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Review

Use of virtual clinical education in emergency nursing care: a scoping review

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ABSTRACT

Background: Head-mounted devices (HMDs), such as smart glasses, are being implemented to deliver virtual clinical education (VCE) in emergency care, yet their value and practical limitations remain unclear.
Objective: To synthesise evidence on HMDs enabled VCE usage by healthcare professionals and students in emergency care, and to identify reported benefits and challenges.
Methods: A Joanna Briggs Institute (JBI) guided scoping review was conducted. Five databases and grey literature sources were searched, without date restrictions, for English-language studies describing HMD use for VCE in emergency care. Sixteen studies met the eligibility criteria. Data were charted and summarised descriptively.
Results: Most studies (50%) were published after 2021, originating from high-income countries. Reported advantages included enhanced two-way communication, faster clinical decision-making, hands-free documentation and remote supervision. Recurrent barriers were short battery life, unstable connectivity, restricted field-of-view, hygiene concerns and medicolegal uncertainty. Small sample sizes, heavy reliability of simulated environments and varied use of outcome measures limits generalisability of the findings.
Conclusion: Early evidence suggests that VCE using HMDs, can enrich emergency care, workflow and teaching, but technical, human-factors and regulatory obstacles persist. Larger, multi-centre studies using standardised metrics and real-world deployment are required before routine adoption can be recommended.

1. Introduction

The COVID-19 pandemic accelerated the adoption of virtual learning platforms, highlighting the need for adaptable educational strategies [1]. With lockdowns and physical distancing disrupting traditional clinical instruction, institutions turned to virtual solutions like video conferencing, asynchronous learning, and immersive simulations [2]. Virtual clinical education (VCE), particularly using head-mounted devices (HMDs) like smart glasses, has become vital in time-sensitive settings such as emergency care. This is especially relevant for nurses, who are often "first responders" during emergencies. Conventional training lacks opportunity to prepare nurses for complex emergencies [3], while VCE live-streams real-time clinical events, allowing remote learners to engage with complex scenarios and supporting experiential learning, clinical reasoning, and professional growth [4].

In emergency care, VCE via HMDs enables hands-free instruction while managing critically ill patients, overcoming spatial, temporal, and logistical barriers of traditional education [5]. VCE's ability to teach across geographic boundaries makes it especially useful in rural or resource-limited areas [6]. Despite these advances, limitations remain. Early evidence supports VCE's feasibility and pedagogical value, but knowledge gaps persist regarding user interaction with the technology [7]. The knowledge gap became particularly pronounced following the COVID-19 pandemic, which accelerated the adoption of technology-enhanced clinical education, especially within the nursing profession [8], while simultaneously highlighting the vulnerability of traditional face-to-face training models in emergency departments [1]. Challenges related to device usability, training, technological reliability, patient privacy, and data security continue to hinder full integration into clinical practice [5].

Although virtual and digital learning approaches in healthcare education have been explored, existing reviews tend to focus on simulation-based technologies [9], virtual environments [10] and telemedicine [11], rather than specifically on the use of HMDs for real-time

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VCE. There is limited synthesis of evidence examining how such technologies are used within emergency nursing practice and education, despite nurses forming the largest workforce in emergency care [8]. This gap limits the ability of educators and institutions to make informed decisions about curriculum design, competency development, and safe clinical integration of HMDs. Consequently, a focused scoping review was undertaken to map the available evidence on HMD-enabled VCE in emergency care, with particular relevance to emergency nursing education and practice.

While the term 'virtual clinical education' (VCE) is used throughout this review, it is important to acknowledge that many HMD-enabled interventions discussed here, were primarily implemented for telemedicine communication, workflow support, or remote clinical decision-making. Educational benefits were frequently described as secondary or implicit outcomes rather than formally evaluated learning interventions. Therefore, this review adopts a broad interpretation of VCE that includes clinically driven applications with potential educational value.

2. Methods

A scoping review methodology was selected due to the emerging and heterogeneous nature of the evidence base. Given the predominance of feasibility, usability and qualitative research, a scoping review was considered most appropriate to map the existing evidence, identify knowledge gaps, and inform future research directions. The scoping review was conducted following Joanna Briggs Institute (JBI) methodology [12] and reported using PRISMA-ScR guidelines [13].

2.1. Search strategy

In collaboration with an information specialist, five databases; namely EBSCOhost, PubMed, Scopus, Web of Science, and ProQuest; were systematically searched using Population, Concept and Context (PCC)-based keywords (Table 1). Reference lists and Google Scholar were also screened for additional and grey literature.

2.2. Eligibility criteria

Included were peer-reviewed articles, grey literature, and consensus documents in English, with no date restrictions. Studies were included where HMD-mediated communication supported learning, supervision, or experiential exposure, even where the primary study aim focused on clinical workflow or telemedicine functions. These studies focused on nurses, doctors, and emergency care practitioners using HMDs like Google Glass to stream real-time emergency events for clinical education in emergency care settings. Studies based solely on simulated or computer-generated environments were excluded to ensure that the review focused on real-time VCE involving authentic clinical contexts, even where some included studies incorporated simulated elements. Table 1 depicts the eligibility criteria for the study.

Table 1
Eligibility criteria for studies, according to the PCC framework.

PPC elements	Description
Population	**Inclusion:** HCPs OR graduate OR undergraduates NOT **Exclusion**: Allied health professional AND
Concept	**Inclusion:** Virtual clinical education OR smart glasses OR virtual clinical training and learning OR "Rods and Cones" OR continuous professional development OR in-service training OR short learning programs NOT **Exclusion:** Virtual environment OR virtual/augmented reality OR computer-generated images/scenarios OR case studies OR simulations OR virtual extended reality AND
Context	**Inclusion:** Emergency departments (EDs) OR, trauma units, emergency rooms (ER) OR, accident and emergency departments (A&E) OR prehospital settings OR emergency care NOT **Exclusion:** Healthcare settings other than ED and classrooms AND
Source of evidence	**Inclusion:** Peer-reviewed reports (including dissertations and theses), OR reviews, OR consensus documents, OR grey literature. There is no time limit on the above sources NOT **Exclusion:** Editorials OR, commentaries OR, letters to editors OR, conference preceding OR, conceptual papers.

2.3. Evidence selection

Search results were exported to EndNote 21 for reference management and duplicates removed. Records were then transferred to Rayyan software, where two reviewers (LS and MEC) independently screened titles and abstracts blindly using eligibility criteria. A third reviewer (TH) resolved conflicts. Eligible studies underwent full-text screening with the same blinded process. Included articles were then reviewed in detail for data extraction (Fig. 1).

2.4. Data extraction, critical appraisal and analysis

Data from the included articles were extracted and entered into a Microsoft Excel spreadsheet. Data extraction was done by one reviewer, and a descriptive analysis of the results were conducted. In line with scoping review methodology, no formal risk of bias quality appraisal of the included studies was conducted. This limits conclusions regarding the strength of evidence but aligns with the aim to map the extent and nature of existing research.

3. Results

Sixteen articles from 2014 to 2024 met the inclusion criteria. Research increased significantly after 2021, with half published in the last three years, coinciding with the COVID-19 pandemic. Several included studies specifically involved nurses or nursing students and examined the use of smart glasses for triage, assessments, supervision, and training, highlighting their relevance to emergency nursing practice and education. Most studies originated from high-income health systems. The included studies showed high methodological diversity. A descriptive summary is provided in Table 2. Where relevant, proportions and absolute frequencies are reported descriptively to enhance interpretability, given the exploratory nature of the included studies.

Characteristics and key findings of the included articles are indicated in Table 3.

4. Discussion

Although this review uses the term VCE, many included studies primarily evaluated telemedicine communication, workflow optimisation, or remote clinical support rather than formal educational outcomes. Educational implications were often inferred through supervision, experiential exposure, or skill development opportunities rather than measured learning gains. Therefore, this review examined a range of studies that investigated the implementation, benefits, and limitations of VCE in emergency care. The findings revealed a consistent pattern supporting the potential of VCE, particularly using HMDs, to enhance various aspects of emergency healthcare delivery and education. The studies included in the analysis also reported on the limitations of implementing HMDs in emergency care.

4.1. Development and evolution of HMD-enabled virtual clinical education

The development of HMDs for clinical education has progressed from experimental applications to more integrated clinical tools. Initial implementations, such as early versions of Google Glass, focused

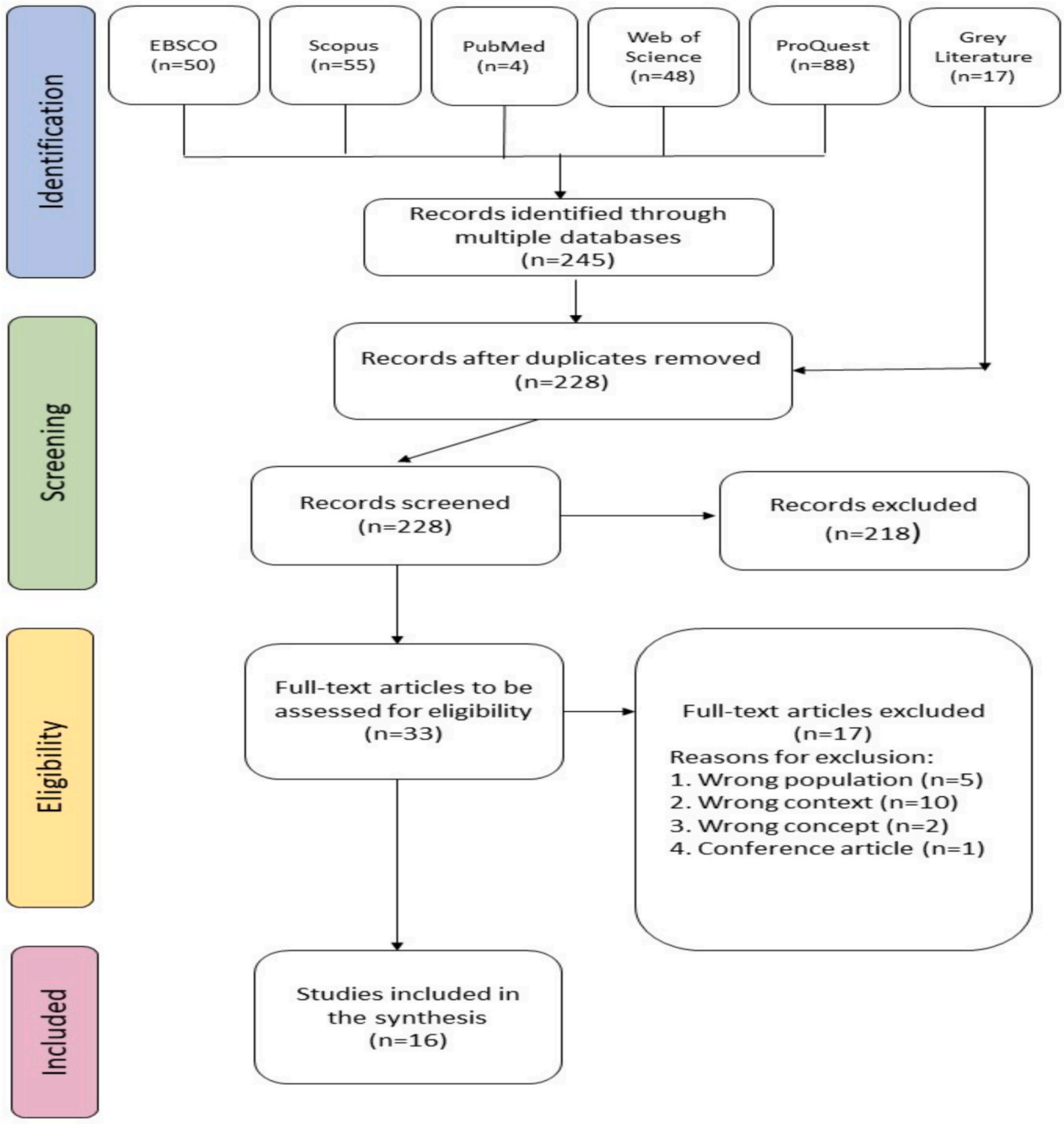

Fig. 1. PRISMA flow diagram of the search and screening process.

primarily on feasibility and proof-of-concept demonstrations, often within simulated environments [14,15]. Over time, advances in hardware reliability, connectivity, and audiovisual quality enabled broader exploration of real-time clinical use, particularly in emergency care settings [16]. This evolution reflects a gradual shift from technology exploration toward clinically embedded educational and decision-support applications [8].

Building on this technological maturation, the COVID-19 pandemic acted as a catalyst for this progression, accelerating the adoption of digital, remote, and technology-enhanced clinical education strategies [17]. Restrictions on clinical access, staffing pressures, and infection prevention requirements exposed the vulnerabilities of traditional face-to-face training models in high-acuity environments [1]. Consequently, a clear distinction can be observed between pre-pandemic and post-pandemic applications of HMDs in emergency care education. Prior to COVID-19, studies largely focused on feasibility, usability, and proof-of-concept implementations, frequently conducted in simulated settings with limited participant numbers [5,18–22]. In contrast, the post-pandemic period has seen accelerated adoption toward real-world clinical deployment, driven by increased reliance on remote supervision, distributed learning models, and technology-mediated clinical support [1,23–27]. This transition reflects a maturation of the field, although much of the current evidence remains exploratory rather than evaluative.

Within this evolving landscape, it is important to situate HMDs as a component of a broader ecosystem of wearable and digital technologies used in emergency care [28,29]. Alternative or complementary wearables, such as body-worn cameras and smart watches, may offer

Table 2
Descriptive overview of findings.

Item (n = 16 studies)	Key figures*
Publication window	2014 – 2024 (median = 2022)
Temporal distribution	2014 (1), 2015 (1), 2016 (2), 2018 (1), 2019 (1), 2021 (1), 2022 (4), 2023 (1), 2024 (4)
Countries represented	USA 6, Thailand 2, Japan 1, Brazil 1, Switzerland 1, Denmark 1, Singapore 1, Korea 1, Netherlands 1, Hawaii 1**
Primary study designs	Feasibility 3, Retrospective 2, Usability/reliability 2, Qualitative 2, Semi-structured interview 2, RCT 1, Observational 1, Mixed-methods 1, Other 2
Participant groups***	EMS / pre-hospital personnel 9, Nurses 7, Physicians 6, Students 1
Most-reported benefits of smart-glass VCE	Enhanced communication (9 studies), richer information transfer (8), faster task completion/time-saving (6), hands-free workflow (3)
Most-reported technical challenges	Battery life (6 studies), network/connectivity instability (4), display size / field-of-view & screen legibility (4), audio quality (3), motion-related discomfort (2)

*Absolute counts followed by ranking; percentages omitted for brevity (n = 16)
** The Hawai'i study reported data separately from mainland United States investigations
*** Many studies involved more than one professional group; counts therefore exceed 16

overlapping or hybrid functionality. Integrating HMDs with these technologies may enhance flexibility, redundancy, and context-specific use, particularly where constraints related to cost, infrastructure, or user preference limit exclusive reliance on HMDs [29].

4.2. Demographics

Most studies were conducted in high-income countries with well-established healthcare infrastructures. The United States contributed most studies [11,18,20,24–26], followed by research from Europe [21,22,27]. The distribution indicated a global interest in the technology but also revealed a research gap in low- and middle-income countries, where contextual challenges, such as limited technological infrastructure and resource constraints, could significantly influence implementation [30]. HMD-enabled VCE may hold particular promise for low- and middle-income countries by supporting remote supervision, reducing travel demands, and extending specialist input to resource-constrained settings [31]. However, the dominance of high-income country studies may obscure contextual barriers faced in LMIC settings, including infrastructure instability, bandwidth limitations, training capacity, and differing regulatory frameworks [30]. Without representation from resource-constrained environments, the transferability of findings remains uncertain, highlighting the need for context-sensitive implementation research. The narrow geographic scope and relatively small sample sizes of some of the included studies further limits generalisability of the findings [5,16,22,26].

4.3. Designs

The studies employed diverse research designs (Table 1), ranging from randomised controlled trials and retrospective analyses to feasibility studies and qualitative methods. Many studies relied on self-reported perceptions of usability, confidence, or satisfaction rather than validated educational or clinical performance measures, introducing potential response bias and limiting causal interpretation [11,18,20,21,24,27]. Semi-structured interviews and feasibility assessments were among the most frequently used approaches [11,18,20,21,24,27], reflecting the exploratory nature of this emerging field. This methodological heterogeneity highlights the early developmental stage of VCE research and indicates that many investigations aim to establish initial feasibility rather than assess long-term outcomes or generalisability. The absence of consistent evaluation frameworks also complicated interpretation across studies. Effectiveness metrics varied widely [32], including user satisfaction [33], time efficiency [16], task completion [19], usability perceptions [11]; and often lacked validated tools, relying on anecdotal or self-reported data. This inconsistency introduced variability in outcomes and limited meaningful synthesis of results.

4.4. Benefits of VCE using HMDs in emergency care

Several benefits of VCE were identified from the included studies and are discussed thematically below.

4.4.1. Enhanced communication and real-time consultation

Smart glasses enable real-time, two-way communication between prehospital and hospital providers, improving coordination, triage, and treatment decisions. "See-what-I-see" video feeds allow EMS to transmit vital signs, assessments, and scene details to ED physicians, enhancing shared situational awareness [21,24,33]. Remote consultations boost EMS confidence and support timely interventions [26,34], while combined audio-visual communication reduces miscommunication [27,32].

4.4.2. Workflow efficiency and accuracy in emergency care

Studies show smart glasses improve EMS workflow efficiency, especially in mass casualty incidents. Apiratkwarakul et al. [34] found they significantly reduced casualty counting time versus manual methods, particularly with large groups (11–30). The technology supports more accurate triage and treatment planning, with real-time feedback enhancing confidence in procedures like intubation and ultrasound [5,16,32]. HMDs enable task simultaneity and lower cognitive load, speeding clinical decisions [5]. Their hands-free design preserves manual dexterity [20], while features like automatic estimated time of arrival (ETA) calculation and streamlined interfaces optimise workflows [11].

4.4.3. Technological advantages and user experience

HMDs offer audiovisual input, intuitive controls, and touchless voice commands, enhancing usability in high-stress environments [5,26]. Their unobtrusive design integrates well with PPE, reducing interference compared to handheld devices [20,27]. Users report high satisfaction with screen resolution, voice command responsiveness, and comfort during extended use [23,26], which supports ongoing adoption in emergency care.

4.4.4. Clinical impact and patient outcomes

HMDs improve diagnostic accuracy, speed of treatment initiation, and enhance patient outcomes. In STEMI cases, telemedicine and smart glasses enabled earlier pharmaco-invasive treatment through real-time cardiologist input [19]. For stroke, wearable technology supports early, accurate on-scene assessments [20], bridging the prehospital-to-hospital information gap. HMDs also enable early hospital preparation by mobilising equipment and staff, based on incoming data, potentially reducing door-to-treatment times and improving care continuity [32].

4.4.5. Educational and system-level applications

Beyond clinical use, HMDs support tele-supervision, training, and quality assurance by enabling remote guidance and education for HCPs, promoting skill development and standardised care [19,25]. Real-time video and data documentation facilitates post-event review and quality improvement [23]. Integration with health information systems allows real-time data sharing and electronic documentation, enhancing system efficiency and care traceability [19,23]. From an educational perspective, HMD-enabled VCE offers opportunities to support competency-based education by facilitating real-time supervision, feedback, and assessment of clinical reasoning and procedural skills in authentic contexts [5,16,20,24,32–34]. Such technologies may contribute to the development of clinical decision-making models and

Table 3
Summary of included studies.

Author/s, Year & Country	Population a) **EMS** b) **ED personnel**	Research design & Study objective	VCE HDM'S a) **Benefits** b) **Challenges**	Limitations & Research gaps
Apiratkwarakul et al. [34] 2022 Thailand	a) Advanced emergency medical technicians b) Emergency physicians, registered nurses, emergency nurse practitioners	Randomised controlled trial Objective: Comparing accuracy and time usedwith smart glasses to manual counting to assess number of casualties.	a) Reduced triage time compared to manual counting; Improved accuracy in casualty counting during mass-casualty simulations; Enabled real-time transmission of patient data to command centres; Facilitated remote physician guidance, improving patient outcomes; Increased EMS personnel confidence. b) Two participants discontinued use due to dizziness	Single-site simulations limit generalisability; outcomes may differ by user and setting.
Apiratkwarakul et al. [32] 2023 Thailand	a) EMS	Retrospective study Objectives: Comparing duration of patient care in an ambulance between the use and non-use of smart glasses. Identifying characteristics of data communication between ambulance and hospital.	a) Enabled real-time streaming of audio, video, vital signs, physical exams, and scene footage to ED staff; Allowed ED staff to relay patient history and procedural guidance to paramedics; Shortened evaluation and treatment times; Facilitated early preparation of ED equipment; Boosted provider confidence during chest compressions, point-of-care ultrasound, and intubation. b) Participants with motion sickness were excluded	CCTV-based findings lack generalisability due to cross-country EMS differences in staffing, vehicles, and protocols.
Broach et al. [33] 2018 Hawai'i	a) EMS b) Physicians	Reliability analysis Objective: Assessing smart glasses for usability and reliability, specifically whether EMS and physicians could make accurate triage decisions.	a) Provide an unobtrusive, point-of-view communication link between EMS teams and ED physicians; Enhance situational awareness during mass-casualty incidents; Aid in effective resource allocation. b) Hardware durability concerns; Software reliability issues; Need for rapid user training;	Small, convenience-based sample limits generalisability.
Cicero et al. [18] 2015 USA	a) EMS b) Physicians	Feasibility study Objective: Exploring practicality and acceptability of using wearable technology to support communication between prehospital providers and physicians during triage.	a) None reported Short battery life, especially during streaming; Poor microphone placement causing background noise and missed voice commands; Low screen contrast in outdoor conditions; Significant video lag (~20 s); No screen-lock feature; Forced operating system updates disrupting planning and device consistency. b) Dependence on internet connectivity;	Small sample, limited physician input, and non-EMS device design reduced study power; other tools unassessed.
Ishikawa et al. [16] 2022 Japan	a) EMS b) Physicians	Retrospective study Objective: Determining whether smart glasses were used bidirectionally between prehospital settings and receiving hospitals.	a) Faster device start-up; Enhanced EMS personnel sense of security via remote physician supervision; Enabled sharing of wound conditions and ECG data between prehospital and hospital teams. b) Communication instability (voice and image clarity issues); Delays in physician response; Physical obstruction caused by the smart glasses during some activities.	Further investigation into benefits for patients are required.
Macedo et al. [19]	b) Nurses & emergency physicians	Observational study Objective: Comparing the use of pharmacoinvasive strategy and mortality	a) Increased use of pharmacoinvasive strategies in STEMI care; Trend toward reduced mortality;	Non-randomised, retrospective design limits causal inference.

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Table 3 (*continued*)

Author/s, Year & Country	Population a) **EMS** b) **ED personnel**	Research design & **Study objective**	VCE HDM'S a) **Benefits** b) **Challenges**	Limitations & **Research gaps**
2016 Brazil		in patients with ST elevation myocardial infarction transferred pre- and post-chest pain protocol with access to telemedicine in a private hospital network.	Direct cardiologist access enabled timely fibrinolysis or catheter lab activation; Expert input helped reduce diagnostic errors; Image transmission issues in < 1% of cases; Required IT team intervention when issues occurred.	
Noorain et al. [20] 2019 USA	b) Nurses & neurologist	Feasibility and reliability study Objective: Assessing feasibility and inter-rater reliability of wearable video technology in assessing neurologic deficits in patients with suspected stroke.	a) Enables hands-free, real-time stroke assessment in prehospital settings; Closes the information gap between the scene and the ED; Allows paramedics to begin evaluations earlier; Provides a first-person view for remote providers; Integrates easily into clinical workflows with minimal positioning or manual input required.	The device was easy, reliable, and comparable to existing methods; prehospital use may improve early stroke evaluation and streamline transfers.
Schaer et al. [21] 2016 Switzerland	a) EMS b) Emergency physician	Qualitative pilot study Objective: Investigating changes introduced by a new communication platform using smart glassesfor emergency situations.	a) Improved communication between paramedics and hospitals; Enabled faster expert input; Allowed integration of clinical data into health records; Supports large-scale deployment across facilities; Offers opportunities for paramedic continuing education; Facilitates hands-free video conferencing; Opens possibilities for new health apps to streamline clinical workflows. b) Connectivity instability; Significantly reduced battery life during video conferencing.	A larger study is needed to confirm observations.
Schmidt et al. [22] 2014 Denmark	b) Nurses	Quantitative survey Objective: Evaluating experiences of using Google Glass as a communication device instead of traditional mobile phones.	b) Sound quality.	Further research is needed to explore broader applications of wearable technology.
Sumner et al. [5] 2024 Singapore	b) Nurses	Mixed-methods study Objective: Investigating real-world experiences of nurses' using smart glasses to triage patients in an urgent care centre.	a) Clear guidance and strong supervisory support reported by nurses; Enabled simultaneous task performance, enhancing team communication and clinical understanding; Comfortable to wear with PPE; Easy-to-use control buttons without surgical gloves; Generally high-rated sound quality. b) Short battery life; Unstable network connectivity; Device durability; Insufficient visual quality for certain assessments; Compatibility issues with prescription glasses and face shields; Control buttons harder to operate with surgical gloves; Communication affected by poor weather and limited field of vision.	Single-site nurse study lacked long-term or outcome data; possible Hawthorne effect; workflow benefits were self-reported.
Yoon et al. [23] 2021 Korea	b) Nursing students	Usability study Objective: Assessing feasibility of a desktop interface with Google Glass EE2 for remote collaboration and evaluating whether real-time video and audio support information sharing.	a) Mirror-reflected screens were useful; General satisfaction with screen resolution; Fair to good video streaming experience via desktop monitors. b) Narrow field of view and motion blur; Mirror-mode display limited	Small, young sample limits generalisability; technostress in older staff unexamined; uncertified device; user experience and two-way collaboration unmeasured.

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Table 3 (*continued*)

Author/s, Year & Country	Population a) **EMS** b) **ED personnel**	Research design & Study objective	VCE HDM'S a) **Benefits** b) **Challenges**	Limitations & Research gaps
			situational awareness and caused directional confusion; Short filming distances and unstable network reduced video clarity; Trainee hand movements were difficult to discern; Inconsistent audio performance.	
Zhang et al. [24] 2022a USA	a) EMS	Qualitative study Objective: Understanding the potential of smart glasses to support work practices of prehospitalproviders.	a) Enhanced communication between prehospital and hospital teams; Enabled hands-free data collection and documentation; Supported clinical decision-making and situational awareness; Contributed to quality assurance and training. b) Need for improved mounting techniques to ensure device stability and proper positioning during use.	Participants didn't use the device; urban, male-heavy U.S. EMS sample limits generalisability; findings from interviews only, no scenario or usability data.
Zhang et al. [25] 2022b USA	a) EMS	Participatory design and adoption of smart glasses in fast-paced medical settings.	a) Streamlined EMS workflows through improved real-time video communication; Enhanced information sharing and care coordination with hospital teams; Reduced errors in field documentation. b) Device durability, disinfection, battery life, network connectivity; Poor interoperability with existing EMS systems; Clickable buttons raised cross-contamination concerns; Small screen posed usability issues; Additional concerns: ergonomics, patient intimidation, user distraction; Potential medicolegal and data security risks.	Smart glass not fully deployed, limiting real-world insights; online workshops lacked hands-on use; single-method study without validation or triangulation.
Zhang et al. [11] 2024a USA	a) EMS	Qualitative study Objective: Designing and evaluating a smart glass application tailored for prehospital communication.	a) Enabled real-time video consultations with physicians for direct patient assessment; Facilitated EMS–ED communication; Helped reduce triage congestion; Automatically calculated hospital ETA; Application was intuitive and user-friendly. b) Poor performance of voice commands and hand gestures; Annotation tool was distracting due to multiple steps; Difficulty hearing physicians clearly through device speakers; Impractical without internet access; Battery life concerns.	Study not conducted in real-world settings; physician perspectives not included; findings may not apply outside the U.S.; usability assessed without measuring clinical impact.
Zhang et al. [26] 2024b USA	a) EMS	Participatory design Objective: Designing and developing user-friendly smart glass applications to support EMS work	a) Supported touchless operation via intuitive voice commands matching on-screen labels; Tangible buttons familiar to users and resulted in fewer errors than voice or gesture inputs; Minimal impact on communication with patients or partners. b) Voice commands unreliable in noisy environments, prone to mis-triggers, and awkward in public; Hand gestures had a steep learning curve, were difficult to perform correctly, and impractical during ambulance movement or patient care; Tangible buttons raised cross-contamination concerns.	Limited training and small, controlled sample may have affected performance; software-specific voice and gesture issues limit generalisability.
Zuidhof et al. [27] 2024 Netherlands	b) Nurses	Qualitative study Objective: Identifying aspects regardingadoption, mediation, and the use of smart glasses.	a) Enabled efficient remote viewing and reduced travel; Offered a less intrusive alternative to handheld video	Mixed professional backgrounds may have influenced responses; qualitative analysis is subject to interpretive bias; findings are exploratory and require

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Table 3 (*continued*)

Author/s, Year & Country	Population a) **EMS** b) **ED personnel**	Research design & **Study objective**	VCE HDM'S a) **Benefits** b) **Challenges**	Limitations & **Research gaps**
			cameras; Visual communication was faster than verbal explanations; Quick access to records and documentation via HMD; Supported bedside teaching; Potential to enhance care quality and medical education. b) Technical challenges including battery problems, small display, and limited functionality.	quantitative validation in future research.

entrustable professional activities relevant to emergency nursing practice [8].

Future development of HMD-enabled VCE is likely to involve closer integration with emerging technologies, including artificial intelligence, augmented reality, and advanced telemedicine platforms [35]. AI-assisted decision support, automated data capture, and context-aware prompts may enhance clinical reasoning and learning during real-time care, while augmented reality overlays could support procedural guidance and situational awareness [11]. Integration with existing telemedicine systems may further strengthen remote supervision, interdisciplinary collaboration, and continuity of care [11].

4.5. Limitations of VCE using HMDs in emergency care

Despite the benefits of VCE, all reviewed studies reported notable limitations of VCE by using HMDs in emergency care settings. The absence of clear educational, clinical, and regulatory guidance regarding the use of HMDs in emergency care contributes to uncertainty around adoption, workflow integration, infection control, patient consent, and medicolegal accountability, particularly for nursing staff.

The widespread adoption of HMD-enabled VCE is further influenced by regulatory, ethical, and economic considerations [36]. Unclear governance regarding data protection, patient consent, recording of clinical encounters, and medicolegal accountability may hinder institutional uptake, particularly in emergency nursing contexts [37]. Cost-effectiveness remains an important consideration, as expenses related to device procurement, maintenance, training, and infrastructure may limit scalability. Ethical concerns, including patient privacy, equity of access, and the acceptability of wearable recording devices during vulnerable clinical encounters, further underscore the need for clear guidelines and evidence-informed policy development [38].

4.5.1. Hardware limitations

The use of smart glasses in emergency care is hindered by hardware challenges that limit practical utility. Battery life is a major challenge, especially during live-streaming or video conferencing, making devices unsuitable for extended emergencies [20,25 23]. Connectivity problems worsen usability, as reliable internet is often unavailable, disrupting image transmission and video feeds [16,21,33]. Additional challenges include motion sickness, poor voice command responsiveness, small screen size, low outdoor contrast, narrow field of view, and motion blur [11]. All of these challenges reduce the ability to observe clinical signs or training details effectively [21]. Ergonomic difficulties arise for users wearing prescription glasses, surgical gloves, or face shields, with discomfort during extended wear or ambulance transport [5,20].

4.5.2. Software and interface challenges

Software challenges include video latency exceeding 20 s, disrupting real-time teleconsultations despite near-instant audio, causing desynchronised communication [34]. User interface challenges involve infection risks from physical buttons, lack of screen-lock features leading to accidental interruptions, and disruptive forced operating system updates that interfere with workflow [5]. Small displays, confusing mirror modes, and cumbersome multi-step annotation tools distract users. Voice and gesture controls are often unreliable in noisy environments or public settings, with gestures difficult to master, causing frequent command failures [23].

4.5.3. Clinical and human factors

Device operation demands cognitive effort, diverting focus from critical EMS tasks and reducing situational awareness, especially with on-screen annotations [23]. The device's visible presence can intimidate patients, particularly children, affecting trust in sensitive settings [5]. Infection control is problematic due to difficult-to-disinfect surfaces, risking cross-contamination in strict hygiene environments [24].

4.5.4. Data privacy and security

Users express concerns about data security and medicolegal risks of patient-identifiable data transmission or storage via smart glasses. Uncontrollable automatic updates and data management exacerbate these worries [5].

4.5.5. Device durability and reliability

Though breakage is rare, dust, moisture, and movement in chaotic EMS environments threaten device robustness and reliability during transport [20].

5. Limitations

Only studies published in English were included, which may have excluded relevant evidence from non-English-speaking contexts. Consistent with standard scoping review methodology, no formal critical appraisal of the included studies was conducted, limiting the ability to assess the quality or strength of the evidence. The field of VCE is still evolving, and inconsistent definitions and terminology across studies may have influenced the inclusion process and synthesis of findings. Recent advances in the field have also underscored the need for standardised evaluation frameworks, clear data security protocols, and deliberate curricular integration to ensure that HMD-enabled VCE is both educationally meaningful and clinically safe.

6. The value of this study for emergency nursing

This review highlights the emerging role of VCE using HMDs in emergency care, showing its potential to transform clinical training in high-pressure, time-sensitive situations. By synthesising global evidence, HMDs' impact on real-time education, communication and decision-making is emphasised. The review offers foundational understanding of the benefits and challenges of integrating wearable technology into training and practice in emergency care, supporting the

development of more resilient, adaptable education systems. This insight is valuable as emergency care seeks innovative solutions for workforce training, efficiency, and patient safety amid growing challenges.

7. Recommendations for future research

To enhance future research on VCE in emergency care, studies should use larger, multicentre designs across diverse geographic and cultural settings. Involving multidisciplinary stakeholders can improve understanding of cultural and systemic implementation factors [23]. Interdisciplinary collaboration between clinicians, educators, engineers, and health informatics specialists will be essential to design evaluation frameworks that capture both clinical and educational impact.

Developing standardised tools to consistently measure usability, efficiency, and accuracy is essential to ensure comparability between studies. Given VCE's novelty, longitudinal studies are needed to evaluate their sustained use and long-term impact in emergency care. Future research should also examine objective patient-level outcomes, cost-effectiveness, treatment timelines, safety metrics and clinical effectiveness in conjunction with the long-term educational impact of HMD-enabled VCE (including skill retention and clinical performance).

8. Conclusion

Evidence suggests that HMD-enabled systems primarily support remote clinical communication and workflow processes, with emerging but still indirect implications for clinical education and supervision. Benefits include improved communication, real-time knowledge transfer, and observational learning. However, challenges concerning hardware, unstable connectivity, interface flaws, infection control, and patient acceptance remain. Despite these limitations, evidence highlights HMDs' ability to overcome spatial and logistical barriers, especially during limited clinical access. Success depends on ongoing technological improvements, user-focused design, training, and real-world evaluation.

Artificial intelligence statement

The authors declare that artificial intelligence was not used to generate the content of the manuscript (including text, tables, or images).

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Liesel Smit: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Tanya Heyns:** Supervision, Project administration, Methodology, Data curation, Conceptualization. **Maria Elizabeth Cochrane:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Data curation, Conceptualization. **Marlize Kuhn:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability statement

Raw data can be viewed with the following FigShare link: Data Extraction.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ienj.2026.101776.

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