Collaboration for preliminary design of a mobile health solution for ambulance dispatch in Rwanda

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Introduction

The first 60 minutes after a trauma are described as "the golden hour." For each minute of prehospital time, the risk of dying increases by 5% (Sampalis *et al.*, 1999). Since 90% of the global burden of injuries occur in low- and middle-income countries and lead to 5.8 million deaths annually, addressing rapid access to emergency services is critical in these settings (Nielsen *et al.*, 2012). In most low- and middle-income countries (LMICs), there are no formal trauma systems, and many lack organized prehospital care (Nielsen *et al.*, 2012). Emergency medical dispatch and communication systems are a foundational component of emergency medical services (World Health Organization, 2005). Yet there are no established recommendations of creating these systems in LMICs.

Rwanda, a country of over 12 million people, is a rapidly developing leader in East Africa. The Ministry of Health of Rwanda established the Service d'Aide Medicale Urgente (SAMU) in 2007, recognizing the need for public emergency medical services. SAMU's national dispatch center receives roughly 3,000 calls per month through a national 912 hotline. It organizes regional transportation with 260 total ambulances located at hospitals throughout the country and provides prehospital emergency services in the capital city of Kigali with a fleet of 12 ambulances. In the city, each ambulance has a driver, nurse and anesthetist dispatched for every call. Emergency department nursing and anesthetist staff are dispatched from hospitals around the country to respond to regional emergencies. No formal prehospital cadre of the workforce exists although the SAMU staff have extensive field experience in prehospital care. SAMU has several challenges to rapid prehospital emergency care including lack of addresses beyond the capital city, unclear location data in densely populated areas, complex communication processes with little information about health facility capacity, and no established electronic dispatch system. The average response time for SAMU ambulances was 59 minutes in 2018, but 39% of calls were not completed within the golden hour.

Improving delivery of prehospital emergency care in this setting is challenging. Mobile applications have been used with increasing frequency in addressing health related problems, also in LMICs (Latif *et al.*, 2017). Several applications support emergency dispatch and communications in high-income countries such as the USA, but they do not transfer to the LMIC context with ease. Some of the other challenges with implementing mobile health solutions in this setting include unreliable technology, limited data storage capacity and lack

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of regulation, and inadequate cellular infrastructure (Wallis *et al.*, 2017). Our collaboration between Virginia Commonwealth University and SAMU as a branch of the Rwanda Ministry of Health, aimed to study the context in Rwanda and the needs of the public and the ambulance staff and then determine if technology may offer novel methods of addressing challenges to prehospital emergency care in Kigali, Rwanda. The collaboration created a Memorandum of Understanding in 2017 to facilitate trauma and emergency systems development. Through this collaboration, we have engaged in training of SAMU staff through short courses, data registry implementation and management, and standardization of prehospital care through protocols and checklists. A partnership was created with The RwandaBuild Program, a local software accelerator supporting young Rwandese software developers to design and develop innovative technological solutions to address local challenges.

In this paper, we describe our experience in collaboration, understanding the environment and designing a context-appropriate mobile phone-based dispatch platform as a potential strategy to streamline communication and improve prehospital transportation times in Kigali, Rwanda.

Setting

Rwanda is a landlocked East African country with a population of over 12 million (National Institute of Statistics Rwanda, 2020). The population is young, with 42% between 0-15 years of age (National Institute of Statistics Rwanda, 2017). When a person calls the toll-free emergency number (912) from anywhere in the country, the dispatch operator answers the call in Kigali and determines the nature of the complaint and the rough location of the call. The operator then makes a separate call to the ambulance staff to communicate this information and receives suggested clinical intervention information from the ambulance which they pass onto the caller while the ambulance is en route. The dispatch staff may or may not have medical training to communicate with the public and no specific dispatch training exists for the staff. Once the ambulance arrives on scene, the staff assess the patient and then call the dispatch center to alert them of the details of the case and the anticipated needs at the hospital level. The dispatch center initiates a call to the closest hospital to verify that there are enough beds and equipment resources to manage the patient before routing the ambulance to that hospital. If the hospital does not have the appropriate resources, the dispatch operator calls the next closest hospital and verifies if it has enough resources and so on until a suitable hospital has been identified. The dispatch staff then communicate this information to the ambulance staff and direct them to the appropriate health facility. No information is communicated electronically between patient, ambulance staff, dispatch or hospital. Road traffic rules limit access to the scene and from the scene to the hospital. There is currently no regulatory mechanism to clear the roads to allow ambulances to pass routine vehicular traffic during emergencies in the city of Kigali where sirens are also not allowed by law.

Understanding needs

We conducted surveys of staff in the ambulance service and the public to understand the existing pathways of communication and current challenges and to determine the public's opinion on matters regarding medical emergencies. A 12-question anonymous survey included questions on demographic information, what people would do in case of a medical emergency, methods of transport to the hospital, awareness of the public emergency medical service phone number, and any previous experiences with the ambulance service. Volunteer research assistants interacted with the community at major public markets to gain information regarding the medical emergencies and asked questions in Kinyarwanda in an attempt to avoid bias or language barriers.

Key local stakeholders were sought in order to understand the needs and design a product that would be responsive to local needs. Individual discussions were conducted with SAMU dispatch staff at the centralized 912 office and SAMU nurses, anesthetists, drivers and leadership. Discussions with leadership of the University Teaching Hospital of Kigali Emergency Department also led to a better understanding of their needs and concerns about patient handover and communication with the ambulance service. A meeting with the Rwanda National Police allowed for additional discussion on road traffic crashes and navigation of ambulances. Meetings were conducted at high levels with the leadership of the Ministry of Health of Rwanda to develop a shared understanding of the challenges and potential solutions that can be developed through innovation and led to written support for further testing and implementation.

Preliminary design

A preliminary design of Rwanda912 used key features identified through the surveys and meetings with the key stakeholders. The existing GPS locations are often incorrect in Rwanda. Street addresses were implemented a few years ago but are still not routinely used. There is no dataset of exact geolocation in Kigali. This means road locations, names, and driving directions are often incorrect. The local mobile network providers do not support GPS locations of mobile devices to dispatch through their network equipment, which is how 911 calls in the United States are located. The RwandaBuild Program has manually created a large dataset of GPS locations in Kigali including known street addresses and popular sites and restaurants in Kigali. The design will use this data and be able to send and retrieve a GPS location from the public calling from a landline with minimal information.

Because the hospitals vary in their ability to provide services, there can be vastly different capabilities from institution to institution with district hospitals offering limited specialist services and provincial and referral hospitals offering increasingly more complex services. Furthermore, day-to-day variability in resources such as ventilators also mean that ambulance and dispatch staff often need to contact different facilities before making the decision to transport. There is currently no mechanism that allows dispatch call center or ambulance staff to determine which hospital has the resources that a patient in the field might require.

In the first step of the designed solution, the public can push a call 912 button on their application user interface if they have a smartphone. This will send data including GPS location to servers for processing and calculates location and directions to the patient based on traffic patterns. If the caller does not have a smartphone and uses the existing 912 system to call into the dispatch center, their call will be recorded and available in the ambulance for playback. The ambulance will then receive the GPS location of the patient and driving directions with route logic based on the current traffic patterns incorporated into the software. Mobile device tracking using real time GPS and mobile secure connectivity to traffic lights can be incorporated into the design to allow implementation with buy-in from the traffic police and allow for traffic lights to change automatically as the ambulance approaches. This system would allow notifications to traffic police of real time location and oncoming ambulances so the police can help control or hold traffic. The system is also designed to provide decision support for field triage and select the level of care a patient will need and the health center, district hospital, referral hospital or tertiary care center based on the patient's medical issues and vital signs. The design then would allow ambulance staff to communicate with emergency department staff by sending data including photographs and clinical information to allow for preparation in advance of the patient's arrival.

The design was entered into two public innovation competitions in Kigali. The Toyota Innovating Mobility Ideathon in 2018 and the Smart Kigali competition had 176 teams and 150 teams, respectively, across a variety of mobile uses. The Rwanda912 design was selected as a top 5 finalist in both competitions and gained written support from the Ministry of Health for further development and implementation.

Discussion

Addressing prehospital emergency care in low- and middle-income countries, which face 90% of the global burden of trauma, is critical. Delays in access to definitive care increase mortality after motor vehicle crashes and novel applications are necessary especially in LMICs which have unique problems compared to the US or Europe (Byrne *et al.*, 2019). Challenges to prehospital emergency care LMICs can be addressed through collaboration between trauma and EMS system experts and context experts who have in-depth understanding of the local challenges.

In this project, our collaboration determined some of the needs and challenges to prehospital emergency care in Kigali, Rwanda and designed a context-specific software solution that has the potential to improve prehospital emergency care through decreased ambulance response times and transport times. The Rwanda912 online ambulance service was designed through engagement of key stakeholders - SAMU emergency medical service, emergency physicians, Rwanda National Police and the Ministry of Health - as well as software developers and trauma and EMS experts from Virginia Commonwealth University. This technology may be the foundation of emergency communication infrastructure for the Ministry of Health of Rwanda and allow coordination and deployment of emergency services to the public in an efficient manner.

There are other dispatch and communication models such as RapidDeploy (https://www.rapiddeploy.com) and A2D24 (https://www.a2d24.com) which offer support for prehospital emergency services in the African setting. This setting is unique from American and European environments in a variety of ways including availability of telecommunications infrastructure, government investment in emergency services and geographic differences. RapidDeploy differs from Rwanda912 because it does not offer direct communication with hospitals. A2D24 ambulance dispatch service focuses on vehicle tracking and demonstrated 15-30% decrease in response times after implementation of a real-time android-based ambulance dispatch service in South Africa within the first 2 weeks. The Rwanda912 service design aims to have a more expansive aim encompassing the public, dispatch, ambulance staff, police and emergency departments in Kigali. Such a comprehensive design for prehospital emergency communication systems has not been reported from LMICs.

There are several limitations to this project. First, smartphones are widely available in the capital city of Kigali but less so in rural parts of the country. Therefore, those areas may have to continue to rely on the less optimal 912 phone call system which will not allow GPS based geolocation or electronic communications with the dispatch center or hospitals. Second, the hospital communications require that all facilities have hardware to communicate resource availability to the dispatch center as well as the ability to track bed and equipment availability. This does not yet reliably exist in many hospitals although at the University Teaching Hospital of Kigali, the medical staff have implemented a WhatsApp(TM) based messaging system to track bed availability throughout the hospital on a daily basis. Such existing technology may be able to be leveraged for implementation of this online service. Third, while the dispatch and communication challenges can largely be resolved through this service, additional hardware innovations will be necessary to implement road traffic light control to allow ambulances to travel unimpeded along the streets. Furthermore, for this project we gathered basic data from the public and the ambulance staff but did not engage in an extensive needs assessment nor formal qualitative assessment of barriers to use emergency services. These are additional topics that would need to be addressed before software development and implementation can occur. Lastly, while we designed this solution to address the needs and challenges we identified, integration into the software that exists in the Ministry of Health to allow for sustainable and long-term use will be required.

Our next steps are to identify funding to build a testable prototype based on this design, after iterative testing and refinement, with continued feedback from collaborators and intended users, before a final version can be established. A formal framework for user-centred design of mobile health tools, such as that proposed by Farao et al. (2020), would enable the development of a robust solution. Then it would have to be tested in the real world setting to determine if further optimization is necessary and assess how it can be integrated with hospital-based communication systems and how SAMU can transition from the current system to this online service. Establishing clear process and outcome metrics to evaluate the effectiveness of implementation will also be necessary. Ongoing support from the Ministry of Health of Rwanda as well as interest from the Ministry of Infrastructure suggests that this service has tremendous potential for implementation.

This is our collaboration's first step in understanding the challenges to prehospital emergency care delivery in Rwanda and designing a solution for this environment. Further development, testing and evaluation of the service is required.

Author contributions

AR and RR were responsible for the conceptualization of the work described, while AR and JMU were responsible for developing the methodology. RR was responsible for the design of the solution. AR and SJ were responsible for the writing of the manuscript. AR, FZU, GM, JMU, IK, TD and SJ contributed to data collection, analysis and project management for the work for which the authors' experiences are described in the manuscript. All authors made substantial contributions to the design and drafting of the manuscript, critical revisions and final approval.

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