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ORIGINAL RESEARCH

Enhancing Emergency Medical Services with Smart Glasses Technology for Optimal Ambulance Positioning in Simulated Critical Patient Care Scenarios

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Purpose: To implement smart glasses with augmented reality distance measuring technologies in conventional self-assessment techniques, to improve ambulance location accuracy during simulated emergency scenarios.

Patients and Methods: Eighty-two emergency medical services professionals participated in this simulation-based study at Srinagarind Hospital, Thailand. Participants positioned ambulances in simulated chemical, biological, radiological, nuclear, and explosives (CBRNE) and non-CBRNE scenarios using traditional self-assessment methods, followed by positioning using smart glasses technology after a 120-minute training session. Smart glasses equipped with a measurement-augmented reality application were utilized. Positioning accuracy was assessed.

Results: The participants had a median age of 36.1 years, with males comprising the majority (63.4%). Emergency nurse practitioners and students constituted the largest group (56.1%). Most participants (51.1%) reported over a decade of EMS experience. Smart glasses technology significantly improved positioning accuracy in both scenario types ($p<0.001$). In CBRNE scenarios, accuracy increased from 47.6% with self-assessment to 83.3% with smart glasses. In non-CBRNE scenarios, accuracy improved from 66.7% to 83.8%.

Conclusion: Smart glasses technology with augmented reality distance measurement capabilities substantially enhances ambulance positioning accuracy, particularly in complex CBRNE scenarios. The technology's ability to standardize performance across emergency types, and potentially across responder experience levels, suggests significant value for improving emergency medical service delivery, patient care, and responder safety.

Keywords: augmented reality, decision making, emergency mobile units, technology

Introduction

Emergency Medical Services (EMS) face critical challenges in optimizing ambulance positioning during patient care, where every second impacts patient outcomes.[1–3] The strategic placement of ambulances at emergency scenes represents a fundamental yet often overlooked aspect of prehospital care delivery. In our routine practice, EMS personnel typically depend predominantly on experience and intuition rather than evidence-based protocols when assessing ambulance positioning in relation to patients needing urgent medical care. This positioning decision is particularly consequential in time-sensitive emergencies such as cardiac arrest, major trauma, and stroke, where treatment delays of even minutes can significantly affect survival and recovery.[4–7]

In Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) incidents, accurate ambulance placement is essential for the safety of responders and the efficacy of patient care. The Emergency Response Guidebook (ERG)

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delineates minimum safe distances between 100 and over 800 meters, contingent upon the hazardous material involved.[8,9] Furthermore, in standard emergency responses, the placement of ambulances greatly influences operational efficiency and safety results. Research on traffic safety reveals that inadequately placed emergency vehicles lead to secondary accidents, resulting in emergency responders experiencing a fivefold heightened risk of traffic-related injuries relative to the general population.[10,11]

EMS services in Thailand begin with a call to the emergency number 1669. The dispatcher gathers a history and assesses initial symptoms, then triages the case according to the standards of the Thailand National Institute of Emergency Medicine.[12–14] Emergency cases are classified into three severity levels: red, yellow, and green. Based on this classification, the dispatcher assigns the nearest and most appropriate emergency medical operations unit. Upon arrival at the scene, EMS personnel must determine a suitable ambulance parking location. When dealing with extra threats like chemical spills, fires, or gas explosions, when keeping a suitable distance from the scene necessitates careful evaluation, this choice is particularly crucial.

Smart glasses, which are wearable gadgets with wireless networking, cameras, and heads-up displays, have fascinating uses in a variety of healthcare applications. These gadgets have been effective in surgical guiding, telemedicine, and medical education,[15,16] their potential to enhance emergency scene management remains largely unexplored. Integrating smart glasses into EMS protocols could provide real-time visual guidance, augmented reality overlays of optimal positioning patterns, and performance metrics that support both operational decision-making and subsequent training.[17]

The integration of smart glasses with distance measuring constitutes a unique approach that assists EMS personnel optimize ambulance location. The results of this study may have implications that extend beyond immediate enhancements for EMS systems. Insights obtained may guide the formulation of standardized positioning techniques, improve EMS education courses, and augment the existing literature on technology integration in emergency care. Furthermore, this research addresses the multidisciplinary intersection of emergency medicine, health informatics, human factors engineering, and patient safety, domains central to contemporary healthcare delivery models focused on optimizing outcomes through evidence-based practices and technological innovation.

The primary objective of this study was to investigate the efficacy of smart glasses technology in improving ambulance positioning during simulated critical care scenarios. We aimed to establish evidence-based parameters for optimal positioning.

Materials and Methods

A database of closed-circuit video recordings and assessment record forms documenting the determination of optimal ambulance placement was used in this single-center, retrospective field exercise study. The study was conducted at Srinagarind Hospital, Faculty of Medicine, Khon Kaen University, Thailand, between December 1 and December 31, 2024.

Data Collection

This study included all EMS personnel, including advanced emergency medical technicians (AEMTs), registered nurses (RNs), emergency physicians (EPs), and emergency nurse practitioners (ENPs). Individuals who experienced dizziness, vertigo, and disequilibrium, or who had prior experience with augmented reality technology, such as smart glasses, were excluded from this study.

The 30-simulated scenario was carried out by a multidisciplinary expert panel made up of three subject matter experts: Senior EMS personnel with field operations experience, Board-certified Emergency Medicine professionals with five to ten years of clinical experience, and HAZMAT specialists certified in emergency response protocols. Thirty simulated emergency scenarios were initially created based on real-world incident reports from regional emergency databases, international emergency response guidelines, and local hazard vulnerability assessments. An expert panel conducted an independent evaluation of all scenarios for clinical precision, realness, and educational usefulness. The Modified Delphi process attained consensus (≥80% agreement) regarding the appropriateness of the scenario. Conclusive verification of optimal positioning solutions utilizing established safety distance protocols. The final scenarios were categorized as CBRNE scenarios (n=15): Chemical spills, radiological incidents, and biological hazards; Non-CBRNE scenarios (n=15): Traffic accidents, cardiac arrest, and medical emergencies.

Participants were tested in two rounds, with a total of 30 scenarios per individual, conducted on the days of the field exercise. In the first round, participants performed a self-assessment to determine optimal ambulance positioning in simulated critical patient care scenarios. During the self-assessment phase, participants utilized their clinical experience and visual estimation to ascertain the optimal positioning of ambulances. In the second round, they used smart glasses.

After completing the self-assessment evaluation, participants underwent a 120-minute training session on the use of smart glasses. The training session covered the following topics: Introduction to smart glass technology (15 minutes), Measure AR application tutorial and practice (45 minutes), hands-on device familiarization and basic operation (30 minutes), and simulated positioning exercises with feedback (30 minutes). Following each test, participants were immediately removed from the testing area to prevent discussion among participants. The flow of this study is illustrated in Figure 1.

The HMT-1 model of smart glasses[17] from RealWear Inc. (Vancouver, Washington, USA) was used in this study. The device operated on Android 10.0 and featured a 2.0 GHz, 8-core Qualcomm CPU. It supported Wi-Fi (2.4 GHz and 5 GHz) and Bluetooth Low Energy 4.1.

The Measure AR (Xreal) application (Bacau, Romania) was installed on the smart glasses for measuring distances from the emergency scene to the optimal ambulance position in simulated critical care scenarios. This smart augmented reality measuring tool could measure vertical or horizontal distances in real-time, with an accurate margin of 1.5 cm.

The test's accuracy was assessed in CBRNE scenarios based on adherence to the Emergency Response Guidebook (ERG)[9] and in non-CBRNE scenarios included standard emergency situations such as cardiac arrest, trauma, and medical emergencies which was validated based on compliance with Thai Emergency Ambulance Safety guidelines, as outlined in the National Standard Curriculum for Emergency Vehicle Operator (Ambulance) Training Course.[18] Trained research assistants, who were EMS professionals, measured the distance of the ambulance's position using a tape measure and documented the accuracy of the measurements. Then, independent experienced Emergency Physicians (EPs) assessed these measurements against predetermined criteria.

The EPs who participated as assessors in our study were Board-certified in Emergency Medicine, possessing 5–10 years of clinical experience, regular engagement in hospital-based emergency response coordination, and expertise in medical oversight of regional EMS operations via hospital emergency department protocols. The data was retrieved and evaluated, encompassing each participant's precision in determining optimal ambulance placement. The data from the second round were subsequently entered. In instances of discrepancies, a senior EP with over 10 years of experience was consulted to verify and authenticate the data.

Sample Size

A standard normal value of 1.96 and an expected prevalence of 0.31 were used to determine the sample size required for estimating a proportion in an infinite population. An alpha level of 0.05 and an absolute precision of 0.10 were applied for the power analysis. Based on these parameters, the authors calculated that a sample size of 82 participants would be required.

Statistical Analysis

The statistical analysis was conducted using IBM SPSS for Windows, version 27.0, licensed by Khon Kaen University (Khon Kaen, Thailand) (IBM Corp., Armonk, New York, USA). Categorical data were expressed as frequencies and percentages, whereas continuous data were reported as median and interquartile range for non-normally distributed distributions. In the case of a normal distribution, we presented the means and standard deviations (SD). Pearson's chi-square test of independence was utilized to assess the association between categorical variables. All anticipated cell frequencies were ≥5, fulfilling the chi-square test criterion. The categorical nature of the outcome variables (accurate versus inaccurate positioning) was suitable for chi-square analysis. Comparing the positioning accuracy (correct/incorrect) of smart glasses and self-assessment techniques is the main analysis. Evaluation of the accuracy variations between CBRNE and non-CBRNE scenarios is known as secondary analysis. A two-tailed p-value below 0.05 was deemed statistically significant.

Results

Our study on smart glasses technology integration for ambulance positioning involved 82 EMS professionals (Table 1). The participants had a median age of 36.1 years (IQR 25.9–45.2), with males comprising the majority (63.4%).

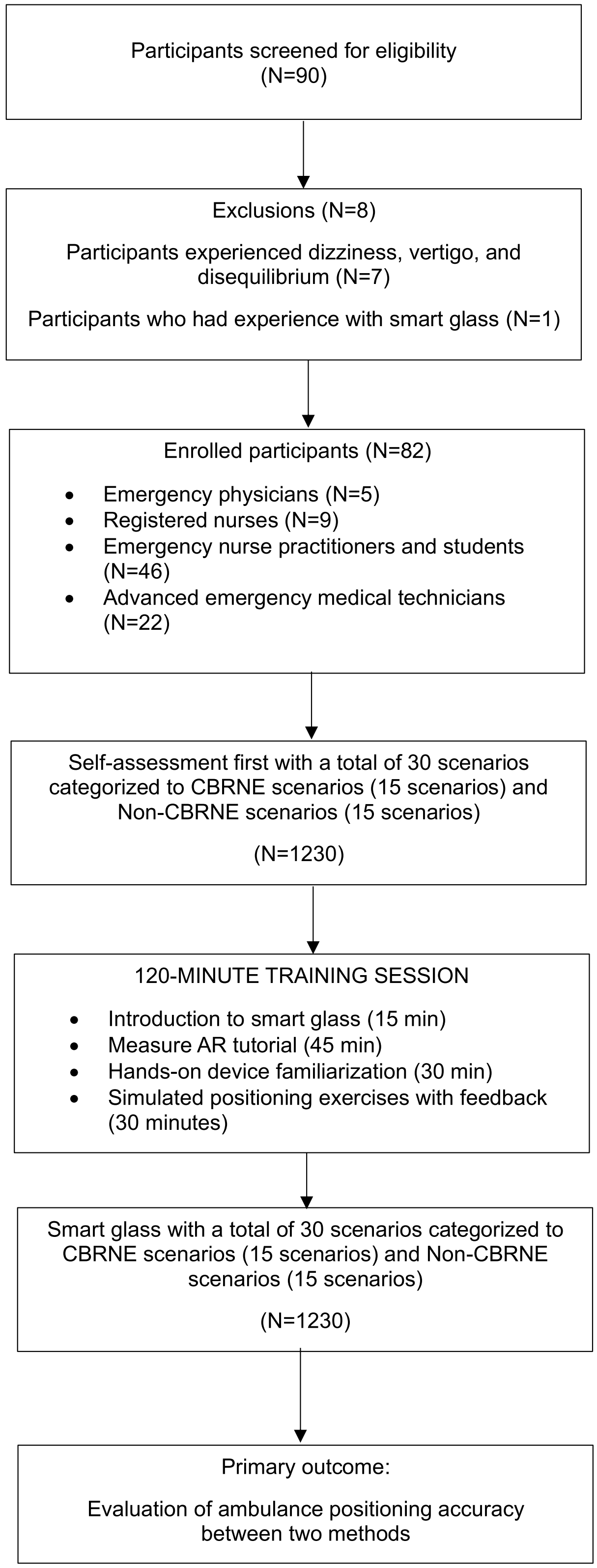

Figure 1 The study flow diagram.

Table 1 Participant Information

Variables	Participants (N = 82)
Age (year), median (IQR)	36.1 (25.9, 45.2)
Male, %	52 (63.4)
EMS Role, %	
Emergency physicians	5 (6.1)
Registered nurses	9 (11.0)
Emergency nurse practitioners and students	46 (56.1)
Advanced emergency medical technicians	22 (26.8)
Experience in EMS (year), %	
<1	2 (2.4)
1–5	6 (7.3)
5–10	32 (39.2)
>10	42 (51.1)

Abbreviations: IQR, interquartile range; EMS, emergency medical services.

Table 2 Accuracy in Optimal Ambulance Positioning (N=2460)

Scenarios	Self-assessment		Smart Glasses		P-Value
	N (%)	IQR	N (%)	IQR	
CBRNE	586/1230 (47.6)	40.1–50.6	1025/1230 (83.3)	75.8–89.9	<0.001
Non CBRNE	821/1230 (66.7)	60.6–72.3	1031/1230 (83.8)	76.1–90.3	<0.001

Abbreviations: CBRNE, chemical, biological, radiological, nuclear, and explosives.

Emergency nurse practitioners and students constituted the largest group (56.1%), followed by advanced emergency medical technicians (26.8%), registered nurses (11.0%), and emergency physicians (6.1%). Most participants (51.1%) reported over a decade of EMS experience, while 39.2% had 5–10 years in the field.

Table 2 presents a comparison of accuracy rates in optimal ambulance positioning between self-assessment methods and smart glasses technology across different emergency scenarios. A total of 2460 positioning attempts were analyzed. In CBRNE scenarios, the accuracy rate using traditional self-assessment methods was 47.6% (586/1230). When smart glasses technology was employed, accuracy increased significantly to 83.3% (1025/1230; $p<0.001$). For non-CBRNE scenarios, self-assessment methods yielded an accuracy rate of 66.7% (821/1230), which improved to 83.8% (1031/1230) with the implementation of smart glasses.

Discussion

Our study demonstrates that smart glasses technology significantly improves the accuracy of ambulance positioning in simulated emergency scenarios. The findings show substantial improvements in positioning accuracy across both CBRNE and non-CBRNE scenarios, with the most pronounced enhancement observed in CBRNE situations.

The baseline accuracy rates using traditional self-assessment methods (47.6% for CBRNE and 66.7% for non-CBRNE scenarios) reflect the inherent challenges emergency medical personnel face when relying solely on experience and visual estimation. This discrepancy between scenario types is noteworthy, suggesting that conventional methods are particularly inadequate in high-risk, complex emergencies where precise positioning is most critical. When equipped with smart glasses technology, participants achieved remarkably consistent accuracy rates of approximately 83% across both scenario types, effectively eliminating the performance gap between routine and complex emergencies.[19,20]

The standardization of performance across different emergency scenarios[21–23] represents one of the most valuable contributions of this technology. Smart glasses technology helped normalize performance standards regardless of scenario complexity or responder experience level.[23–26] This standardization has important implications for emergency service delivery, particularly in regions with varying levels of EMS training and experience.

From a pragmatic standpoint, enhanced precision in ambulance positioning directly influences patient treatment and the safety of responders. Optimal location guarantees that EMS personnel can swiftly reach patients while preserving a suitable safety margin from any dangers.[27–29] Inadequate placement may necessitate repositioning, resulting in delays in treatment during time-sensitive scenarios. Improved positioning could facilitate equipment access and patient transport.

For CBRNE scenarios in particular, where traditional assessment methods yielded less than 50% accuracy, the implementation of smart glasses technology could substantially reduce responder exposure to harmful agents while improving response efficiency.[29]

The incorporation of distance measuring functionalities into an augmented reality interface resolves a critical issue in emergency scene evaluation. This enhancement was accomplished with just a 120-minute training session on the technique. Our findings correspond with recent studies[30–32] on technology integration in emergency services, which consistently show that well-structured technological interventions can improve decision-making in critical situations. The relatively inexpensive and portable nature of smart glasses technology makes it especially suitable for widespread implementation across EMS systems, regardless of resource constraints.

The strengths of our study were that the present research is the first investigation into smart glasses technology utilizing augmented reality distance measurement for optimal ambulance positioning in emergencies. Although smart glasses have been investigated for diverse healthcare applications (surgical guidance, telemedicine, medical education), their utilization in EMS positioning decisions constitutes an innovative use case. Furthermore, our research distinctly illustrates the varying effects of technological assistance in CBRNE compared to non-CBRNE contexts. The discovery that smart glasses technology standardizes performance across various emergency types, achieving approximately 83% accuracy for both, represents a significant contribution, especially considering the considerable baseline performance disparity (47.6% versus 66.7%).

Several limitations warrant consideration when interpreting our results. First, the simulation-based design, while essential for standardization and safety, may not fully replicate the psychological pressure, environmental conditions, and complications encountered in actual emergencies. Secondly, our study concentrated solely on ambulance positioning, disregarding to investigate downstream effects on patient care metrics, including clinical relevance, patient outcomes, or team performance. Finally, participants had limited exposure to the technology prior to testing, which may underestimate the potential benefits that could emerge with longer-term use and integration into routine practice.

Conclusion

This study illustrates that smart glasses technology markedly enhances ambulance positioning precision in controlled simulations, attaining roughly 83% accuracy, in contrast to 47.6% for conventional self-assessment in CBRNE scenarios and 66.7% in non-CBRNE contexts. The technology demonstrates potential for standardizing positioning decisions in various emergency situations, thereby minimizing variability in responder performance. Nonetheless, these simulation-derived results signify initial evidence of technological capability rather than convincing validation of clinical advantage. Additional research is required to determine the practical clinical significance and feasibility of implementation, encompassing field trials in genuine emergency situations, evaluation of patient outcomes, and assessment of compatibility with current EMS protocols. The present findings establish a basis for subsequent research to investigate the practical implementation and economic viability of this technology in emergency medical services.

Abbreviations

CBRNE, chemical, biological, radiological, nuclear, and explosives; EMS, emergency medical services; AEMTs, advanced emergency medical technicians; RNs, registered nurses; EPs, emergency physicians; ENPs, emergency nurse practitioners.

Data Sharing Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Ethics Approval and Informed Consent

The Khon Kaen University Ethics Committee for Human Research approved the study, which was conducted in accordance with the Declaration of Helsinki and the ICH Good Clinical Practice Guidelines (HE681054). Informed consent was not required. All identifying information was removed from the collected data to ensure confidentiality.

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Author Contributions

All authors made substantial contributions to the conception, study design, implementation, data collection, analysis, and interpretation of the work. They participated in drafting, revising, or critically reviewing the article; approved the final version for publication; agreed to the article's submission to the journal; and accepted full responsibility for the work.

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Disclosure

The authors report no conflicts of interest in this work.

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