An intelligent ecosystem for providing support in prehospital trauma care in Cuenca–Ecuador

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Abstract

According to given facts by the World Health Organization, 1 in 10 deaths worldwide is due to an external cause of injury. In the field of prehospital trauma care, adequate and timely treatment in the golden period can define survival of a patient.

The aim of this paper is to show the design of a complete ecosystem proposed to support the evaluation treatment of trauma victims, using standard tools and vocabulary as OpenEHR, mobile systems and expert systems to support decision-making. Preliminary results of the developed applications are presented, as well as trauma related data. (city of Cuenca - Ecuador).

Keywords:
Clinical decision support systems; emergency medicine; mobile applications; injuries.

Introduction

The trauma is considered a pandemic worldwide that mostly affects young persons, therefore; has negative impact on the production system of any nation [1][2]. This situation is not different in Ecuador, where since 1995 the injury burden has been documented in a national statistics database [3][4][5]. However, external causes of injury are not grouped as a single category, but rather are identified as separate etiologies such as, traffic accidents, falls, violence, burns, animal bites, among others [6][7].

According to the Ecuadorian Institute of Statistics and Census (INEC), in 2011 the leading cause of death was diabetes mellitus with 7.15%, while land transportation accidents were the fifth leading cause, and homicides occupied the seventh place. Therefore, if we add all the traumatic events, trauma becomes the leading cause of mortality on a 8.76% [8].

For almost 2 years now, trauma care in the province of Azuay is provided at the Vicente Corral Moscoso Regional Hospital, by an Integrated Security System (SIS ECU 911) [9] which coordinates relief agencies in pre-hospital care (PHC) such as the Ministry of Public Health (MSP), the Fire Department, and the Ecuadorian Red Cross. During this period, trauma related emergencies correspond to 46% of all care provided, and 70% of this is managed at the public health hospital [4].

On those grounds, we have analyzed the interaction between the prehospital primary attention services and the transfer to the hospital. Based on this general analysis (response times, false trauma alerts, etc.) we have determined that the communication system between ambulances and hospitals requires improvements. Therefore, implementation of an improved data transmission system was undertaken. The aim of this paper is to describe how an ecosystem related software can accomplish this improvement in patient care. Likewise, in this paper we will present preliminary results of first support application developed: a mobile tool to improve trauma data collection, communication with the hospital, route planning, and data arrival estimation.

The rest of the paper is organized as follows. In Section 2 we present a general overview of the proposed ecosystem and its main components. The experiment carried out as well as the preliminary results are detailed in Section 3. In Section 4 we present some relevant researches and discuss some applications of information systems for decision support and trauma care. Finally, in Section 5 some conclusions and future work are presented.

Methods

The trauma care is a complex field that currently requires an integral solution able to face a wide spectrum of needs as the following:

- Provide effective prehospital attention with the aim of reducing mortality.
- Raise awareness in people that is more prone to suffer accidents related with trauma (persons under 45 years).
- Have robust mobile systems to provide primary healthcare services during the accidents.
- Have ICT-based tools for supporting learning process of medical students.
- Use vocabulary standardized with the aim of sharing and exchanging the patient's information.
- Use knowledge-based models for storing the clinical information.
On those grounds, we have designed an ecosystem that relies on MLST system (mechanism of injury, suspected lesions, vital signs and effected treatment), and is able to manage the critical information from the prehospital care. Likewise, our proposal includes a prototype for the automatic capture of vital signs from the equipment present in the ambulance, and an intelligent system with decision making algorithms for categorization of severity of trauma and prioritization of trauma alert. The captured information of the patient and his medical condition is sent to the nearest hospital as well as the geo position of the ambulance, and the arrival time.

With the aim of providing a complete support for trauma care bearing in mind the needs mentioned above, we have designed a comprehensive ecosystem named SINATRA (Intelligent System to Support Trauma, for its acronym in Spanish). This model (Fig. 1) relies on a layer-based approach that easily allows integrating more modules/services to cover new areas of trauma care, and support the requirements of doctors, paramedics, students, and patients. The main objective of our ecosystem to provide support to carry out activities and tasks that require decision support, and services to share, exchange and analyze information related with trauma care.

**Figure 1 – The proposed ecosystem for trauma support.**

In this section we will provide a general description of the elements that make up the ecosystem as well as the preliminary achieved results using the mobile application.

**Support tools based on ICTs**

This layer is based on a set of ICTs tools that provide the interfaces to register the medical information, access to knowledge database, and perform the training with medical students:

- The **mobile support environment** is a set of mobile applications that provide supporting in the execution of several tasks as registering critical information generated in the ambulance (prehospital care), remote patient monitoring, and registering and analyzing hospitals infrastructure for trauma care (staff, equipment, protocols, etc.).

- The **teledicine KIT** is an electronic device that records patient vital signs (respiratory rate, blood pressure, pulse, and oxygen saturation) when he is being transported to the hospital.

- In order to manage the information stored in the knowledge database, the ecosystem includes a **web information system**. This tool is used to query database, register new cases, generate reports, provide statistics, and support some data mining tasks like cluster creation according to several variables (geographical area of accident, demographic patient information, type of injury, ..). Some components are based on OpenEHR archetypes and templates (www.openehr.org)

- With the aim of reinforcing some learning activities as well as raising the awareness about trauma, the ecosystem includes a learning environment based on augmented reality and virtual reality (AR/VR). This environment can be used during classes at university, or awareness campaigns for yong drivers, seniors, and general population.

**Knowledge management and representation**

This layer relies on a set interfaces and provides several services to manage the information. Likewise, in this layer it is possible to incorporate intelligent modules to cover areas related with machine learning, decision support, pattern recognition, data mining, learning support, among others.

Some of the most relevant elements are the following:

- The **decision support system** uses decision trees, neural networks and case-based reasoning to support decision-making in various aspects such as determining the type of alert that is sent to hospital after prehospital care (analysis of trauma, patient condition, etc.), allocation of resources for patient care (both human and material), as well as diagnosis and treatment.

- The **trauma knowledge domain** contains a complete set of protocols, procedures and trauma-related ontologies (initial management of trauma, shock, traumatic brain injury, infections, etc.)

- With the aim of providing the necessary tools to access to knowledge base and share information with applications from other platforms, the ecosystem includes a set **information exchange services**. These services include the templates generated from archetypes, export functionalities, querying functions, among others.

- For a medical student that is in the academic training phase, it is very important to address real cases related with specific trauma situations. This way, our proposal incorporates an **information system for academic tutoring** that is able to generate random cases of patients with different cases of injuries. With the aim of saving the patient life or provide an adequate treatment, the student should make a decision according to presented information. The system will rate the decision and will present a valid solution.

**Knowledge database**

- The **OpenEHR archetypes** allow to model us the different procedures, observations, instructions and data required to register information related to trauma. Figure 2 depicts an example of an archetype for a case of monitoring a blunt traumatic injury.

- The **standardized vocabulary** contains the codes of classification and coding of diseases and a wide variety of signs, symptoms, abnormal findings, complaints, social circumstances and external causes of injury and / or illness.
In the clinical data repository all information coming from different sources (prehospital, hospital, diagnosis, treatment, etc.) is consolidated.

**Results**

MOSPA is an Android® application that is part of the mobile support environment of the proposed model. This application allows to record the most important patient information based on MLST system (mechanism of trauma, suspected injury, vital signs, and, treatment performed such as, CPR, endotracheal tube placement, etc.). Also the pregnancy status and gestational age, among other prehospital information incorporated is. In addition, the application is able to calculate the type of alert (severe, mild or none) to be sent to the hospital personnel and to estimate travel time from the scene to the hospital (using Google® maps) the total number of variables that are handled by the application is 29 (according to MLST).

Figure 3 shows and example of the process that allows to determine the kind of alert that must be sent from the ambulance to the receiving hospital. As shown, the system must analyze the values of each variable of MLST and how they are combined (two or more critical values, two or more no-critical value, etc.). For example, whether a patient presents arterial hemorrhage or major bleeding, the system must automatically send a critical alert to hospital. Likewise, whether a patient has lost more than 500 cc of blood and has been unconscious for more than 5 minutes, the system will send a critical alert.

To verify the tool, we conducted a laboratory pilot test with 32 participants who were trained in the use of the application. As a first step, random searches of trauma cases were generated, and then participants were requested to record such cases in the mobile application. As the participants filled-in all information of the cases the time taken to record each was measured. This is illustrated in table 1.

**Table 1– Preliminary evaluation results of MOSPA.**

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>32</td>
</tr>
<tr>
<td>Average filing time</td>
<td>59 seconds</td>
</tr>
<tr>
<td>Average number of errors committed</td>
<td>7</td>
</tr>
</tbody>
</table>

As we can see, the average time is about 1 minute, which is an encouraging result, since the participants involved are not professional paramedics and this allowed us to establish that the application is an excellent alternative to be used in ambulances. To the best of our knowledge, the MLST system commonly is applied for trauma attention by using air transport. The maximum time to enter the information of trauma in these cases must be no more than one minute. Therefore, we consider that for terrain transportation of trauma patients, the time should be similar.

Figure 4 (a) depicts a screenshot of the window that allows entering the information related to pregnancy. Figure 4 (b) shows the route and estimated time of arrival of the ambulance to the receiving hospital.

**Discussion**

Today, intelligent systems have become a tool that supports the most diverse areas of science, providing various services such as support in decision-making, information discovery, pattern analysis, artificial vision, among others. Just one of the sciences where such systems can provide important support is medicine because of the wide range of existing knowledge and the complex problems they must deal with every day [10].
Existing developments are varied and include the application of various techniques related to the fields of engineering and especially with artificial intelligence.

A report presented by Fitzgerald [11] aims to demonstrate that the computer systems of decision support can reduce errors during the first 30 minutes of resuscitation for trauma occurs. Also, Han [12] presents a study on the use of expert systems to monitor biometric signals of patients who are at home.

Other areas of action of expert systems to support decision making in medicine focus on the following lines:

- Analysis and prediction of adult patients with intracranial hemorrhagic trauma (HIT). Nishijima conducted a study where an expert system based on rules to determine whether patients over 18 years with HIT should move to the ICU [12]. The developed system uses a set of rules derived from classification and Regression Trees and obtains promising results.

- Early diagnosis cervical vascular injuries. Purvis [13] propose using Decision Trees for early detection of cervical vascular injuries obstruction. Based on this research the prevention of such injuries is expected, therefore the aftereffects in patients.

As shown, the proposed ecosystem could effectively replace the existing system, given that the paramedics (Cuenca) currently use only radio communication, and the staff hospital can not monitor in a real-time the patient condition. Likewise, currently the ambulance conductor provides an estimation of arrival time, and does not have an automatized support to determine the nearest hospital or the best route to follow.

**Figure 3**—Logical process to determine the kind of alert that will be sent to hospital.

[Diagram of logical process]

**Figure 4**—(a) Screen capture of registration of pregnancy information, (b) route and estimate time of arrival.

(b)

**Conclusion**

To the best of our knowledge, nowadays Ecuador does not have an integrative environment to provide support at the different stages in trauma care. It is crucial to consider all actors involved in this process (doctors, paramedics, support staff, patients and their relatives), and try to optimize the response time and resources required to provide effective trauma care. We believe that the ecosystem described can be
utilized as a tool in the process of managing and sharing information related to patient care.

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References


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