# Advancing prehospital care: A systematic review of technology-enhanced basic life support interventions

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# Advancing prehospital care: A systematic review of technology-enhanced basic life support interventions

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**Abstract**

**Background:** Technological interventions are believed to enhance the quality of resuscitation efforts in prehospital settings. However, the specific applications of technology and the challenges associated with its implementation remain underexplored.
**Purpose:** To examines the integration of technology into basic life support (BLS) practices in prehospital settings, along with the challenges encountered in its use.
**Method:** A systematic literature review was conducted, gathering data from Scopus, Springer, and PubMed databases using the keywords "basic life support" AND prehospital AND technology, focusing on articles published between 2019 and 2024. A total of 365 articles were initially identified, with 9 meeting the inclusion criteria for further analysis. These articles were systematically reviewed and analyzed.
**Results:** Technological innovations in BLS have shown significant potential in improving resuscitation quality by reducing intervention delays and increasing accuracy. However, several challenges remain, including technical and connectivity issues, user-related barriers, insufficient system integration, and psychosocial impacts.
**Conclusion:** While technological advancements have enhanced BLS in prehospital settings by shortening response times, improving precision, and minimizing human error, challenges such as technical reliability, user acceptance, and the lack of long-term validation must be addressed. Future research should focus on real-world applications, survival outcomes, and long-term retention of skills acquired through these technologies.

**Keywords: Basic Life Support; Prehospital; Technology.**

## INTRODUCTION

Prehospital basic life support (BLS) is a critical component of emergency medical response, particularly for out-of-hospital cardiac arrest (OHCA), where timely intervention can significantly impact survival rates (Scquizzato, Gamberini, & Semeraro, 2022; Thannhauser, Nas, Waalewijn, van Royen, Bonnes, Brouwer, & de Boer, 2022). Technological innovations, such as mobile applications, virtual reality (VR) training, and telemedicine, have been integrated into prehospital BLS to improve response times and the quality of care. For instance, mobile applications have been designed to reduce errors in

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resuscitation procedures and medication preparation by guiding responders with real-time instructions (Alamgir, Mousa, & Shah, 2021; Hutton, Lingawi, Puyat, Kuo, Shadgan, Christenson, & Grunau, 2022; van den Beuken, Sayre, Olasveengen, & Sunshine, 2023). VR-based training systems have also shown promise in improving practical skills and reducing no-flow time in CPR, allowing responders to practice under simulated, yet realistic, conditions (Shatpattananunt, Petpichetchian, Pinsuwan, Chaloempong, Waraphok, & Wongwatkit, 2023). Telemedicine, particularly video-assisted dispatcher-guided CPR, has been found to enhance the quality of resuscitation efforts by allowing remote medical professionals to provide real-time guidance to bystanders (Brent, Cheskes, Castrén, & Brooks, 2023; Kim, Groombridge, Romero, Clare, & Fitzgerald, 2020; Murphy, Cohen, Hwang, Avery, Balakrishnan, Balu, Chowdhury, Crabb, Elmelige, Maciel, Gul, Han, & Becker, 2022).

While these technologies have demonstrated success in controlled environments and simulations, their real-world effectiveness in diverse and high-pressure prehospital settings remains underexplored. Many studies, including those using smart glasses and VR, have focused on the effectiveness of these technologies in controlled or training settings, leaving gaps in understanding their impact during actual emergency events (Levitt, Boone, Tran, & Pourmand, 2023; Metelmann, Metelmann, Kohnen, Brinkrolf, Andelius, Böttiger, Burkart, Hahnenkamp, Krammel, Marks, Müller, Prasse, Stieglis, Strickmann, & Thies, 2021; Wang, Ma, Chen, Fan, & Hou, 2023). Additionally, research on the long-term retention of skills acquired through these technological platforms, such as VR training, is limited. It is also unclear how well these tools perform in rural or resource-limited areas, where factors like internet connectivity and device availability could pose significant challenges (Levitt et al., 2023; Murphy et al., 2022).

The major gap in current research lies in the translation of promising results from simulated environments to real-world applications. While technologies like VR and mobile applications have been shown to improve responder skills and reduce errors in simulated scenarios, their effectiveness in diverse, real-world emergency contexts, particularly in under-resourced areas and how these technologies can be adapted for bystanders with varying levels of technological proficiency is still lack to understand. We conducted a systematic literature review to better understand how technology can be used to improve the quality of BLS. In addition, we also analyze the challenges faced in the implementation of technology in prehospital settings. The results of this literature study are expected to be used as a reference to develop the use of technology in resuscitation efforts in various prehospital situations.

## RESEARCH METHOD

This study follows a systematic literature review approach to identify and select relevant articles that align with the research objectives. The process began by formulating the research objectives and defining the key question: "How can technology improve the quality of prehospital BLS, and what challenges are encountered?"

To address this question, we conducted a comprehensive literature search across three databases: Scopus, Springer, and PubMed. The search was restricted to original research articles published between 2019 and 2024, using the keywords "basic life support" AND prehospital AND technology. The initial search yielded 365 articles. We applied several screening steps to refine the selection following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline. At initial screening, a total of 317 articles were excluded (237 articles were published before 2019, 77 articles were not original research articles, 1 article was not in English, and 2 articles were duplicates). Of the remaining 48 articles, 21 were deemed irrelevant to the research objectives and questions based on their titles and abstracts. We conducted a detailed eligibility

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assessment of the remaining 27 articles by reviewing the full text. This process excluded 18 articles (15 articles did not involve technological interventions, 1 article was not an appropriate population, 1 article was not an original research article, and 1 article without full-text availability). In the final selection, 9 articles met all inclusion criteria and were included in the study. These articles were then subjected to a quality assessment before undergoing systematic review and analysis.

## RESEARCH RESULTS

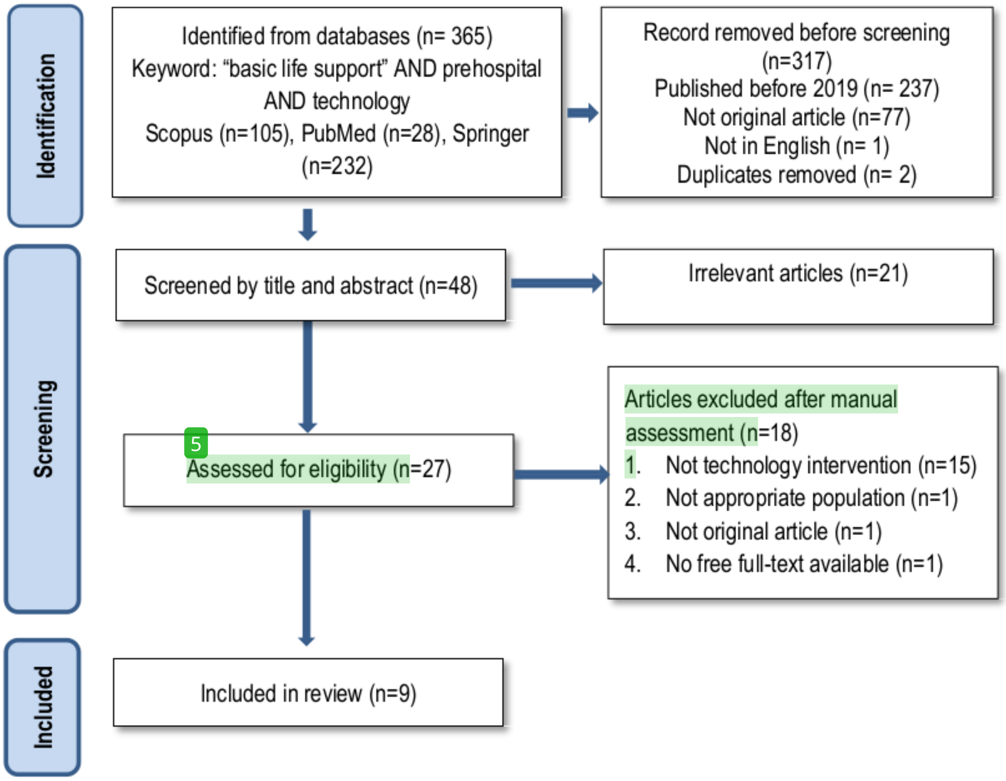


**Figure PRISMA flow diagram**

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**Table The Main Characteristics of Included Studies**

| Author (Year) (Country) | Population (P) | Intervention (I) | Comparison (C) | Outcomes (O) | Limitation/challenges |
|---|---|---|---|---|---|
| Pommerenke et al. (2023) (Germany) | First responders and patients experiencing OHCA | the use of KATRETTER app, a smartphone-based community first responder (CFR) system that activates nearby volunteers to assist in suspected OHCA cases. The app mobilizes volunteers to perform basic life support (BLS) until emergency medical services (EMS) arrive. | The study compares the number of activations, responses, and outcomes from the KATRETTER system over time. | A total of 16,505 activations with 38.4% patients contact by first responders, 34.6% CPR performed by first responders, 12.7% AEDs used before EMS arrival. Early intervention by first responders helps reduce the no-flow time, but no conclusive evidence on direct survival improvements. | False Positive Activations<br>Systemic and User-Related Issues<br>Responder Dropouts<br>Limited AED Integration<br>Potential for Under-Reporting<br>The app lacks robust bi-directional communication between first responders and control centers, which can limit the control center's ability to manage and monitor the situation after the first responder's activation.<br>Psychosocial Impact on First Responders. |
| Upendra et al. (2019) (India) | 60 nursing students | simulation-based learning using METIman, a high-fidelity computerized manikin | pre-test and post-test skill scores of the nursing students, assessing their clinical | Pre-test average score: 14.42 (SD = 6.168).<br>Post-test average score: 29.83 (SD = 5.869). | A small sample size (60 nursing students) and single center. The study also did not include a control group, as it employed a one-group pre- |

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| | | that simulates real-life clinical settings. | skills before and after the simulation-based learning intervention. | Paired t-test showed a significant improvement with a t-value of -12.668 and a p-value of 0.001, indicating that simulation-based learning significantly improved the clinical skills of the nursing students. | experimental design, which limits the ability to attribute improvements solely to the intervention. |
| Igarashi et al. (2022) (Japan) | 70 first-year college students from a health sciences department | Dispatcher-assisted first aid delivered via video calls (intervention group) | Voice-only calls (control group) | After the initial oral instruction, the proportion of excellent or acceptable first aid not significantly different between the two groups (41% vs. 50%, respectively). After transitioning to video calls, the proportion of excellent or acceptable evaluation increased significantly in the video call group (82%) vs voice-call group (50%).<br>Poor participant significantly lower in the video-call group (50% vs. 82% in the voice-call group, p=0.049). | The study was a simulation.<br>The study participants were young and familiar with smartphones, the results may not generalize to older or less tech-savvy populations.<br>Video-call failure occurred in 24% of simulations. |

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| Author (Year) (Country) | Population (P) | Intervention (I) | Comparison (C) | Outcomes (O) | Limitation/challenges |
|---|---|---|---|---|---|
| Siebert et al. (2019) (Switzerland) | 128 nurses | The use of the PedAMINES app, a mobile device designed to reduce medication errors and time to drug preparation and delivery during pediatric resuscitation scenarios. The app assists paramedics in calculating drug dosages and preparing medications in emergencies. | Conventional drug preparation methods (without the app, only with calculators and manual calculation) | Among the 128 drug preparations associated with each of the two methods, 96 (75%, 95% CI 67–82) delivered using the infusion-rates table were associated with medication errors compared with nine (7%, 3–13) delivered using the mobile app. Medication errors reduced by 68% (95% CI 59–76%; p<0·0001) with the app compared with the table, as was the mean time to drug preparation (difference 148·2 s [95% CI 124·2–172·1], a 45% reduction; p<0·0001) and mean time to drug delivery (168·5 s [146·1–190·8], a 40% reduction; p<0·0001). | The study is conducted in a simulation-based environment rather than in real-life scenarios. Although high-fidelity simulation is considered a valid research method, it may not capture all real-life complexities.<br>Training with the app is limited to a 5-minute session, which may not reflect real-world usage where paramedics may not frequently use the app.<br>The study uses a self-reported Likert-scale questionnaire to assess stress, which may not fully capture objective stress levels. |

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| Bylow et al. (2019) (Sweden) | 1,301 laypeople from non-healthcare workplaces (adults over the age of 18 who had either no prior BLS training or had not received training in the last five years) | Self-learning training (SLT): Participants received individual instructions for BLS and practiced while watching a standardized instructional film (video). | Instructor-led training (ILT): Participants received the same instructional film along with guidance from an instructor who provided theoretical explanations and practical help. The study assessed participants' skills directly after training and six months later. | Directly after training, the instructor-led group had a higher total score (median 61 vs. 59). Self-assessed knowledge, confidence, and willingness to act were higher in the instructor-led group immediately after training.Six months after training, there was no statistically significant difference in practical skills between the two groups (median score of 59 for both groups). | The study was conducted in a simulated environment on a Mini-Anne manikin.<br>There was no follow-up beyond six months to evaluate long-term skill retention.<br>The study did not evaluate the actual survival outcomes from out-of-hospital cardiac arrests, focusing only on skill performance. |
| Ellebrecht & zur Nieden (2019) (Germany) | EMS professionals (including paramedics and emergency physicians) and patients treated through | the use of telemedical systems (systems that allow emergency physicians to assist paramedics remotely during emergencies through audio and video | Traditional face-to-face EMS scenarios | The study highlights that telemedical systems increase the reliance on formal guidelines and shift more responsibility toward paramedics. It also shows that while telemedicine can enhance accessibility, it complicates the presence and | The study notes that telemedicine creates challenges in communication and decision-making, particularly in terms of responsibility sharing. There is also a potential risk of communication breakdowns, and the shift in responsibility to paramedics may lead |

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|---|---|---|---|---|---|
| | telemedicine in emergency medical scenarios. | links including telemetry for sending patient data and video streams to physicians located in control centers) | | interaction between medical professionals. | to increased stress and "media overload." |
| Barcala-Furelos (2022) (Spain) | 12 professional fishermen (mean age of 46 years and at least 10 years of experience in fishing). | The using of smart glasses (SGs) to guide basic life support (BLS) procedures during simulated out-of-hospital cardiac arrest (OHCA) scenarios on fishing boats (Participants used SGs to receive real-time dispatcher feedback while performing BLS, including the use of an automated external | First minute: Participants performed CPR without dispatcher feedback.<br>Second minute: Participants performed CPR with continuous feedback from the dispatcher via the smart glasses. | Dispatcher feedback through smart glasses improved participants' BLS performance. After dispatcher feedback:<br>Correct hand placement remained challenging (improved from 53% to 54%).<br>Chest compression depth significantly improved from 48% (first minute) to 70% (second minute).<br>Time to first defibrillation averaged 162 seconds. | The study had a small sample size of 12 participants, limiting the generalizability of the results.<br>The simulation was conducted in a controlled environment, which not fully reflect the real emergency conditions.<br>Connectivity challenges and technical issues with the smart glasses, such as startup time and device heating, could impact their feasibility in real emergencies. |

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| | | defibrillator (AED) and CPR). | | Fishermen could perform all BLS steps, but dispatcher feedback was necessary in 72% of the cases. | |
| Shatpattananunt (2023) (Thailand) | 70 undergraduate students (divided into experimental and control group, with 35 students in each group). | the use of the MFU BLiS VR training system, which provides virtual reality training in basic life support (BLS) for out-of-hospital cardiac arrest (OHCA). The experimental group received BLS training through VR in addition to traditional face-to-face teaching, while the control group only received traditional teaching. | traditional BLS training | The study found that the experimental group had significantly shorter no-flow time (the period during which chest compressions were not performed) and higher scores in BLS knowledge and practical skills compared to the control group. | The sample consisted only of students who voluntarily participated in an extracurricular activity, which may introduce selection bias.<br>The VR system is currently only compatible with Android devices, limiting accessibility.<br>The study did not assess long-term retention of BLS knowledge or skills beyond the immediate post-test.<br>The usability of the VR system may be affected by cybersickness or other health conditions, limiting its generalizability to the broader population. |

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| López-Izquierdo (2024) (Spain) | 7,909 adult patients with acute life-threatening illnesses managed by Emergency Medical Services (EMS) | the use of prehospital point-of-care testing (POCT) and on-scene vital sign measurements to determine clinical phenotypes for risk stratification through a machine learning. EMS teams used POCT devices to analyze biomarkers such as venous or arterial blood gas levels, renal profiles, glucose, lactate, and others. | The study compared the outcomes of three phenotypic clusters (alpha, beta, and gamma) derived from machine learning based on prehospital vital signs and biomarker data. Mortality rates and clinical characteristics of these phenotypes were compared. | Three phenotypic clusters were identified:<br>Alpha (16.2% of patients): high-risk, older patients with significant comorbidities, requiring more advanced life support interventions and ICU admissions. Mortality rates were 18.6% at 2 days, 24.7% at 7 days, and 33% at 30 days.<br>Beta (28.8%): moderate risk with a mortality rate of 4.1% at 2 days, 6.2% at 7 days, and 10.2% at 30 days.<br>Gamma (55%): lower risk with a mortality rate of 0.8% at 2 days, 1.7% at 7 days, and 3.2% at 30 days. | The EMS records were paper-based, increasing the time needed for data collection and risking manual data entry errors.<br>Not all EMS units were equipped with POCT devices, limiting the completeness of biomarker data.<br>The study was conducted before and during the COVID-19 pandemic, which may have affected EMS activation and patient outcomes. |

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## DISCUSSION

In this systematic literature review, 9 articles were obtained. Seven studies were simulations, and the other 2 studies used data from real cases. Seven studies were conducted in developed countries, and the other two were conducted in developing countries. Three of the nine studies used a smartphone-based application. Meanwhile, the other 6 studies used various technologies, namely computerized manikin, video learning, virtual reality (VR), telemedicine, smart glasses, and machine learning. Following the objectives of the research, our discussion focuses on the use of technology in improving the quality of resuscitation and the challenges faced in implementing it.

### Effectiveness of Technology in Improving Resuscitation Quality

Technological innovations in Basic Life Support (BLS) for out-of-hospital cardiac arrest (OHCA) scenarios have shown considerable promise in enhancing resuscitation quality, particularly by minimizing delays in intervention and improving procedural accuracy. For example, smartphone-based applications such as KATRETTER, which activate community first responders, have demonstrated a reduction in "no-flow time"—the period when no chest compressions are being performed—thereby increasing the likelihood of survival in OHCA cases. Despite these promising results, the direct impact of these technologies on long-term survival rates remains inconclusive, as other variables may also play a role in patient outcomes (Pommerenke, Poloczek, Breuer, Wolff, & Dahmen, 2023).

Another example is the PedAMINES mobile application, which has been shown to significantly reduce medication errors by 68% during pediatric resuscitation scenarios. Additionally, the app enhances drug preparation and delivery times, illustrating the potential of mobile technology to minimize human error in high-stress prehospital settings. These findings emphasize the utility of smartphone applications in streamlining complex procedures, ultimately leading to safer and more efficient patient care (Siebert, Ehrler, Combescure, Lovis, Haddad, Hugon, Luterbacher, Lacroix, Gervaix, Manzano, Gehri, Yersin, Garcia, Hermann Marina, Pharisa, Spannaus, Racine, Laubscher, Vah, & Juzan, 2019).

High-fidelity simulation and virtual reality (VR) tools such as METIman and MFU BLiS VR have also been effective in improving resuscitation skills. Participants trained with these technologies demonstrated faster response times and more accurate chest compressions during cardiopulmonary resuscitation (CPR). VR training, in particular, bridges the gap between theoretical knowledge and hands-on application by providing a highly immersive and realistic learning environment, which leads to better skill retention and improved practical performance (Shatpattananunt et al., 2023; Upendra, Barde, Sawane, & Shitalwaghmare, 2019).

Telemedicine represents another valuable tool in prehospital care, offering real-time support to paramedics and lay responders through audio and video consultations with emergency physicians. This method not only enhances decision-making accuracy but also speeds up critical interventions by providing immediate expert guidance during emergencies (Ellebrecht & zur Nieden, 2020; Igarashi, Suzuki, Norii, Motomura, Yoshino, Kitagoya, Ogawa, Yokobori, & Yokota, 2022). Such remote guidance has the potential to reduce treatment errors and optimize patient outcomes, particularly in regions where access to medical expertise is limited.

### Challenges in Implementing Technology in Prehospital BLS

While technological advancements have improved BLS outcomes, several significant challenges continue to impede widespread adoption and effectiveness. These challenges include technical and

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connectivity issues, user-related barriers, lack of system integration, and psychosocial impacts on responders.

Technological devices and applications used in prehospital settings, such as smart glasses for real-time feedback or video-assisted CPR, often encounter technical issues like connectivity failures, device malfunctions, or delays. For instance, in simulated scenarios, video-call assistance failed in 24% of cases, while smart glasses experienced problems like startup delays and overheating. Such limitations can undermine the reliability of these tools in real emergencies where swift and dependable responses are crucial (Barcala-Furelos, Aranda-García, Otero-Agra, Fernández-Méndez, Alonso-Calvete, Martínez-Isasi, Greif, & Rodríguez-Núñez, 2023; Igarashi et al., 2022).

Adoption of these technologies is further hindered by user-related barriers. These include unfamiliarity with the devices, reluctance to use them, or confusion over their operation. For example, some first responders missed emergency notifications or struggled with smartphone settings, preventing timely intervention. Additionally, individuals less experienced with smartphones, such as some first-year college students, faced difficulties using video-call features effectively, compromising the quality of care (Igarashi et al., 2022; Pommerenke et al., 2023).

A critical challenge in implementing technology in prehospital emergencies is the lack of system integration. Many tools are not fully integrated with existing emergency response infrastructures, such as automated external defibrillator (AED) retrieval systems, limiting the potential for early defibrillation—a key component of effective BLS. Furthermore, applications like KATRETTER have been criticized for lacking bi-directional communication features, which prevents control centers from providing adequate monitoring and guidance to first responders (Pommerenke et al., 2023).

The use of technology in high-pressure environments can also increase the psychosocial burden on first responders, particularly if they are not well-versed in the tools being used. Adequate training is essential to ensure confidence and efficiency in real-life emergencies. However, many studies provide only minimal training—for example, a 5-minute introduction to PedAMINES—which may not be sufficient for effective, real-world application (Pommerenke et al., 2023; Siebert et al., 2019).

**Gaps in Research and Future Directions**

While the evidence suggests that technology can significantly enhance BLS performance, several key research gaps remain that must be addressed to fully understand its long-term impact. These gaps include long-term skill retention, real-world validation, and survival outcomes—critical areas highlighted by reviewers as priorities for future research.

One major gap is the focus on immediate post-intervention outcomes, with limited attention to the long-term retention of skills. It is unclear whether the initial improvements observed with simulation-based or VR training persist over time and translate into sustained competence in real-world emergency scenarios (Shatpattananunt et al., 2023; Upendra et al., 2019). This raises questions about the true effectiveness of these technologies in maintaining BLS proficiency beyond the training environment.

Additionally, much of the existing research—such as studies involving smart glasses, VR, and the PedAMINES app—has been conducted in simulated settings. While simulations provide controlled conditions for evaluation, they may not accurately capture the complexity and unpredictability of real-life emergencies. As a result, there is a pressing need for further studies that assess the efficacy of these technologies in real-world prehospital environments, where variables such as environmental factors, human behavior, and unpredictable circumstances can significantly impact outcomes (Barcala-Furelos et al., 2023; Igarashi et al., 2022; Shatpattananunt et al., 2023; Siebert et al., 2019; Upendra et al., 2019).

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Furthermore, although improvements in CPR performance and response times are well-documented, many studies fail to report patient survival rates following BLS interventions. Understanding the link between technological advancements and clinical outcomes, such as survival to hospital discharge, is essential for determining the true value of these innovations. Future research should prioritize exploring how these technologies affect patient survival and long-term recovery, offering a more comprehensive view of their real-world benefits (Bylow, Karlsson, Claesson, Lepp, Lindqvist, & Herlitz, 2019; López-Izquierdo, del Pozo Vegas, Sanz-García, Mayo Íscar, Castro Villamor, Silva Alvarado, Gracia Villar, Dzul López, Aparicio Obregón, Calderon Iglesias, Soriano, & Martín-Rodríguez, 2024; Pommerenke et al., 2023).

## CONCLUSION

Technological advancements have undoubtedly improved the quality of BLS in prehospital settings by reducing response times, enhancing skill accuracy, and minimizing human error. However, for these tools to be truly effective in real emergencies, several challenges must be overcome. Issues related to technical reliability, user adoption, and the lack of long-term validation remain significant barriers to widespread implementation. To fully harness the potential of these innovations, future research should prioritize evaluating their real-world applicability, their impact on patient survival outcomes, and the long-term retention of skills acquired through these technologies. Addressing these gaps will be critical in ensuring that technological interventions not only improve immediate BLS performance but also lead to lasting improvements in patient care and outcomes.

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