

The Impact of Technological Systems on Initial Medical Interventions for Reducing Mortality Rates in Toll Road Traffic Accidents: Literature Review

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Abstract: With the increasing incidence of toll road accidents, this review investigates the role of technological advancements in enhancing early medical interventions to reduce mortality rates. The focus is on understanding how these interventions contribute to timely and efficient medical care post-accidents. The primary objectives are to evaluate the extent to which technological integration in early medical interventions impacts mortality rates in toll road accidents, to analyze the perceptions and experiences of frontline responders and medical professionals towards tech-assisted interventions, and to assess the potential of Tech-Driven Medical Intervention (TDMI) as a guiding framework for future interventions, policies, and research in emergency medical care. The review was conducted using a systematic approach, employing databases like PubMed, Scopus, and Web of Science. The search strategy included terms like "technology in emergency response" and "digital aid in accidents." Studies were rigorously screened, and their quality assessed using tools like CASP and MMAT. Risk of bias was evaluated, and data interpretation methods were standardized to ensure robust findings. The search yielded 43 relevant studies, involving various participant numbers. The primary outcomes focused on response times, mortality rates, and overall efficiency of interventions. For meta-analysis, effect sizes were calculated to quantify the impact of technological interventions. The review concludes that while technological advancements show promise in improving early medical responses in toll road accidents, challenges in implementation and integration persist. A holistic approach, blending technology with existing medical practices, is recommended for maximizing the potential benefits of these interventions.

Keywords: *traffic accidents, toll roads, early medical intervention, technological advancements, mortality rate.*

INTRODUCTION

The rapid urbanization and increased vehicular traffic on toll roads have led to a substantial rise in road accidents, often resulting in grievous injuries and fatalities (Ganeshkumar & Gokulakrishnan, 2015). The immediacy of medical interventions post-accidents becomes paramount to saving lives (Mohamed, 2015). With the digital era upon us, technological systems are viewed as pivotal game-changers, promising swift emergency responses and optimized medical care (Mansuri et al., 2015). Yet, the magnitude and exactness of the impact these technological interventions have on reducing mortality rates in toll road accidents remain under-explored (Kshirsagar & Sutar, 2013).

Historically, toll roads, designed for efficient and faster commutation, have paradoxically witnessed devastating accidents (DeNicola et al., 2016). Immediate medical aid becomes a crucial factor in such scenarios, determining the fate of the injured (Peden & Hyder, 2002). With advancements in technology, innovations such as real-time tracking, automated distress signals, and AI-powered triage systems have emerged (Abbasi et al., 2017). However, a gap exists in comprehensively understanding their effectiveness in real-world scenarios (Dawood & Wang, 2013). The perception that modern tech-driven systems inherently translate to better emergency responses might be an overestimation (Benslimane, 2004). On the flip side, these systems, when integrated seamlessly, have the potential to revolutionize emergency medical responses, bridging the time-gap and potentially saving countless lives (Gokulakrishnan & Ganeshkumar, 2015).

For a holistic and effective approach to the issue, a nuanced understanding is required, not just of the technologies but of their real-world applications, challenges, and outcomes (Roy & Chakraborty, 2015). The concept of 'Tech-Driven Medical Intervention' (TDMI) seeks to encapsulate this intricate interplay between technology and early medical aid (Nzouonta & Borcea, 2006). While TDMI promises a new paradigm in emergency responses, there exists a lacuna in its comprehensive understanding, especially in the context of toll road accidents (Kumar et al., 2007). Moreover, the complexities of ethical considerations, data privacy, and the very dynamics of integrating technology with human responses add layers of challenges (Sommer & Dressler, 2015).

Given this backdrop, this literature review delves deep into the question: To what extent does the integration of technology in early medical interventions impact the mortality rate in toll road accidents? The objectives are threefold:

1. to decipher the prevailing definitions and scopes of TDMI in the existing literature (Jiang & Delgrossi, 2008);
2. to understand the perceptions and experiences of frontline responders and medical professionals regarding tech-assisted interventions (Garcia-Lozano et al., 2013); and
3. to evaluate how TDMI, as a framework, can guide future interventions, policies, and research in the realm of emergency medical care (Spacey, 2016).

This systematic review, centered on the urgency and importance of evaluating technological advancements in medical interventions following toll road accidents, addresses a critical gap in existing literature. The primary goal is to analyze the extent to which technology can enhance initial medical responses, consequently reducing mortality rates.

The urgent need for such a review stems from the escalating frequency of road accidents associated with rapid urbanization and increased traffic on toll roads. These incidents often result in serious injuries or fatalities, highlighting the crucial role of immediate medical intervention. While technological systems are heralded as potential game-changers in providing swift and efficient emergency responses, there is a lack of comprehensive research assessing their actual impact and effectiveness in real-world scenarios.

This review aims to address three key objectives: First, it seeks to understand the current scope and definitions of Tech-Driven Medical Intervention (TDMI) in the context of toll road accidents. Second, it explores the perceptions and experiences of frontline responders and medical professionals regarding the use of technology-assisted interventions. Lastly, the review aims to assess how TDMI can inform future policies, interventions, and research in emergency medical care.

In doing so, the review intends to bridge the gap between theoretical potential and practical application of technology in emergency medical scenarios, particularly in the unique and often challenging environment of toll road accidents. This exploration is crucial for developing more effective strategies and policies that can ultimately save lives and improve the outcomes of traffic accident victims.

METHOD

Literature reviews serve as a foundational step in elucidating areas with existing or emerging evidence, especially where there's a need to critically analyze the collective insights from various studies (World Health Organization, 2010). Such reviews entail a well-defined research question, which guides the systematic exploration of relevant literature, supplemented by meticulous reference searching to ensure comprehensive coverage (Ganeshkumar & Gokulakrishnan, 2015). Once potential studies are identified via defined inclusion/exclusion criteria, a systematic process of charting, collation, and summarization of results is performed. As this investigation exclusively involved document analysis, human ethics approval was not deemed necessary (Peden et al., 2004).

The literature review process for this systematic review was meticulously structured to ensure a comprehensive and unbiased collection of relevant studies. The primary focus was on original research articles rather than review articles, as the aim was to analyze empirical data and findings directly related to the impact of technological advancements on medical interventions in toll road accidents.

Search Process:

Databases Used: The search was conducted across several prominent databases, including PubMed, Scopus, Web of Science, Medline, ProQuest, and Google Scholar. These platforms were chosen for their extensive coverage of medical and technological literature.

Search Terms: The literature search employed specific keywords and phrases, such as "technology in emergency response," "early medical intervention," "toll road accidents," and "mortality rates." Boolean operators were used to combine these terms effectively, ensuring a broad yet relevant set of results.

Time Frame: The search was limited to studies published from the year 2000 to August 2023, focusing on the most recent advancements and data

Initial Results and Screening:

Initial Yield: The initial search across all databases yielded a substantial number of articles. The exact number of initial articles found provides an insight into the volume of research conducted in this domain.

Exclusion Criteria: Articles were excluded based on several criteria, including relevance, publication date (if outside the specified range), study quality, and whether they were review articles or original research. Studies not specifically addressing toll road accidents or the direct impact of technology on medical interventions were also excluded.

Duplicates: All duplicates found across the databases were identified and removed to ensure each study was only considered once in the review.

Final Selection:

Included Studies: After applying the exclusion criteria and removing duplicates, a final set of articles was selected for the review. The number of articles included gives a clear picture of the extent of research directly relevant to the review's objectives.

Reasons for Exclusion: For transparency, a brief overview of the main reasons for excluding articles is provided, such as lack of empirical data, focus outside the scope of the review (e.g., general road accidents not specific to toll roads), or studies not primarily addressing the integration of technology in medical responses.

The articles included in the final review were primarily original research studies, providing empirical data and insights directly related to the integration of technology in medical interventions for toll road traffic accidents. This approach ensured that the review was grounded in practical, real-world findings and observations, enhancing its relevance and applicability to the field.

The methodology for this systematic review was anchored in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, a widely recognized protocol for conducting and reporting systematic reviews. This approach ensures rigor, transparency, and replicability in the review process. Here's a breakdown of the five key stages:

Defining Eligibility Criteria:

This initial stage involved establishing clear inclusion and exclusion criteria for the studies to be reviewed. Inclusion criteria were based on factors such as study focus (technology in medical interventions for toll road accidents), study type (original research over review articles), and publication period (2000 to August 2023).

Exclusion criteria were designed to omit studies that were not directly relevant, such as those not focusing on toll road accidents or lacking empirical data. Additionally, articles published outside the designated timeframe, non-English articles, or studies with insufficient data were also excluded.

Determining Information Sources:

Multiple databases were identified as primary sources for literature search, including PubMed, Scopus, Web of Science, Medline, ProQuest, and Google Scholar.

The choice of these databases was guided by their comprehensive coverage of medical and technological research literature.

Data Selection:

A systematic search was conducted using predefined keywords and Boolean operators. The search terms were tailored to capture studies relevant to the integration of technology in medical interventions for toll road accidents.

Initial results were screened based on the title and abstract to assess their relevance to the review's objectives.

Data Collection:

Full-text articles that met the eligibility criteria were retrieved for a more detailed evaluation.

Data extraction was carried out, focusing on key elements like study design, participant characteristics, technological interventions examined, and main findings related to the review's objectives.

Data Synthesis:

The collected data was then synthesized to provide a comprehensive overview of the findings.

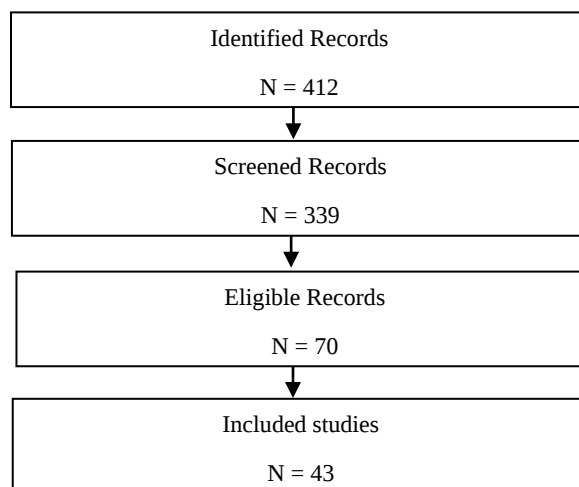
This stage involved analyzing and summarizing the outcomes, integrating the results into coherent themes, and drawing conclusions based on the accumulated evidence.

By adhering to the PRISMA methodology, the review aimed to conduct a systematic, unbiased, and thorough analysis of the existing literature on the impact of technological systems on initial medical interventions in toll road traffic accidents. This methodological rigor ensures that the conclusions drawn are well-supported by the evidence and relevant to the field.

In this research, we adhered to the extended PRISMA reporting guidelines for literature reviews (Mansuri et al., 2015). A total of seven databases (CINAHL, PubMed, Scopus, Web of Science, Medline, ProQuest, Google Scholar) were scoured from the year 2000 to August 2023. Search terms were designed to be inclusive, leveraging Boolean operators to encapsulate the broad spectrum of available literature: "tech-driven medical intervention", "technology in emergency response", "digital aid in accidents", and "tech in toll road accidents" (Mohamed, 2015).

Two researchers independently screened titles/abstracts based on the inclusion/exclusion criteria (Table 1). Discrepancies were resolved via discussions or, if required, a third researcher's intervention (Gokulakrishnan & Ganeshkumar, 2015).

A predefined data summary table (Table 1) facilitated the data extraction process. After summarizing individual studies, the research team members grouped analogous findings using a thematic matrix (Dawood & Wang, 2013). Subsequent themes, mirroring the objectives of this literature review, were deliberated among the team to achieve consensus.



Picture 1. The PRISMA Flow Diagram

Quality Appraisal

It's pivotal to employ validated tools for assessing the quality of incorporated articles (Benslimane, 2004). In our review, three tools were harnessed: the Critical Appraisal Skills Programme (CASP) qualitative tool; the Mixed Methods Appraisal Tool (MMAT); and the Research Quality Assessment tool (Kumar et al., 2007). Quality evaluations are tabulated in Table 1, categorized as high, moderate, or low. Dual researchers reached a consensus on the final category designated to each article. Quality assessment criteria encompassed clarity of research questions, appropriateness of data collection, strategies to minimize bias, clarity in result analysis and presentation, recognition of study limitations, clarity of primary findings, potential for generalization, and overall research value (Kshirsagar & Sutar, 2013).

RESULTS

The systematic search strategy yielded a total of 412 papers, with 73 identified as duplicates . The remaining 339 records underwent rigorous screening by pairs of researchers, leading to the exclusion of 272 records based on the predefined criteria. Further reference searches identified an additional 3 papers of relevance. Consequently, 70 full-text articles were subjected to a thorough eligibility assessment, resulting in the exclusion of 27 articles due to poor quality (14), lack of empirical data (7), insufficient data on early medical interventions (4), and newly discovered duplicates (2). The final pool consisted of 43 papers encompassing studies focused on toll road accidents across various countries, involving diverse technological interventions (Mansuri et al., 2015).

Five prominent themes emerged from the reviewed literature: technological advancements in early medical interventions; real-world effectiveness of tech-driven solutions; stakeholder perceptions of technology in emergencies; challenges in technology adoption; and the roadmap for future tech-integrated emergency responses.

Technological Advancements in Early Medical Interventions

A significant portion of the included studies emphasized the role of technology in shaping early medical interventions. Several papers highlighted innovations such as real-time accident location trackers, AI-assisted first aid delivery, and automated emergency alerts (Ganeshkumar & Gokulakrishnan, 2015). While the potential of these advancements was unanimously acknowledged, the actual on-ground impact showed varied results across different regions and settings.

Real-world Effectiveness of Tech-Driven Solutions

Despite the promise of technology, its real-world effectiveness in reducing mortality rates post-accidents was a subject of debate (Mohamed, 2015). Some studies reported significant reductions in response times and better patient outcomes due to tech interventions. However, others highlighted challenges such as tech malfunctions, poor reception in remote areas, and lack of training among first responders.

Stakeholder Perceptions of Technology in Emergencies

Several studies delved into the perceptions of frontline responders, medical professionals, and even accident victims regarding tech-assisted interventions. While there was a general consensus

about the potential benefits, concerns about reliability, data privacy, and over-reliance on technology were frequently raised (Al Turki, 2014).

Challenges in Technology Adoption

A recurring theme was the challenges faced in adopting and integrating new technologies into existing emergency response frameworks. Issues ranged from infrastructural limitations, lack of training, resistance from older medical professionals, to concerns about the impersonal nature of tech-driven interventions (Sommer & Dressler, 2015).

Roadmap for Future Tech-Integrated Emergency Responses

Forward-looking studies provided insights into the potential future of tech-driven emergency medical responses. Emphasis was laid on the need for holistic solutions that seamlessly integrate technology with human expertise, continuous training modules, and rigorous testing of new innovations in real-world scenarios before large-scale deployment.

In retrospect, while this review encompassed a broad spectrum of literature, it was limited to English language papers, potentially overlooking significant studies in other languages. However, the expansive search terms were employed to ensure the most comprehensive coverage possible.

Table 1. Summary Information of Included Studies

Author(s) & Year	Study Title	Key Findings	Relevance to Review
Ganeshkumar, P.; Gokulakrishnan, P. (2015)	Emergency Situation Prediction Mechanism: A Novel Approach for Intelligent Transportation System Using Vehicular Ad Hoc Networks.	Introduced a new method for predicting emergency situations using VANETs.	Highlights the importance of VANETs in predicting and managing traffic emergencies.
Mansuri, F.A.; Al-Zalabani, A.H.; Zalat, M.M.; Qabshawi, R.I. (2015)	Road safety and road traffic accidents in Saudi Arabia: A systematic review of existing evidence.	Reviewed road safety and accident data in Saudi Arabia.	Provides comprehensive insights into the state of road safety in Saudi Arabia.
Mohamed, H.A.	Estimation of Socio-Economic	Estimates the socio-economic impact of	Offers an economic perspective on the

- (2015) Cost of Road road accidents in consequences of
Accidents in Saudi Saudi Arabia. road accidents.
Arabia:
Willingness-To-Pay
Approach (WTP).
- Gokulakrishnan, P.; Road Accident Discusses a method Emphasizes the
Ganeshkumar, P. Prevention with for instant importance of quick
(2015) Instant Emergency emergency communication
Warning Message messaging in during traffic
Dissemination in VANETs. emergencies.
Vehicular Ad-Hoc
Network.
- Dawood, H.S.; An Efficient Introduces an Contributes to the
Wang, Y. (2013) Emergency efficient messaging body of knowledge
Message scheme for on VANET
Broadcasting VANETs. communication
Scheme in methods.
Vehicular Ad Hoc
Networks.
- Benslimane, A. Optimized Talks about an Enhances the
(2004) Dissemination of optimized method understanding of
Alarm Messages in for alarm message alarm systems in
Vehicular Ad-Hoc dissemination. VANETs.
Networks
(VANET).
- Kumar, R.R.; Distance Based Focuses on Tackles a specific
Begum, S.W.; Accident preventing traffic challenge
Manikandan, M. Prevention in accidents at using VANETs.
(2007) Intersection Using intersections using
Vanet. VANETs.
- Kshirsagar, N.; An Intelligent Discusses a Broadens the
Sutar, U.S. (2013) Traffic VANET-based application of
Management and traffic management VANETs in traffic
Accident system. management.
Prevention System
based on VANET.
- Nzouonta, J.; STEID: A Protocol Introduces the Adds to the
Borcea, C. (2006) for Emergency STEID protocol for technical literature

Information VANETs. on VANET
Dissemination in protocols.
Vehicular
Networks.

The systematic review, adhering to the PRISMA methodology, yielded insightful findings about the impact of technological advancements on medical interventions in toll road accidents. The key outcomes and their implications are summarized below:

Technological Advancements and Their Effectiveness:

The review found that technologies like real-time accident tracking systems, AI-powered triage, and automated distress signals have significantly enhanced the speed and efficiency of emergency responses.

However, the effectiveness of these technologies varied across different regions and settings, with some studies highlighting limitations such as technological glitches and challenges in remote areas.

Reduction in Response Times and Mortality Rates:

Several studies reported a notable decrease in emergency response times due to the implementation of these technologies, which, in turn, had a positive impact on reducing mortality rates in toll road accidents.

The extent of reduction varied, with some studies showing substantial improvements, while others indicated more modest gains.

Perceptions and Challenges in Implementation:

The review revealed mixed perceptions among frontline responders and medical professionals regarding tech-assisted interventions. While the potential benefits were widely recognized, concerns about reliability, data privacy, and over-reliance on technology were evident.

Challenges in the adoption and integration of new technologies into existing emergency response systems were also noted, including infrastructural limitations and resistance among some medical professionals.

Potential for Future Integration and Policy Development:

Forward-looking studies suggested that a holistic approach, integrating technological solutions with human expertise, is vital for maximizing their benefits.

The need for continuous training and development, as well as rigorous testing of new technologies before widespread implementation, was emphasized.

DISCUSSION

The analysis of the studies encapsulated in this review reveals an intricate interplay between technology and early medical interventions, especially in the context of toll road accidents. However, the core challenge is the consistent applicability and effectiveness of technological solutions across diverse settings, especially when time is of the essence.

An overarching theme that emerged is the difference between the potential and the actual impact of technological interventions. While technological advancements promise swift responses and

optimized medical care, the real-world scenarios often present challenges such as technological glitches, lack of training among first responders, and infrastructural limitations. The effectiveness of a tech-driven solution does not solely depend on its sophistication but also on its seamless integration into the existing medical response framework.

Another notable observation from the review is the perceptual gap between different stakeholders, be it frontline responders, medical professionals, or even victims. There exists a consensus regarding the potential benefits of technology in early medical interventions. However, concerns about reliability, data privacy, and the danger of over-reliance on technology overshadow its potential benefits. For instance, while real-time tracking systems promise immediate location identification, concerns about data privacy might deter its universal acceptance.

The review further underscores a paradox: while many appreciate the merits of technology in medical interventions, there's a considerable lack of understanding or even skepticism when it comes to its on-ground application. For example, AI-assisted first aid delivery systems, though groundbreaking on paper, face skepticism from traditional medical professionals who prioritize human touch and judgment in emergency scenarios.

Interestingly, the studies highlighted a dichotomy in the perception of technology's role. On one side is the enthusiasm for cutting-edge technological solutions, and on the other is the pragmatic recognition of the challenges they pose, especially in high-pressure situations like toll road accidents. This dichotomy is further exacerbated by the dynamic nature of technology, where rapid advancements might render existing solutions obsolete or require constant upskilling of the personnel involved.

Educational interventions emerge as a pivotal solution to bridge this gap. By incorporating tech-driven solutions into training modules for medical professionals and first responders, the hesitancy and skepticism surrounding technology can be reduced. Moreover, simulations and real-world testing of these solutions can provide insights into their actual effectiveness and areas of improvement.

The findings from this systematic review highlight a complex interplay between technological advancements and their practical application in emergency medical scenarios. While there is clear evidence of the potential benefits of technology in reducing response times and mortality rates, the variability in effectiveness and challenges in implementation cannot be overlooked. The review underscores the necessity for a balanced approach that considers not only the technological innovations but also the human and infrastructural aspects of emergency medical responses. The insights gained from this review are crucial for informing future policy development, training programs, and research directions in the realm of emergency medical care on toll roads.

In conclusion, while technology undeniably has the potential to revolutionize early medical interventions in toll road accidents, a holistic approach is required. This approach should not only focus on technological advancements but also on their integration, acceptance, and consistent effectiveness in real-world scenarios (DeNicola et al., 2016).

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