage in rural regions, where limited availability of stable data connections represents a fundamental technical hurdle for reliable telemedicine use [77].

The financial sustainability of tele-emergency medicine depends on reimbursement frameworks that appropriately value remote clinical services. The introduction of surcharges for emergency care with telemedicine services has been proposed as a mechanism to incentivize adoption, with reimbursement policies recognizing the clinical value of remote consultation in emergency settings [77]. However, reimbursement models for tele-emergency care remain inconsistent across payers and jurisdictions, creating financial uncertainty that can discourage investment in telemedicine infrastructure. The WHO's Global Strategy on Digital Health emphasizes that digital initiatives should be embedded within broader health system goals and supported by governance structures that address interoperability, equity, and trust, yet most evaluations of tele-emergency programs remain short-term and usage-focused, with limited evidence on equity, caregiver burden, workforce effects, long-term outcomes, and system-level financing [74]. This evidence gap complicates the development of sustainable financing models and underscores the need for rigorous economic evaluations that capture the full range of costs and benefits associated with tele-emergency medicine.

## Ethical Considerations in Remote Emergency Care

The ethical dimensions of tele-emergency medicine extend beyond conventional medical ethics to encompass novel challenges arising from the technology-mediated nature of remote care. Informed consent represents one of the most complex ethical challenges in tele-emergency settings, particularly when patients are incapacitated, in distress, or unable to provide explicit consent due to the urgency of their condition [78]. In prehospital emergency medical communication centers, obtaining informed consent from callers remains a critical challenge, as this step may lead to delays, confusion, or outright refusal, particularly in high-stress situations or when the caller is not the patient [78]. To streamline the process, consent is generally implied when callers authorize the activation of their camera and the transmission of video, yet the ethical and legal use of remote visual technologies requires well-defined, flexible protocols that can accommodate the diverse and urgent realities of emergency care [78]. In pediatric

emergency settings, research on consent for telehealth trials during emergency transport has revealed that participants prefer a staged consent process, with a prospective written informed consent approach recommended to build trust and provide legal protection, followed by subsequent contact after the emergency transport to reconfirm consent and answer questions [79].

Privacy and data protection considerations are particularly acute in tele-emergency medicine, where sensitive clinical information is transmitted across digital platforms that may be vulnerable to security breaches. Compliance with regulations such as HIPAA in the United States and GDPR in Europe is driving the development of more secure and privacy-preserving telemedicine solutions, yet privacy and security concerns remain particularly acute in the realm of remote patient monitoring and emergency consultation [80]. The World Health Organization's telemedicine guidance emphasizes legal clarity, data protection, and professional accountability in digital care, principles that are reflected in national frameworks such as Saudi Arabia's Personal Data Protection Law and Telehealth Application Guidelines [74]. However, the digital divide raises profound equity concerns, as the persistence of disparities in access to emergency care—influenced not only by the type of phone patients own but also by their geographic location—threatens to exacerbate existing health inequalities [78]. A systematic review on telehealth and access disparities in the United States during the COVID-19 pandemic showed that telehealth did not reduce disparities, with uptake being highest among non-minority groups, suggesting that tele-emergency medicine may inadvertently widen gaps in access if implementation is not deliberately designed to promote equity [73].

The integration of artificial intelligence into tele-emergency medicine introduces additional ethical complexities that require careful governance. A study examining the perspectives of tele-emergency physicians on AI support in prehospital telemedicine identified critical ethical considerations including transparency and explainability of AI recommendations, preservation of physician autonomy, data privacy, potential biases in patient care, and issues of accountability and liability [81]. While tele-emergency physicians are generally positive about the implementation of AI technology in prehospital tele-emergency medicine, considering it potentially suitable for reducing workload and improving quality of patient care when designed effectively, the translation of AI into clinical practice requires rigorous ethical governance addressing algorithmic bias, automation bias, and data privacy [81]. In acute care settings such as emergency departments, AI systems that assist with triage or monitoring can improve outcomes but may also create confusion about who is ultimately responsible for medical decisions, a concern that is amplified in virtual and after-hours care where patients may not realize that a chatbot or automated triage algorithm is influencing how their symptoms are prioritized [82]. Healthcare organizations can build confidence by ensuring clinicians remain the final decision-makers and by maintaining clear documentation of how AI recommendations are reviewed and validated, while transparent communication about the use of AI and its limits can strengthen the patient relationship while providing a defensible record in the event of disputes [82].

## Future Directions and Emerging Innovations

The future of tele-emergency medicine will be shaped by converging technological innovations, evolving regulatory frameworks, and a growing emphasis on equity-focused implementation. Artificial intelligence represents one of the most promising frontiers for enhancing tele-emergency care, with AI-powered tools offering the potential to assist in triage, diagnosis, and treatment recommendations for patients seeking emergency care remotely [83]. A systematic review protocol examining the role of AI in virtual emergency care aims to synthesize the current state of research, identify key challenges and opportunities, and provide recommendations for future research and implementation, incorporating a socio-technical perspective through the Human-AI Collaboration Framework that acknowledges the complex human, organizational, and societal factors beyond technical performance [83]. Beyond AI, emerging technologies including wearable devices, 5G-enabled emergency networks, and scalable telehealth platforms signal promising directions for extending specialist expertise across prehospital, emergency department, and inpatient settings [84]. The technological augmentation of the first responder is an inevitable and necessary evolution, with the potential to deliver definitive care from the very first moment of contact through portable diagnostic tools, point-of-care ultrasound, and real-time specialist consultation [84].

Research priorities for tele-emergency medicine must address significant existing gaps in the evidence base. A study establishing research priorities in emergency medicine telehealth identified that while telehealth has emerged as a potential solution to alleviate pressures on strained emergency departments, research gaps remain regarding its safety, efficacy, intent, and cost-effectiveness [85]. Future research should focus on real-world implementation challenges, including regulatory barriers and systems integration across multiple agencies and jurisdictions, while

larger-scale field studies are needed to establish external generalizability across diverse geographical contexts [86]. The integration of AI early warning, precision biomarkers, and telemedicine across acute critical illness management requires prospective validation, improved actionability, workflow integration, and interoperability, with priorities for clinically meaningful evaluation that extend beyond technical performance to encompass patient-centered outcomes and system-level impacts [84]. Establishing clear best practices and dedicated training frameworks for medical dispatchers and tele-emergency physicians will be essential for ensuring that visual and AI-supported tools are embedded in standard operating procedures rather than regarded as optional adjuncts [78].

The development of interoperable regulatory frameworks that can accommodate cross-border tele-emergency consultation represents a critical policy priority. Tackling the challenges of regulatory heterogeneity, exclusion from international trade agreements, digital literacy gaps, language barriers, and financial constraints requires that regulatory, technological, and operational constraints be addressed through international policy cooperation, with priorities including interoperable regulatory frameworks, reduction or removal of unnecessary barriers, infrastructure investment, data protection, sustainable financing, and emergency preparedness [87]. For national virtual hospital programs and tele-emergency networks, policy principles should include embedding programs within national digital health strategies and governance structures that address interoperability, equity, and trust, supported by organizational change, financing, user perceptions, and legal context [74]. The development of benchmarking indicators for virtual emergency departments, mapped to established telehealth quality frameworks, represents an important step toward standardized performance assessment and can facilitate broader adoption by providing a framework for evaluating and improving virtual care delivery [85]. Ultimately, the future of tele-emergency medicine depends on sustained innovation, equity-focused implementation, and collaborative efforts to fully realize telemedicine's promise in building a more accessible, responsive, and resilient emergency care landscape [88].

## Conclusion

This comprehensive review demonstrates that telemedicine has become an integral and multifaceted component of modern emergency care. Across triage, pre-hospital care, remote specialist consultation, and post-discharge follow-up, telemedicine consistently improves access to timely clinical expertise, enhances diagnostic and treatment decisions, reduces unnecessary transfers, and generates favourable economic outcomes. The evidence is particularly strong for telestroke, tele-trauma, tele-ICU, and pre-hospital teleconsultation, where remote specialist input has been associated with faster time-critical interventions, improved functional outcomes, and reduced healthcare utilisation. High levels of patient satisfaction and clinician acceptance further support the clinical and humanistic value of tele-emergency medicine.

Nevertheless, the review also reveals important limitations. The available evidence is heterogeneous in quality and scope, with many studies being observational rather than experimental. The impact of telemedicine on high-acuity presentations, long-term outcomes, and resource-constrained settings remains insufficiently understood. Implementation barriers—including poor connectivity, inadequate infrastructure, limited integration with electronic health records, insufficient training, credentialing delays, reimbursement inconsistencies, and the absence of physical examination—continue to impede widespread adoption. Ethical and regulatory challenges related to informed consent, privacy, equity, liability, and artificial intelligence governance require urgent attention. Without deliberate policy intervention, telemedicine risks exacerbating existing disparities rather than reducing them.

Looking forward, tele-emergency medicine should be embedded within integrated, hybrid models of emergency care that combine the strengths of remote and in-person assessment. Future research should prioritise large-scale randomised controlled trials, standardised outcome measures, robust economic evaluations, and implementation studies that address real-world workflow, equity, and sustainability concerns. Policymakers should focus on interoperable regulatory frameworks, sustainable reimbursement models, cross-border licensure solutions, and investment in digital infrastructure and workforce training. By aligning technological innovation with ethical governance, clinical evidence, and equity-focused implementation, tele-emergency medicine can play a transformative role in building more accessible, responsive, and resilient emergency care systems worldwide.

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