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eEmergency Health care Information Systems

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Abstract— **In this paper we provide an overview of the way that information and communication technologies have been used for emergency healthcare support. The paper provides a literature review of case studies exploring information systems for monitoring signals, images, medical videos, as well as information protocols used during emergency health care support, and describes future trends. We anticipate that eEmergency systems can significantly improve the delivery of healthcare during emergency cases. However, the monitoring and evaluation of these systems and especially their use in daily practice still remains a goal to be achieved**.

I. INTRODUCTION

The emerging development of emergency healthcare systems and services (eEmergency) in the last decade was made possible due to advances in wireless and network technologies in joint with recent advances in nano-technologies, compact biosensors, wearable devices and clothing, pervasive and ubiquitous computing systems. These advances have a powerful impact in the provision of mHealth (mobile health), and eHealth services at large, and reshape the workflow and practices in the delivery of healthcare services [1], [2]. The objective of this paper is to provide a review of the status and challenges of eEmergency systems, covering both eEmergency management and response processes, as well as mobile health eEmergency systems. One consistent challenge for emergency management and response is communication and information management [3], [4]. Effective response requires a moment-to-moment situational analysis and real-time information to assess needs and available resources that can change suddenly and unexpectedly [4]. Accurate information from the field about the incident impacts the utilization and preparedness of resources such as emergency units, hospitals, and intensive care units. Similarly, information on available and accessible hospital, emergency units, and ambulance resources alters the management and disposition of victims at the scene [3]. The timely and effective way of handling emergency cases can prove essential for the patient's recovery or even for the patient's survival.

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II. TECHNOLOGIES USED FOR eEMERGENCY SYSTEMS

A. Wireless communication networks and standards

In general, systems are based on the following wireless technologies: well established 2nd generation (2G), 2.5G and 3G and more recently 3.5G of mobile telecommunication systems, wireless local area networks (WLANs), mobile ad-hoc networks (MANETs), wireless sensor networks (WSNs) and satellite links. Home/personal/body area networks also drive growth in mobile telemedicine systems. Long term evolution (LTE) (towards 4G) and WiMAX technologies are expected to significantly advance available wireless data rates [2].

B. Mobile computing platforms

The evolution of mobile computing platforms and the introduction of portable devices like PDAs, smart phones, small size laptops, and pen-tablet PCs enables eEmergency systems application developers to create more efficient systems with respect to computing power and functionality, that consume less power, and are more compact, and smaller. Such systems have already appeared in the last decade, and will certainly continue to appear in the next years. For example, in a systematic review of PDA usage surveys by health care providers, it was documented that younger physicians and residents and those working in large and hospital-based practices are more likely to use a PDA [5].

C. Biosignals

The collection of biosignals [1], [2] such as ECG, until now was performed using expensive devices which could only be handled and supported by medical personnel. More recently, the collection of biosignals, such as ECG, can be performed by very small devices. These are not always devices on their own but they might connect to a smart phone, PDA, laptop, or PC in order to display or send the signals, and usually have Bluetooth or GPRS connectivity to wirelessly transfer the signals. In adition major companies like Texas Instruments © (ADS1294) have already presented small chips that can acquire ECG signals and we anticipate that such devices will be presented in the literature in the near future. In particular, the following items are still under consideration there is a lack of: (i) widely adopted compression quality assurance criteria and standards, (ii) widely available benchmark biosignal databases, (iii) interoperability of data acquisition and processing equipment, and (iv) exchange of compressed data between databases from different research groups and/or manufacturers because of their incompatibility.

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TABLE I. EMPIRICAL CASE STUDIES ON THE IMPACT OF COMPUTER-AIDED DISPATCH SYSTEMS IN EMERGENCY MANAGEMENT AND RESPONSE

Author/Year	Country of Study	Key Objective	Key Findings
Dale *et al.* 2003 [13]	UK	Investigate the potential impact for ambulance services of telephone assessment and computer-aided triage for non-serious emergency calls as classified by ambulance service call takers.	Telephone assessment and computer-aided triage can identify non-serious calls, which could have a significant impact on emergency ambulance dispatch rates. Nurses were more likely than paramedics to assess calls as requiring an alternative response to emergency ambulance dispatch, but the extent to which this relates to aspects of training and professional perspective is unclear.
Michael and Sporer 2005 [14]	USA	Evaluate a group of computer-aided dispatch protocols defined as requiring advanced life support [ALS] intervention.	There was variation in clinical practice toward ALS intervention due to the more precautionary approach to care found in this computer-aided dispatch system.
Flynn *et al.* 2006 [15]	Australia	Undertake a sensitivity/specificity analysis to determine the ability of a computer-aided dispatch system to detect cardiac arrest.	The system correctly identified 76.7% of cardiac arrest cases, but the number of false negatives suggests that there is room for improvement to maximize chances for survival in out-of-hospital cardiac arrest.
Reilly 2006 [16]	USA	Assess the relationship between dispatches of a cardiac nature through a computer-aided dispatch system, and the actual clinical diagnosis as determined by an emergency department physician.	The system may over-triage emergency medical responses to cardiac emergencies. This can result in the only advanced life support unit in the community being unavailable in certain situations. Future studies should be conducted to determine what level of over-triage is appropriate when using such systems.
Feldman *et al.* 2006 [17]	Canada	To determine the relationship between a computer-aided dispatch system and an out-of-hospital patient acuity scale.	The system exhibits at least moderate sensitivity and specificity for detecting high acuity of illness or injury. This performance analysis may be used to identify target protocols for future improvements
Buck *et al.* 2009 [18]	USA	Assess the diagnostic accuracy of the current national protocol guiding dispatcher questioning of emergency callers to identify stroke.	Dispatcher recognition of stroke calls using a computer-aided dispatch system algorithm is suboptimal, with failure to identify more than half of stroke patients as likely stroke. Revisions to the current national dispatcher structured interview and symptom identification algorithm for stroke may facilitate more accurate recognition of stroke by emergency medical dispatchers.

D. Transmission of digital images and video

Medical image and video transmission is another issue being presented in many systems; the Digital Imaging and Communications in Medicine (DICOM) committee has adopted two MPEG-2 standards for digital video [6]. While adoption of these standards is inadequate for eEmergency applications, they do provide an important reference framework for frame sizes and frame rates for future applications.

III. PROTOCOLS AND PROCESSES FOR eEMERGENCY MANAGEMENT AND RESPONSE

A. The importance of emergency management and response

Research on medical informatics has examined in depth the role of accurate and real-time information on effective emergency management and response [7]. In particular, research in this area in joint with research in computer science has led to the development of so-called "smart devices," third-generation wireless connectivity, and positioning technologies, all of which have application in emergency management and response because they are location-aware, i.e. they combine timely, clinical information with accurate geographic information. For example, geo-position tracking and smart devices have been tested on soldiers and medics in the military battlefield [8]. In addition, recent advances in triage tagging technology have focused on the use of mobile wireless data acquisition to individually identify and track victims of disasters by assigning a unique identifier to each individual and linking that identifier with triage status [9].

B. The challenge of coordination: The role of standardized priority dispatch protocols

Despite these advances, however, many of the logistical problems faced in emergencies are not caused by shortages of medical and technological resources, but rather from failures to coordinate their distribution [10], with significant possibilities for error and destruction, as occurred at New York's World Trade Center command post on September 11, 2001 [11]. To address the challenge of coordination, emergency dispatch centers around the world are increasingly using some form of priority dispatch protocol when handling emergency calls. The key objective behind these protocols is to ensure that the right response is sent to the right incident at the right time in the right way and to carry out the right procedures until professional help arrives [12]. Over the last 30 years or so, organizations such as the European Emergency Number Association (http://www.eena.org), and the National Academies for Emergency Dispatch in North America (http://www.emergencydispatch.org), have established standards for the development of priority dispatch protocols with which to help the coordination of medical and technological resources towards the effective management and response to emergency incidents. The most popular system of priority dispatch protocols is the Medical Priority Dispatch System (MPDS), developed by the National Academies for Emergency Dispatch in collaboration with the National Association of Emergency Management Physicians, the American Society for Testing and Materials, the

TABLE II. SELECTED MHEALTH EEMERGENCY

Application area	Author	Year	Data Transmitted					Comments
			ECG	Other Biosignals	Images	Video	Communication. Link	
Ambulance systems	Kyriacou *et al.* [21]	03	√	√	SCN		WT	Wireless transmission of biosignals and images from a moving ambulance vehicle to a central hospital.
	Chu *et al.* [22]	04	√		SCN	SCN	WT	Trauma care through transmission of patient's video, medical images and ECG.
	Kontaxakis *et al.* [23]	06				US	WT	Tele-echography system and 3D-ultrasound
	Garawi *et al.* [24]	06				US	WT	Tele-operated robotic system for mobile tele-echography (OTELO-Project).
	Panayides *et al.* [25]	08				US	WT	Efficient H.264 coding of medical ultrasound video over wireless channels
RH	Strode *et al.* [26]	03				US	SAT	Examination of trauma using focused abdominal sonography (military).
IH	Kim *et al.* [27]	09				√	WLAN	Transmission of video and audio to consult on the treatment of acute stroke patients.
Civ. Systems	ETIHAD Airways [28]	10	√	√	SCN		SAT	Tempus IC will be installed on long-haul aircraft flights for monitoring the condition of passengers who display signs of illness that might require immediate medical attention.
	Chin-Teng *et al.* [29]	10	√				BLUTH	A wearable system to detect atrial fibrillation using expert systems.

CT: Computed Tomography; MRI: Magnetic Resonance Imaging; SCN: Incident/Patient Scenery; US: Ultrasound; WT: GSM/GPRS/3G; SAT: Satellite; WLAN: Wireless LAN, IH: In Hospital systems, RH: Rural Health Centers systems., Civ.Systems: Civilian Systems

American College of Emergency Physicians, the U.S. Department of Transportation, the National Institutes of Health, and the American Medical Association.

IV. COMPUTER AIDED MEDICAL DISPATCH SYSTEMS

Since the early 1990s, there has been a consistent effort to implement the MPDS and similar priority dispatch protocols through computer-based systems in an effort to automate processes and further minimize human error rates [12]. We have carried out a literature review of empirical case studies illustrating the advantages and disadvantages of computer-aided dispatch systems using priority dispatch protocols. The search was initially carried out in the database *Science Direct* using the term "Computer-aided Medical Dispatch Systems" across 'All fields'. We limited our search to the years 2000-2010 to focus on computer and telecommunication developments of the last decade. The search resulted in 169 articles. Many of these articles were found in subject areas not related to emergency care so the results were filtered according to the following subjects: 'Computer Science' + 'Decision Sciences' + 'Medicine and Dentistry' + 'Nursing and Health Professions'. A representative subset of these papers is presented in Table I. The key findings reported in these empirical case studies show that, despite the evident advantages of computer-aided dispatch systems utilizing priority dispatch protocols, effective emergency management and response cannot be minimized in ritualistic behavior through 'blind' protocol-following [19]. Protocols should be used as standardized, guidance tools, but emergency professionals should not rely on them to complete their tasks. This is because it is impossible to create workflow scenarios that will adequately handle every type of call a dispatcher will take [20].

V. mHEALTH eEMERGENCY SYSTEMS

The MEDLINE and IEEE Explore databases were searched with the terms: "wireless telemedicine emergency", "wireless telemedicine ambulance", "wireless telemedicine disaster", "wireless ambulance", "wireless disaster", and "wireless emergency". The number of journal papers found to be published under these categories is around 220. Out of these a representative subset of the main applications were selected and are briefly summarized in Table II. We tried to select systems that cover the whole spectrum of medical informatics applications for emergency cases that have been published in the last decade.

These papers are grouped under the following eEmergency areas Ambulance Systems, Rural Health Center Systems, In-Hospital Systems, and Civilian Systems. As illustrated in Table II, most of the mHealth eEmergency systems fall under the category of Ambulance Systems. These systems exploit the wireless telephone connectivity GSM/GPRS/3G. Almost all of the systems supported ECG transmission, and other biosignals, whereas a few recent studies supported the ultrasound video transmission.

VI. CONCLUSIONS

This paper reviews eEmergency systems and information technology protocols and processes for emergency management, response, and support of eEmergency systems. The importance and benefits for using these technologies in emergency care are clearly demonstrated, as well as the need for their wider deployment.

The development and continuous improvement of computer-aided priority dispatch protocols supporting the automated implementation of these protocols in practice, has greatly improved emergency management and response. However, further research is needed to address emerging organizational and technological challenges.

Emerging eEmergency telemedicine systems can support the transmission of 2-D/3-D ultrasound and patient video (optical). Wireless medical video transmission has benefited from bitrate availability and extended coverage offered by 3G or current 4G mobile networks. However, the development of reliable eEmergency systems requires efficient encoding that matches achievable data rates and the use of error resilient methods for dealing with error-prone transmissions. Furthermore, the overall systems also need extensive clinical validation using diagnostically relevant metrics.

Research in the aforementioned areas has so far examined either the technological or the organizational challenges associated with emergency management and response, but not both together. We argue that there is a need for a more holistic approach to understanding emergency management and response which would require interdisciplinary research from such disciplines as computer science, medical informatics, and healthcare management.

Concluding, eEmergency systems can significantly impact the delivery of healthcare. However, their use in daily practice as well as the monitoring and evaluation of these systems still remains a goal to be achieved. Ultimately, the use of eEmergency systems should provide a better service to the citizen.

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