GACETA MÉDICA DE MÉXICO

ORIGINAL ARTICLE

Índice de Saturación Modificado y Ambulancias (ISMA): Ambulance assignment and remote Emergency Room Bed Reservation

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Abstract

Introduction: *In most places all over the world –including our country– services in emergency rooms are oversaturated. This situation frequently forces the continuously arriving ambulances to be redirected to other medical units, delaying the admission of patients moved and thus adversely affecting their physical condition.* **Objective:** *To introduce an improvement to the* Índice de Saturación Modificado *computational system, which monitors the degree of saturation of a network of emergency medical services, to include a network of ambulances, enabling in the system: (i) the effective allocation of ambulances to the site of the accident, or severe clinical event, and (ii) the remote booking of beds in the nearest and least saturated emergency room available.* **Material and Methods:** *The evaluation and connectivity of the computational improvement to the* Índice de Saturación Modificado *system was carried out with a computational test verifying these two aspects, using only differences in postal codes, for time measuring.* **Results:** *The verification of its sustainability online showed the new* Índice de Saturación Modificado y Ambulancias *system (ISMA) has a robust structure capable of being adapted to mobile phones, laptops or tablets, and can efficiently administrate: (i) the quantification of excessive demand in the emergency room services of a hospital network, (ii) the allocation of ambulances attending the site of the event or contingency, and (iii) the allocation of ambulances and patients, in the best distance-time conditions, from the site of the accident or clinical event to the nearest and least saturated emergency room service.* **Conclusions:** *This administrative management tool is efficient and simple to use, and it optimally relates independent service networks.* (Gac Med Mex. 2015;151:293-6)
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KEY WORDS: *Emergency room. Network of hospitals. Network of ambulances.*

Introduction

In most parts of the world, including our country, Medical Emergency Departments are oversaturated. This situation frequently forces for ambulances continuously arriving to the Emergency Department to be redirected to other medical units, which delays the admission of transported patients and unfavorably impacts on their evolution. For these reasons, this is considered a specific quality indicator of Emergency Departments. One factor that aggravates this situation[1-3] is unplanned arrival of ambulances with seriously ill or injured patients. Other phenomenon related to these

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events is the unnecessary arrival of two or more ambulances to the accident site, which results in other seriously ill patients' programmed transportation not to be done on time, or in ambulance services not being available to carry out other planned or urgent transportations.

Since from the clinical point of view, a seriously ill patient can be clinically "stable" or "unstable" (in critical state), ambulances for transportation must have high technology equipment and medical and/or paramedical personnel trained to provide pre-hospital care at the site of the event (accident or serious clinical event) and offer advanced pharmacological and/or electromechanical life support on the way to the hospital.

Although it is impossible for an accident to be predicted, with current telecommunication media, a network to connect and manage services can be built based on two computer-based networks: the ambulance network and the Emergency Medical Services network. This link would enable *in situ,* real-time communication of these networks, thus improving ambulance assignment and increasing the likelihood of first transportation of the patient being final and for the patient to receive medical care opportunely.

To this end, we connected the computer system named ISM[4], which focuses on the measurement of Emergency Medical Services oversaturation in a network of hospitals, with a network of ambulances. This new system consders bed reservations[5] at the Medical Emergency Department that is closer to the place of accident or serious clinical event, after automatic designation of the ambulance that must attend the place of accident. We have named this new system ISMA and, similar to the ISM, it is offered for use free of charge.

The ISMA system is basically a manager of services between two computer-based networks: ambulances and Emergency Medical Services. It makes use of the ISM system algorithms for availability of useful beds and authorizes medical and paramedical crew of the assigned ambulance to make a reservation of a useful bed at the nearest and/or least saturated Emergency Department from the very place of accident or catastrophic clinical event. Additionally, it administers the assignment of ambulances to be sent to the zone of the event according to geographic closeness and availability.

The ISMA system is a tool that answers in real time and is available from any computer, or else can be adapted to be consulted from any mobile telephone, laptop or tablet. It doesn't require licences or special software requirements, since its algorithms consider only the difference between the postal codes corresponding to the accident site and ambulance location, as an

approximate measurement for time of arrival estimate. Its simplicity makes it easy to understand and provides a detailed overview on overdemand variables at the appointed Medical Emergency Departments, with the assignment of ambulances for the care of critically ill patients being added, as well as temporary reservation of useful beds at the closest Emergency Departments. The ISMA passed the computational tests successfully.

Material and methods

The ISMA system is a computer-based mathematical method that includes the metrics of the already published ISM system[4], and that now allows for the management of information on the ambulance network.

The ISMA system

Ambulance assignment

The system selects, within the appointed ambulances network, the available ambulance closest to the site of the event, and assigns it to go to this place. Simultaneously, it calculates the approximate time of arrival of the ambulance from its initial location to the accident site using the following algorithm:

> Ambulance time of arrival (in minutes) =
> ([ambulance location postal code] –
> [accident site postal code]) x (750 x 0.002000)
> Where 750 is considered to be the average distance between postal codes and 0.002000 represents the multiplicative inverse of the ambulance average speed (30 km/h) expressed in meters per minute.

The ambulance assignment is carried out depending on closeness and availability, since the ISMA system assesses with the above algorithm all the ambulances appointed to the network, in order to ultimately assign the ambulance with the lowest estimated time of arrival. Once assigned, it is asked for confirmation to set out towards the accident site.

Reservation at the Emergency Department

The ambulance that has been assigned to the site of accident or serious clinical event is able to reserve a useful bed at the Emergency Department that is closest to the accident site, since the ISMA system calculates the approximate time of arrival of the ambulance from the accident site to the Emergency Department with the following algorithm:

Table 1. Description of the fields the ISMA system shows to the user immediately after each update

no.	Description	Definition
1	Ambulance location	Postal code of the place where the ambulance is located
	Site of accident or serious clinical event	Postal code of the accident site
2	Ambulance	Ambulance ID
3	Condition of the seriously ill/injured patient	Assingnment according to colors: [R]ed: unstable [Y]ellow: stable
4	Age	Approximate age of the injured person
5	Gender	Male or female
6	Site of the accident (postal code)	Accident site postal code

Time of arrival to the Emergency Department (in minutes) =
([Emergency Department postal code] –
[accident site postal code]) x (750 x 0.002000)

Where 750 is considered to be the average distance (in meters) between postal codes and 0.002000 represents the multiplicative inverse of the ambulance average speed (30 km/h), expressed in meters per minute.

The ISMA system evaluates all Emergency Departments appointed to the network with this algorithm and recommends that with the shortest time of arrival, while asking the Emergency Department for confirmation accepting or not the ambulance's reservation.

The ISMA system: retrospective analysis

The ISMA system shows the oversaturation variables of the ISM computer-based system in real time[3], as well as the following (Table 1):
– Accident or serious clinical event
– Ambulance assigned by the system to go to the accident site and aprroximate time of arrival to the Emergency Department where a useful bed has beeen "reserved" by the physicians and/or paramedics of the ambulance.

Since the ISMA system shows only the latest variable variations, all modifications to these variables are stored in a "historical" file to allow for a restrospective analysis to be carried out anytime by means of Time Series. This will allow for time variations by each hospital unit to be observed.

The ISMA system: testing

Verification of the ISMA system was strictly computational and did not include any type of exhaustive or random test. Individual tests focused on two aspects:

– Ambulance assignment.
– Reservation of useful beds at the Emergency Department.

The nature of the changes that gave way to the ISMA system does not, according to the authors' judgement, require other type of tests, since the improvements are strictly computational and in this sense were they verified; this observation is discussed later.

The ISMA system: connectivity

The ISMA system has been developed for a portable computer platform with remote connection via port 22, protected against non-human attacks (from other computers); its time-distance metrics for ambulances and Emergency Departments assignment and reservation are based on postal codes, and the design of the system is of the modular-structured type, so its conversion to mobile telephones, laptops and tablets with Android OS operative system[6] and location via GPS[7] is simple, though laborious.

Results

The system did not show any error in the computational tests, which considered: transaction traffic between Emergency Departments, ambulance sites relocation, assignment of ambulances to accidents and reservation of beds at Medical Emergency Departments from the ambulances.

Discussion

Although the multiple and varied factors that determine Medical Emergency Departments oversaturation originate in different parts of the health sector, from the medical and administrative point of view, it is useful to analyze the problem with a functional focus from the