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Literature Review

The role of fifth-generation mobile technology in prehospital emergency care: An opportunity to support paramedics

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ABSTRACT

Prehospital paramedics play a critical role in the process of making decisions about patient safety, prehospital transportation, and treatments/procedures. There has been an increase in efforts to improve emergency medical services (EMSs) using new technologies and mechanisms. Notably, fifth-generation (5 G) mobile technology has many beneficial features (e.g., a high-speed and broader network, ultra-reliable low-latency communication, improved privacy and security), which can help prehospital paramedics provide better EMSs. This innovative technology can help streamline prehospital emergency care by enhancing the timeliness and efficiency of EMSs delivery and facilitating the provision of appropriate patient care, which in turn may improve patient outcomes. Despite its beneficial features, 5 G technology entails several issues and challenges, such as the following: (1) limited regulations and privacy and security concerns about the transmission of patient information through a 5 G network; (2) insufficient robust evidence upon which policies that aim to reform EMSs using 5 G technology can be founded; and (3) a lack of access to 5 G networks in many medically underserved and remote rural areas. These issues should be addressed by policymakers, technology developers, practitioners, and other stakeholders because their resolution is likely to improve healthcare quality and outcomes.

Introduction

During medical emergencies, patients require immediate medical care. When compared to regular patients, emergency patients are more likely to be exposed to danger or at risk of dying; therefore, they require additional medical care. When emergency patients sustain an injury or contract an illness, they should receive medical treatment or undergo necessary medical procedures within 60 min, and treatment should not be terminated until they reach the emergency room (ER) of a hospital [1]. In this regard, the reception of timely and appropriate emergency medical services (EMSs) can save patients' lives and, consequently, lead to improved outcomes.

Prehospital diagnoses facilitate the provision of appropriate patient care and timely transportation of the patient to the hospital; thus, it can save lives and improve patient outcomes. When a patient sustains severe injuries or experiences trauma that necessitates emergency care, it is crucial to quickly and correctly identify and diagnose the injury/trauma and transport him or her to the nearest appropriate hospital to ensure that he or she receives the necessary treatment [1, 2]. As a part of prehospital emergency care, both physicians and paramedics act as advanced providers of emergency medical care and play a vital role in providing patient care [2, 3]. Indeed, paramedics primarily deliver vital information about a patient's condition/symptoms to physicians in the ER of a hospital [4].

New technologies and mechanisms have been developed and used in EMSs systems to improve them, primarily in developed countries. For example, in the United States (U.S.), the National EMSs Information System has been developed [5]. It aims to enhance patient care by serving as a standardized national EMSs database. [5]. Additionally, in Canada, the British Columbia Ambulance Service was developed and implemented to improve the EMSs system; notably, it relies on e-ambulance services and electronic record and reporting systems that utilize telematics [6]. Furthermore, in recent times, there has been a growing interest in the

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use of fifth-generation (5 G) mobile technology in the EMSs system. According to the International Telecommunication Union [7], 5 G technology has ushered in a new era of rapid connectivity and high-quality performance that can meet diverse user needs.

The purpose of this article is to delineate the potential of 5 G technology in improving prehospital emergency care by supporting prehospital paramedics. Specifically, the twofold aims of this article are to (1) review the existing literature on the use of 5 G technology in prehospital EMSs and (2) accordingly recommend its role in supporting paramedics and, consequently, improving prehospital EMSs and patient outcomes. It is hoped that this paper will contribute to the existing literature on EMSs by examining the role of 5 G technology in helping paramedics deliver EMSs more efficiently and address the challenges that they face during this process.

The role of 5 G technology in EMSs

It is noteworthy that 5 G technology, which is not merely a newer generation of fourth-generation (4 G) technology or an officially used specification, offers beneficial features such as completed wireless communication, faster data transmission, and real wireless world (which is also called the "World Wide Wireless Web") [8]. It offers the following three types of services: massive machine-type communication, enhanced mobile broadband, and ultra-reliable low-latency communication [9]. Notably, 5 G networks support real-time communication (i.e., through audio, video, and messaging formats), which EMSs require. Additionally, it can improve the security and privacy of the process of delivering patient data/information [10]. Furthermore, when used on a mobile device, the 5 G network can expand the communication channel and increase uplink capacities, thereby ensuring that paramedics and off-site physicians always stay connected [11, 12]. In prehospital settings, where patients need to immediately reach a hospital, 5 G technology can help save time by identifying the optimal routes to a hospital using the most recent data and providing important patient information with the aid of a high-speed and broader network [9, 13, 14]. Further, it facilitates high-quality video communication during the provision of on-site emergency care, which can help save lives and improve patient outcomes [9].

A growing body of evidence suggests that 5 G technology is being widely applied in EMSs. For instance, in 2017, the Nokia Corporation and China Mobile Limited introduced a "super ambulance," which was equipped with a computed tomography (CT) scanner, an X-ray machine, and the devices that are required for video communication through a 5 G network [15]. Using this technology, off-site physicians can monitor a patient's vital signs and directly order a CT scan. Moreover, this innovative system can be connected to other hospitals so that the closest and most appropriate ambulance is promptly sent to the emergency site. In the meantime, off-site physicians can diagnose and treat patients using 5G-enabled telehealth (i.e., diagnosis and treatment) technologies. Additionally, the 5 G Connected Ambulance that has been introduced in Ireland utilizes several innovative technologies and provides real-time information, which is necessary to provide prehospital emergency care [13]. Specifically, the devices that are used by paramedics provide real-time data through videos and sensors. Further, the innovative interactive communication feature of the system can facilitate the process of making decisions about prehospital treatments/procedures and improve the quality of EMSs [13]. South Korea launched 5 G service networks in April 2019. Currently, the Korean government is preparing to implement a national 5 G strategy. Specifically, its Ministry of Science and Information Communication Technology has been working toward the following initiative: "Connect Artificial Intelligence (AI)-based EMSs using 5 G communication" [16]. Meanwhile, Almadani et al. [17] have proposed an e-ambulance framework, which permits real-time monitoring of a patient's status and generates automatic responses during transportation to a hospital. It relies on 4 G/5 G technology to deliver real-time e-ambulance data; this in turn increases responsiveness and consistency in the medical treatments that are provided to patients.

Furthermore, the available evidence suggests that 5 G technology can address the limitations of existing networks. For example, Markakis and Politis [12] have recommended the use of the 5 G network architecture in addressing the limitations of the traditional EMSs network, which is based on long-term evolution (LTE) and the global system for mobile communications. This system (a) offers the capabilities of a high-quality virtual domain by relying on mobile edge computing (MEC) [18] and (b) supports services with low latency and an improved bandwidth and quality of service [19]. Potential emergencies are identified through MEC, which providers control, and all the data are managed at the Cloud Edge. Moreover, 5 G networks allow emergency staff and physicians to access and manage real-time data that have been gathered from the emergency site. Additionally, Oleshchuk and Fensli [10] have proposed a new approach that utilizes the 5 G infrastructure to address the limitations of using body area networks in mobile communication. Specifically, several challenges, including a limited general packet radio service system for the real-time transmission of patient information/data, can deter remote patient monitoring. To address these limitations, they have recommended the use of 5 G networks as an innovative means of facilitating patient monitoring, the continuous transmission of data about a patient's status, and real-time communication. Moreover, the use of the 5 G architecture can help develop cloud computing and enhance the availability and reliability of health services, which offer beneficial features (e.g., high and reliable connectivity and a high-bandwidth internet connection).

There is evidence to suggest that broadband technology (i.e., 4 G/5 G) can further support or improve EMSs that are provided as ambulance-based telemedicine [20, 21] and through CT-capable mobile stroke units [22]. For instance, Smith et al. [21] conducted a mobile telemedicine (iTREAT) study, in which they developed a tablet-based platform for prehospital transportation utilizing 4 G LTE commercial broadband and evaluated its reliability and feasibility through simulations. They found that, overall, the mobile telemedicine system was clinically reliable and technically feasible. Further, its features permitted bidirectional video communication between EMSs providers and neurologists in hospitals. Further, they highlighted the importance of mobile broadband in access to reliable and seamless connectivity, which enables continued and uninterrupted communication. Additionally, another iTREAT study, which was conducted in a rural EMSs setting, focused on a mobile telemedicine platform that had been developed to provide high-speed wireless connectivity to prehospital stroke service providers. The authors reported that they were able to achieve continuous mobile audiovisual connectivity during prehospital transportation using a commercial cellular network [20]. The authors highlighted the importance of high-speed broadband to the feasibility of the mobile telemedicine platform and also addressed the unique challenges that are involved in providing mobile telemedicine in rural settings (i.e., insufficient broadband infrastructure).

The use of 5 G technology in EMSs has been increasingly recommended. However, there is evidence to suggest that 5 G technology can be best distributed across EMSs by sharing and promoting partnerships with commercial cellular network providers. For instance, by partnering with AT&T, FirstNet, which was established by the U.S. government as an independent authority within the National Telecommunication and Information Administration, distributed the national broadband network across first responders (i.e., paramedics/EMSs providers) with the aim of saving lives and

safeguarding communities within the U.S. [23]. Further, FirstNet and AT&T utilize Cradlepoint's 5 G Evolution routers, which run on the communication platform and network, to equip first responders with the fastest speeds and upgrades [24].

Role of paramedics in prehospital emergency care

In prehospital settings, paramedics play a crucial role in the process of making decisions about patient safety, transportation, and treatments/procedures [4]. In general, paramedics are required to make decisions under complicated and unexpected circumstances, and most decisions are made prior to transportation [25]. Under these circumstances, paramedics' knowledge and experiences regarding prehospital emergency care are vital factors that determine (a) whether patients receive timely and appropriate treatment/procedures and (b) their health outcomes. Past studies have identified the factors that are related to decision-making among paramedics in prehospital settings. Specifically, the findings suggest that paramedics often rely on their subject-matter expertise, knowledge, previously acquired information, experiences, and insights to make decisions during the provision of EMSs [4, 26, 27]. Furthermore, paramedics frequently rely on EMSs providers' evaluations of their decisions in prehospital settings [28].

Although paramedics play an important role in prehospital emergency care, they are often faced with challenges when they assess a patient's status or provide care. For instance, most ambulances offer little or no diagnostic imaging capabilities [1]. Moreover, EMSs providers/paramedics in rural areas may be faced with distance-related limitations (e.g., a lack of hospitals for emergency patients in neighboring locations) or an insufficient telecommunication infrastructure (which is required to provide EMSs) [29]. Furthermore, paramedics often encounter obstacles or challenges when they have to make a prehospital diagnosis and communicate with emergency department (ED) providers. In their prospective observational study, Eckstein and Suyehara [30] aimed to examine paramedics' ability to appropriately use the "RALES" protocol to diagnose congestive heart failure (CHF). Only half of the dyspneic patients with CHF were correctly identified by paramedics; however, their evaluation of CHF was highly predictive once the diagnosis had been made. They underscored the important role of paramedics in reassessing patients and providing continuous prehospital care prior to arrival at the ED.

As a result of substantial technological developments and innovations, EMSs providers/paramedics can utilize various technologies and tools to improve the delivery of prehospital emergency care. Bluetooth technology, for example, allows prehospital paramedics to observe the vital signs of a patient without multiple wired devices, which can slow down the transportation process [31]. Moreover, innovative high-technology appliances (e.g., ultrasound technology) are used to examine medical problems (e.g., a faint heart or lung) during transportation to a hospital. Additionally, commercial broadband technology (e.g., 3 G and 4 G technology) has already been used in ambulance transportation services. They facilitate the provision of prehospital care to patients and communication between paramedics and ED physicians [20, 21]. Further, 5 G technology, which offers many beneficial features (e.g., hyper-connectivity, high capacity to deal with throughput, security, and ultra-low latency), has been used in ambulance-based EMSs [32]. Rehman and colleagues [33] have recommended the use of 5 G technology in medical ultrasound video streaming during ambulance transportation. Further, they have highlighted the role of 5 G technology in enhancing network performance among paramedics who provide EMSs inside ambulances (e.g., diagnosis, real-time remote communication, data transmission to a hospital).

Supporting paramedics using 5 G technology

There is a growing interest in the use of advanced technology and devices in enhancing EMS. However, paramedics/EMSs providers face many challenges when they assess a patient's status or provide prehospital care. Specifically, the hour following the onset of the symptoms of many time-sensitive conditions (e.g., stroke, myocardial infarction, and trauma) is referred to as the golden hour. However, it may be difficult for paramedics to conduct a complete assessment of a patient's status and provide adequate care/treatment within this time frame. Under such hectic and time-sensitive circumstances, paramedics must receive information about a patient's condition and the corresponding diagnosis as quickly as possible in order to make appropriate decisions about treatments and/or procedures. This poses a significant challenge to paramedics with insufficient experience or knowledge. Further, appropriate communication between paramedics and ER physicians is necessary to ensure that appropriate medical decisions are made based on the information that is exchanged between them. Communication failures during the provision of EMSs can negatively impact patient outcomes, particularly among patients with time-sensitive conditions [34]. Therefore, there is a need to help paramedics/EMSs providers render appropriate prehospital care to patients.

Given the benefits of 5 G technology, its application in prehospital emergency care may help paramedics/EMSs providers offer prompt and adequate EMSs to patients. Thus, 5 G networks are likely to provide them with patient data at faster speeds and in a more seamless manner, and this information can be used to make a diagnosis and assist care processes during ambulance transportation [9, 13, 14]. Furthermore, it facilitates ultra-reliable low-latency communication between prehospital staff and hospitals, thereby promoting the provision of appropriate and proactive care to patients [10, 14]. Notably, 5 G technology with enhanced connectivity and a cloud-based depository allows prehospital staff to utilize even small devices and sensors for communication [10].

Essentially, prehospital paramedics/EMSs providers should be able to appropriately utilize 5G-enabled devices and applications to make timely diagnoses and provide timely care to patients. Even if a 5 G network is available on their devices and applications, they may not be familiar with this technology or know how to use them appropriately. Past studies have identified the challenges that can hinder paramedics/EMSs providers from using new technology to provide prehospital care to patients. According to their findings, mobile devices and applications that aim to improve the delivery of EMSs should be user friendly [35]. Further, they should be developed in such a manner that they facilitate the seamless transmission of patient data/information [35]. More importantly, appropriate prehospital education and training regarding technology use should be provided to paramedics/EMSs providers. For example, ER physicians/hospital-based specialists can train paramedics to conduct prehospital ultrasound imaging for the purposes of diagnostic assessment [36].

Supporting paramedics/EMSs providers through 5 G technology can streamline patient care by enhancing the timeliness and efficiency of EMSs delivery and selection of an appropriate hospital, which in turn may improve patient outcomes. A growing body of evidence suggests that innovative technology will benefit from 5 G infrastructure because it offers enhanced seamless communication and improved security and privacy [10, 14]. Essentially, 5 G technology should be integrated into EMSs delivery models to facilitate the availability and provision of the entire range of EMSs. For instance, several strategies, such as the following, have previously been suggested: (1) examine the options for a digital architecture that can strengthen EMSs delivery models; (2) explore the potential of mobile technology in supporting community paramedicine;

and (3) delineate promising applications in telemedicine-assisted emergency and nonemergency services [35].

Privacy and security concerns surrounding 5 G technology: challenges and potential solutions

Although 5 G technology is expected to transform healthcare, there are security and privacy concerns about the use of 5 G in healthcare. The existing literature suggests that, despite the potential contribution of 5 G to the security of communication systems, there may be a lack of privacy and security in the link between the gateway and sensors that are used in the transmission of patient data [10]. Recent findings have underscored the threats and challenges that are associated with the different computing paradigms that rely on 5 G technology. This is the case because such applications and services that rely on the 5 G network integrate communication systems, servers, devices, and cloud services. For instance, Roman et al. [37] investigated the challenges that are associated with security designs based on threat models that target the features of integrated systems (e.g., ownership, deployment, hardware, service, architecture).

To defend against security threats across multiple layers, 5G-based EMSs should be developed using a systematic and analytical approach rather than based on individual security mechanisms. Specifically, 5G-based EMSs should (a) specify the basic features, differences, and synergies that are related to the integrity of various Internet of Things (IoT) devices, systems, and public services and (b) analyze the potential threats that target each layer as well as the requirements and challenges that pertain to the security mechanisms [37]. The security mechanisms that underlie these multiple layers can include the following: a proximity between user devices and eavesdroppers or attackers [38, 39], mobile caching for security at end nodes through deep learning [40], physical-layer security during task offloading and resource allocation to the cloud or edge servers [41], and a cooperative ecosystem within which multitudes of customers can be served [37].

Widespread efforts have been taken to enhance the privacy and security of the patient information that is used as a part of 5G-based EMSs. For instance, the Korean government intends to create a security policy, which will delineate certification standards for patient information management in 5G-based EMSs [16]. Further, following the development of a new international standard for 5G-based EMSs, Korea has also been involved in establishing the security of the system that has been developed in accordance with the national 5 G strategy and policy [16]. Specifically, it seeks to obtain the ISO27001 certification, which is the international standard for information security and management systems [42, 43]. In particular, it requires the ISO27799 certification, in accordance with the international standard for the security of medical information, which was established in 2008 [43]. These certifications are Health informatics-Information Security Management in EMS using the international standard, as shown in the table below. Through these certifications, it is anticipated that 5G-based EMS will be provided in a more secure environment in which patient information is protected in a more comprehensive, international manner. Particularly, cloud-based EMS will expectably be provided with additional medical information security regulations through the ISO/IEC 27017 [43] (Table 1).

Table 1.
Health informatics: Information security management in EMSs using international standards.

Certification	Organization	Applications
*ISO 27799*ISO 27017*ISO 27018*ISO 22301*CSA STAR (Gold)*SOC 1,2,3	*BSI, Deloitte	EMSs cloud service
ISO 27001	BSI	Management of the IT infrastructure, platform, and data center
ISMS-P	*KISA	Management of cloud services and personal information
*ISMS	KISA	Management of the IT platform and internet data center
*CSAP IaaS	KISA	Public institutions and infrastructure as services
*CSAP SaaS	KISA	Public institutions and software as services: System and website security checkers

Notes: *ISO: International Standard Organization *CSA: Cloud Security Alliance *SOC: Service Organization Controls *ISMS: Information Security Management System *CSAP IaaS: Cloud Security Assurance Program Infra as a Service *CSAP SaaS: Cloud Security Assurance Program Software as a Service *BSI: British Standard Institute *KISA: Korea Internet and Security Agency.

Potential impact of 5 G technology and future implications

There is a growing consensus that 5 G technology will positively impact healthcare quality and patient outcomes, including overall medical cost savings [44, 45]. For instance, monitoring a patient's vital signs in real time and providing timely and appropriate care using 5G-enabled systems can help save his or her life and the

lower hospital readmission rates for various conditions/illnesses (e.g., stroke and cardiac failure), and this in turn can lower medical costs [46, 47]. Further, telemedicine and high-resolution video conferencing through a 5 G network can provide patients who reside in remote rural areas with access to high-quality medical care, which may otherwise be hindered by geographical barriers; consequently, this may reduce healthcare disparities [44]. Moreover, 5G-enabled technologies and devices facilitate the collection and storage (i.e., on a cloud) of patient data (i.e., patient history and characteristics), which doctors need to provide appropriate and adequate care [48]. It is important to provide timely and appropriate prehospital emergency care to patients. In this regard, technology plays a vital role in improving patient outcomes and the quality of EMSs.

When compared to fields such as business and education, emergency medicine has traditionally been regarded as a field that is more reluctant to adopt advanced technologies and innovations, and this may be attributable to the fact that their use in medical practice plays a role in determining whether a patient's life is saved or lost [49]. Nevertheless, emergency medicine is regarded as one of the most critical areas that can benefit from new technologies; for example, the use of 5 G technology to enhance EMSs communication can help save lives and improve patient outcomes [14, 15]. Despite the growing interest in the impact of 5 G technology on healthcare, there are several pertinent issues that require addressal. First, to expand the applications of 5 G technology in EMSs (which may vary across regions and countries), the following problems should be resolved: the existing legal limitations, privacy and security concerns about the transmission of patient information through a 5 G network [50], and issues that pertain to telemedicine [10]. Second, only a few studies have applied 5 G technology to real-world EMSs; therefore, there is a need for additional studies that can offer robust evidence about the application of 5 G technology to EMSs, upon which relevant policies can be founded. In particular, it is important to test the utility of 5 G technology in EMSs for specific medical emergencies (e.g., cardiac arrest, major trauma, cardiovascular and neurovascular emergencies). Finally, since many medically underserved and remote rural areas lack access to 5 G networks, the widespread establishment of 5 G networks should precede the development of specific technologies that can be used to improve EMSs.

Conclusion

Substantial efforts have been taken to use innovative technologies and mechanisms (including 5 G technology) to improve EMSs systems. Paramedics play an important role in the delivery of prehospital emergency care. In this regard, 5 G technology can facilitate care processes and, consequently, improve patient outcomes because it has the following advantageous features: a high-speed and broader network, ultra-reliable low-latency communication, and improved privacy and security. However, 5G-based EMSs entail several challenges and issues, such as the following: (1) limited regulations and privacy and security concerns about sending/sharing patient information through a 5 G network [10, 50]; (2) insufficient robust evidence upon which policies that aim to reform EMSs systems using 5 G technology can be founded [20, 22]; and (3) a lack of access to 5 G networks in many medically underserved and remote rural areas [51, 52]. These issues should be addressed by policymakers, technology developers, practitioners, and other stakeholders. While growing expectation exists about the potential impact of 5 G in health care in terms of quality and outcomes improvement, AI solutions could further be considered for better supporting or enhancing patient care by providing more relevant and accurate care to the patient. Further research is needed to test this possibility.

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