ARTICLE IN PRESS
DECSUP-12864; No of Pages 12
Decision Support Systems xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Decision Support Systems
journal homepage: www.elsevier.com/locate/dss

Emergency Response Community Effectiveness: A simulation modeler for comparing Emergency Medical Services with smartphone-based Samaritan response

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ARTICLE INFO

Article history:
Received 25 December 2016
Received in revised form 11 May 2017
Accepted 12 July 2017
Available online xxxx

Keywords:
Emergency response
Community
mHealth
Simulation
Healthcare policy
EMS

ABSTRACT

Mobile emergency response applications involving location-based alerts and physical response of networked members increasingly appear on smartphones to address a variety of emergencies. EMS (Emergency Medical Services) administrators, policy makers, and other decision makers need to determine when such systems present an effective addition to traditional Emergency Medical Services. We developed a software tool, the Emergency Response Community Effectiveness Modeler (ERCEM) that accepts parameters and compares the potential smartphone-initiated Samaritan/member response to traditional EMS response for a specific medical condition in a given geographic area. This study uses EMS data from the National EMS Information System (NEMSIS) and analyses geographies based on Rural-Urban Commuting Area (RUCA) and Economic Research Service (ERS) urbanicity codes. To demonstrate ERCEM's capabilities, we input a full year of NEMSIS data documenting EMS response incidents across the USA. We conducted three experiments to explore anaphylaxis, hypoglycemia and opioid overdose events across different population density characteristics, with further permutations to consider a series of potential app adoption levels, Samaritan response behaviors, notification radii, etc. Our model emphasizes how medical condition, prescription adherence levels, community network membership, and population density are key factors in determining the effectiveness of Samaritan-based Emergency Response Communities (ERC). We show how the efficacy of deploying mHealth apps for emergency response by volunteers can be modelled and studied in comparison to EMS. A decision maker can utilize ERCEM to generate a detailed simulation of different emergency response scenarios to assess the efficacy of smartphone-based Samaritan response applications in varying geographic regions for a series of different conditions and treatments.

1. Introduction

mHealth has been defined as "healthcare to anyone, anytime and anywhere by removing temporal and locational constraints while increasing both the coverage and the quality of healthcare" [1]. Developments in mHealth have led to a sharp increase in the availability of applications (apps) supporting medically motivated physical interaction between app users, leading to potentially significant changes in healthcare delivery [2,3]. Smartphone applications can support the connection of app users to real-world medical emergency events and are being studied in diverse situations such as the mapping and response-use of AEDs (Automatic Electronic Defibrillators) [4–8], volunteer emergency response [9–14], the physical proximity of diabetes patients in need of glucose or monitors [15], and Emergency Response Communities (ERC) for anaphylaxis events [16,17]. Such systems have the potential to enable a new form of emergency medical response in which the social network-based connection between individuals creates a lay-layer of support, which can augment or potentially modify current forms of EMS [16]. Many available emergency response apps are based on alerting available responders connected through smartphone social networks. Table 1 presents a few examples.

These apps fall into the category of "providing care" in Varshney's framework for emergency care and m-health enhancements [3]. Two important things that all such emergency support smartphone apps have in common are (a) a dependency on variables related to medical condition/treatment, individual user behavior, online community characteristics, and geographic region; and (b) their potential to improve on existing EMS response times.

Varshney discusses the importance of modeling the ways in which mobile technology can change the ways healthcare services are designed and delivered, emphasizing the "need to study how mobile technologies may affect the quality of healthcare in different scenarios",

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http://dx.doi.org/10.1016/j.dss.2017.07.003
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Table 1
Examples of mHealth apps with an emergency alert component.

App name	Condition focus	Alert behavior	URL
Pulsepoint	Cardiac	Notify members with CPR training in vicinity.	http://www.pulsepoint.org
HelpAround Diabetes	Diabetes	Notify members with monitors, syringes or insulin in area.	http://helparound.co
SecuraFone Health	Stroke, Cardiac	Notify predefined social network including doctors and caregivers.	http://www.securafone.com/subpages/health.php
EpDetect	Epilepsy	Notify preset list of up to 3 caregivers	http://www.epdetect.com/
AllergyHero	Anaphylaxis	Social network of members in vicinity	http://www.allergyhero.com

including emergency care [18]. Decision makers tasked with adopting or promoting the community or regional use of apps as part of emergency response protocols, and possibly integrating the use of smartphone-based Samaritan response to enhance existing EMS infrastructures, have no decision tools designed to study the potential effects of these decisions prior to actual investment in adoption and integration. This presents a gap that we address in our research, taking a modeling approach.

1.1. EMS planning

There is substantial research on planning for Emergency Medical Services (EMS). This includes issues such as GIS models for ambulance positioning [19]; analytical tools for evaluating EMS system design changes [20]; DSS incorporating the role of centrality in ambulance dispatching [21]; addressing EMS response times in rural vs urban areas [22] and the use of simulation models to evaluate the performance of EMS [23]. These studies are important in the EMS field, yet have limited applicability for ERC effectiveness assessment for several reasons. EMS operates from fixed dispatch stations compared to ERC which is based on volunteers whose location is neither fixed nor predictable. EMS determines ambulance fleet size and their equipment based on budgetary constraints and resource allocation models, in contrast to the response of ERC volunteers that depends on multiple factors such as their location, location of the patient in distress, volunteer availability, possession of the required medication etc.

1.2. ERC planning

Modeling the potential efficacy of smartphone-based community response in emergencies has complexities that stem from the multiplicity of variables and scenarios that must be accounted for. These variables include those related to individual behaviors such as adherence, willingness to respond, community membership, and online availability, as well as macro level data related to population density, and prescription density within a population. Only once the former and latter are considered, meaningful assessments of the effectiveness of such app-based communities can be undertaken with comparisons to existing EMS response times.

The multitude of intervention apps being tested, recommended, and used today do not consider the performance of such apps in comparison to EMS, which is the consensus responder in emergency conditions. EMS administrators, policy makers, and other decision makers need to determine when such systems present an effective addition to traditional Emergency Medical Services [3,24]. This presents a significant gap that we begin to address in our research. Modeling all regions of a large healthcare system for multiple potential emergency response community apps becomes a daunting task requiring substantial time and effort. To make such tasks easier we developed the Emergency Response Community Effectiveness Modeler (ERCEM), which decision makers can use to simulate the effectiveness of smartphone-based emergency response community and assess its potential performance in comparison to EMS response addressing the same medical emergency need. We emphasize that the purpose of such assessment is not necessarily to replace EMS response but rather to see how it might be augmented through community action enabled by such apps. Such assessment is necessary for decision makers because of the costs and efforts of establishing an ERC, advertising and promoting it, integrating it into existing EMS processes and managing the community [25,26]. We illustrate the use of ERCEM by presenting an analysis of simulated Samaritan response to three different types of emergency event – anaphylaxis, hypoglycemia and opioid overdose, drawn from and compared to actual EMS calls and response times. We note that ERCEM is intended to be used at macro level - when making decision about establishment of an ERC in a given region - and not at micro level such a decision if ERC volunteers should be dispatched in a specific event.

2. Data and methods

In each of the example mHealth applications described above, help can come in the form of emergency medication, such as epinephrine, provided by a nearby patient with the same condition; or in the form of a procedure such as CPR performed by a trained individual irrespective of him/her sharing a medical condition. The parameters that influence potential community response will vary depending on the form of emergency intervention. In the former case, for example, prescription densities and adherence levels will be modelled whereas in the latter case this is replaced by the availability of trained individuals. Our presentation and methods focus on medication provision scenarios but can easily be modified to address procedure-based scenarios.

2.1. Measuring effectiveness

As we have already mentioned, the purpose of ERC is not to replace EMS but to augment the EMS response through faster first help by community members. Intervention by a professional is preferred and is expected to be more efficient than intervention by a lay person, but until an ambulance arrives, the help by a bystander is compared to *no help* and has been found to be effective [27–29]. This is particularly so when the patient himself is trained in administration of the medication and all that is lacking is supply. In the cases that we studied, the AAIs, glycogen kits, and naloxone kits are designed to be used by patients and their family members who often undergo recommended training [30–33]. In an emergency, these medications are provided by another patient or family member who themselves may have had similar training in use of the medication. Other forms of intervention, such AEDs increasingly come with accessible instructions to enable effective use by the untrained.

The actual measure of effectiveness in this research is delivery of the required intervention (e.g. medication or AED) to the scene of the emergency.

2.2. The emergency response community effectiveness model

The model enables estimation of the expected density of responders (ERC volunteers) based on demographic data in the specific region, prevalence of the medical condition, prescription adherence rates, assumptions of ERC adoption and mobile online availability. Having determined the expected number of responders, the model provides quantitative tools to compare the expected response times by ERC members to expected response times of EMS or to a medical outcome-