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TRAINING SYSTEM FOR FIRST RESPONSE MEDICAL EMERGENCY GROUPS TO GUIDE TRIAGE PROCEDURES

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ABSTRACT

The work presents training system which provides a structured, simple and practical approach to triage training, for first response paramedic and emergency medical services personnel, as implementation of the triaging procedures in mass casualty accidents. The proposed training system allows to train the procedures at all three levels of hierarchical chain of strategic, tactical and executive command management. It provides reliable connectivity at the scene based on Bluetooth Low Energy standard or Internet connection with the use of mobile 4G LTE communication networks infrastructure. In training system we use simulators of vital human signs based on mobile devices, which generate so-called the victim's life cycle chart, consisting of the heartbeats and respiratory rates, systolic and diastolic blood pressure, and capillary refill time, used as the basis for triage categorization. Presented training system increases trainees competence level in executive as well as control and governance skills.

Keywords: triage procedures, mass casualty incident, medical emergency group training

1. INTRODUCTION

First response medical emergency groups are services that are called to any accidents involving people. After arriving at the scene of the accident, they evaluate the scale of the event. If the number of victims and the scale of its injuries is so large that it is not possible to provide assistance at the level required by standard procedures, (when there are insufficient resources for medical care of everyone at once) then medical categorization (triage) procedure is necessary. As a result of this procedure, the victims obtain priority related to its injuries, time of assistance, and evacuation (Super 1984, Wallis 2006).

Triaging algorithms are not very sophisticated, they are rather straightforward, and easy to use (Navin 2010a, Jenkins 2008, Lerner 2013). However, they can allow for over or under triaging depending on the situation. Therefore, the idea of performing trainings which impose the desired behaviours, as reflex actions realizing required procedures. This is especially important when mass casualty incidents happen so rarely that first response medical staff forgets details of the required procedures.

According to study conducted with medical rescue staff (Wilk 2015) 28% of respondents had no real experience in medical rescue at mass events. 38% had never participated in training in this field, and 7% had never received professional training at their workplace.

Trainings are obviously not the same as working in real emergency, but it make effective a certain habits, that in real situations allow to maintain a high efficiency of action (Navin 2010c).

1.1. Organization of rescue management

Rescue operations during a mass casualty incident consist of three levels (Fig.1):

- ***strategic level,*** Health Service Commander in Crisis Management Centre coordinates all emergency services with the necessary number of medical resources as dedicated medical staff and medical facilities that are necessary for highest efficiency of rescue operation.

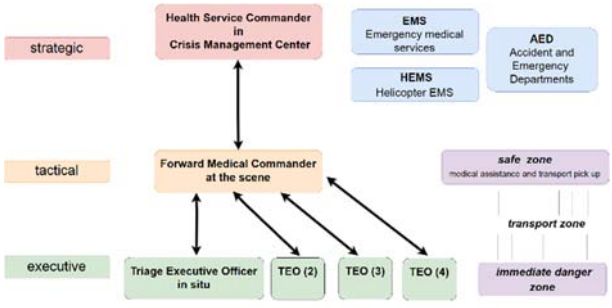

Figure 1: Hierarchy of Rescue Management. Chain of Strategic, Tactical and Executive Command

- ***tactical level,*** Forward Medical Commander, who operate on site of the mass casualty incident, controls the work of all Triage Executive Officers at the scene. He maintain reliable and continuous communication with

Health Service Commander and recognise the actual situation at the scene and notify it the Health Service Commander.

- ***executive level,*** Triage Executive Officers, who cooperate with first responder medical services at the scene of the incident, e.g. physicians, paramedics, nurses, rescue and fire-fighting units.

The rescue operation site is organised in 3 zones (Fig.1):

- ***safe zone,*** which provide the dedicated medical staff and equipment necessary for saving injured victims and prepare them for transport to the hospital. It consists of: casualty collection point, categorized treatment areas, patients loading area. Here the secondary medical segregation (re-triage) is carried out.

- ***transport zone***, there are designated corridors that are used to transport victims to safe zone. For people who can walk independently, separate escape routes are designated.

- ***immediate danger zone,*** determined by the State Fire Service commander who, as the first, arrived at the site of the accident.

1.2. Triage procedures - issues of concern

Triage procedure we use to prioritize emergency care and identify victims who need immediate medical attention because of the nature or severity of their injury. Triage possibilities vary depending on the zone in which the victims are located. Within the immediate danger zone rescuers usually work in protective clothing which limit the possibility of a detailed examination of the victim. So, basically a quick assessment of the victim in terms of the urgency and rationality of evacuation to the safe zone, is required.

Re-triage is carried out within the safe zone, where qualified medical staff in a safe environment can assess the victim condition on the basis of a larger number of parameters.

Finally, the last re-triage takes place in the phase of removing the effects of accident in emergency departments or hospital trauma centres. There, it is possible to re-assess the condition of the victim after a significant time from the first triage procedure performed by the first response medical emergency personnel.

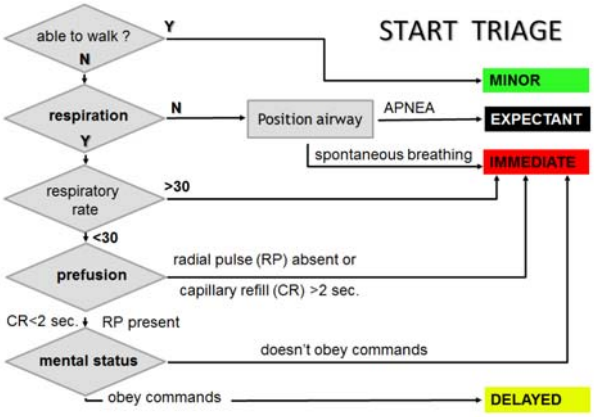

Figure 2: Simple Triage And Rapid Treatment Procedure

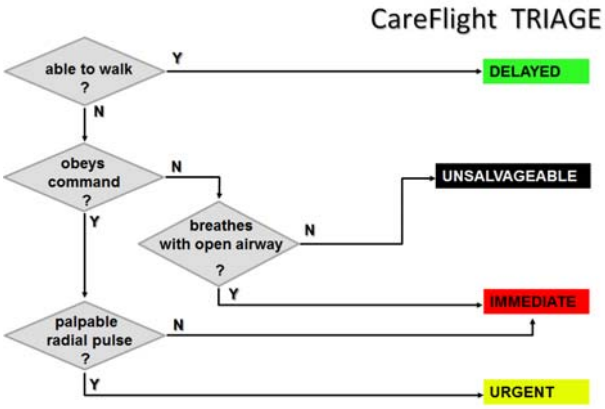

Figure 3: CareFlight Triage Procedure

All data collected by Triage Executive Officers are transferred to the Forward Medical Commander, person guided in situ a medical rescue operations. Based on that information, he has the possibility of combining the victims with the division into the urgency of their evacuation to the safe zone.

Forward Medical Commander has direct communication (usually via a radio or mobile network) with the Health Service Commander. This allows the flow of information on the number of victims, the possibilities of their admission to the specific hospitals and the allocation of the victims to specific medical facilities.

On executive level (Fig.1), triaging algorithms are rather simple, straightforward, and easy to use. To prove that, it suffices to analyse the most-popular procedures such as: Simple Triage And Rapid Treatment (Fig.2) (Kahn 2009), Care Flight Triage (Fig.3), Triage Sieve (Fig.4), Sacco Triage or Sort, Assess, Lifesaving Interventions, Treatment (Navin 2010b).

All triage procedures are based on a common set of 3-4 screening questions. Triage consists of life-saving procedures like; open airway, control haemorrhaging, make chest decompression and then answer the screening question about: mental status, walk ability, respiration, perfusion.

On strategic and tactical levels (Fig.1) triaging procedures ensure excellent strategy and effective tactics to support the implementation of activities on site of the accident. Tactic engaged with strategy results in synergy, but requires good team cooperation on all three levels. Proposed training system doesn't provide genuine hands-on experience, but it can be a complement to the disaster preparedness plan which can ultimately help to save human lives.

2. ARCHITECTURE OF TRAINING SYSTEM

Triage simulation training has been consistently shown to improve triage performance of technical, as well as co-operational teamwork skills (Garner 2001).

The poor communication and cooperation are common-

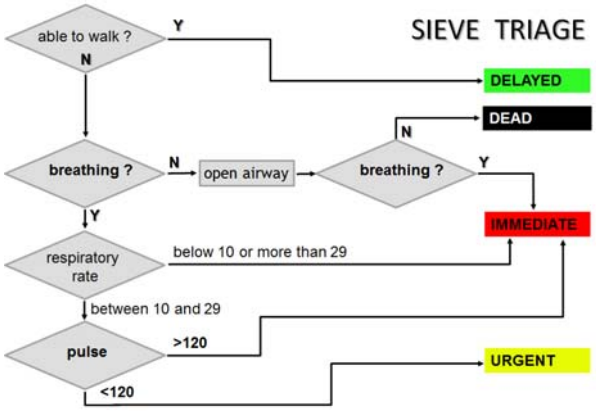

Figure 4: Sieve Triage Procedure

est falling of management effectiveness during mass casualty incident (Gao 2007), that's why our training system provides reliable connectivity at the scene based on Bluetooth Low Energy standard and software which forces the use of procedures specified in mass casualty accident operation guideline manuals.

Despite proven benefits of simulation, current training standards for first response medical services personnel consist primarily of education lectures that do not adequately address the reality of providing triage in a real, emergent in disaster setting. Specifically, simulation has proven effective for training a realistic response while emergency staff working in a stressful environment.

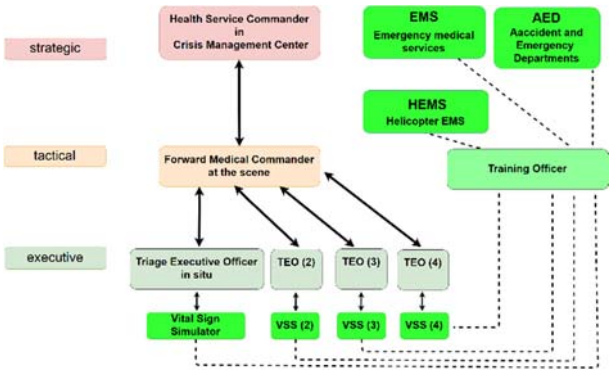

Figure 5: The Structure of Proposed Training System

The proposed training is conducted by the Training Assistant, who prepares tasks and governs exercises (Fig.5). Preparation of tasks consists in:

- specifying the number of injured people and work schedule for Vital Sign Simulators for each victim,
- defining the availability schedule for operating facilities and surgical nursing staff, in a crowded medical facility, emergency ambulances, paramedics or other skilled personnel.

2.1. Simulating of human vital signs

Modern technology offers a whole range of sensors that enable measurement and monitoring of selected physical quantities (Baheti 2009). The development of the wearables technology allowed to miniaturize the systems that monitor vital human activities using non-invasive methods (Stetson 2004). The latest information technologies provide software that integrates various technical solutions and combines them into a single measurement and local communication system, to capturing and transmitting patient data (Niswar 2015).

Wearable and IoT technologies offer more in this area (Yao 2005). The stick-on sensor called VitalTag (Dolon 2018) is fixed to a victim's sternum and wirelessly transmit real-time vital sign measurements such as heart and respiration rates, blood pressure, shock index, blood oxygen saturation etc.

In training system we use simulators of vital human signs based on mobile devices (Fig.6). These devices generate so-called the victim's life cycle chart, consisting of the values (heartbeats and respiratory rates, systolic and diastolic blood pressure, and capillary refill time) used as the basis for triage categorization

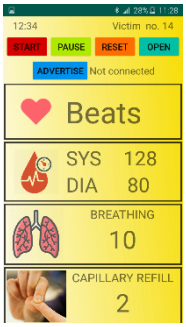

Figure 6: Human Vital Sign Simulator, (Burik 2019)

The victim's life cycle chart simulate victim behaviour for consecutive 20 minutes, and vital signs are broadcast with a 10 seconds period. It is played periodically every 20 minutes (unless the dead/unsalvageable status is reached before).

2.2. Organization of training teammates in triage procedures

Some number of Vital Signs Simulators (mobile devices with running life cycle chart) are placed on the selected training area. The team of first responders arrive on the scene with no foreknowledge how many are injured and how is the nature and extent of their vital signs (simulated by mobile device).

Due to the hierarchical chain of command (strategic, tactical and executive) triage procedures, we stimulate the following person activities (Fig.5):

- *Health Service Commander* in Crisis Management Center, who uses a desktop computer and internet communication channel to link with Forward Medical Commander working at the mass casualty incident area.
- *Forward Medical Commander* at the scene, who uses a tablet device (provided with application) to

communicate with Triage Executive Officers working at the scene.

- *Triage Executive Officers* at the scene categorizing victims according to triage procedures, communicating with both; Forward Medical Commander – as uplink and human Vital Signs Simulator as downlink, using data and advertising channels.

2.3. Team work coordination in triage procedures

The proposed training system allows to train the procedures at all three levels of hierarchical chain of strategic, tactical and executive command management (Fig.5). Wilk (2015), argues that 60% of medical rescue staff indicated organisational difficulties pertaining predominantly to coordinating actions during genuine or simulated mass casualty incidents. 66% of the respondents claimed that the leaders of rescue were chaotic. In order to improve the team work, it is necessary to define a chain of command (strategic, tactical and executive) and identify any actual and potential scene hazards.

On the executive level, the objective of our training exercise is to stage on scene, realistic triage simulation with participation of many victims. Triage Executive Officers organize an appropriate triage, identify and stabilize victims without unnecessary delays. They should correctly categorize patients according to severity of injury and evacuate them from the immediate danger zone. On this level, proposed training system can improve the communication and teamwork skills of the first response personnel and the efficiency with which the team performs challenging triage in a high-stress situation.

On the tactical level, Forward Medical Commander is the main (and only) person who manages all medical activities on accident area. He coordinates the activities of the rescuers. He sizes-up incident, estimates extent of impact area, and number and severity of victims. He creates an aggregative card of the current state of rescue action and based on it, he determines resources required. Effective management is crucial at this level. It is obligatory to co-ordinate activity of 4 types of team (Fig.1); three rescue groups operating in different zones and an vehicles of emergency medical services that provide transport from accident pick up area to emergency departments facilities. Regardless of various disruptions (deterioration of victims condition, deadlocks within transport zone, delays of ambulance arrival), smoothness of the flow of victims from the immediate danger zone to medical facilities needs to be ensured (with guaranteed level of medical services).

On the strategic level, Health Service Commander using an aggregative card of the current state of rescue action focuses on safe zone (where medical assistance (followed by re-triage) is provided, and staff prepare victims for safety transport). The effective coordination of vehicles to transport patients to medical facilities is definitely his management duty.

Because the triage is dynamic process, so it must be repeated at every stage of casualty evacuation chain to detect changes of victim's vital signs. After completing the one victim triage, Triage Executive Officer communicates (using Bluetooth data channels) his decision to the Forward Medical Commander (on Fig.7 *Connection* data channel) and continues the search activity in the scene of the accident. From that moment, the proposed software allows Forward Medical Commander take over the monitoring of vital signs function (Sakanushi 2011), using Bluetooth advertisement channels (on Fig.7 *Scanning-Advertising* data channel). This continuously gathered information is useful to determine the needs and adequacy of subsequent re-triage (Albahri 2018).

3. PROPOSED HARDWARE AND SOFTWARE

Creating a training system (Fig.1) we tended to minimize the difference between the training and the genuine action to be as small as possible. That's why the equipment used during training and the software requirements are similar to those used in real-life actions. Triage Executive Officers use smartphones/tablets and software running under the Android system. Forward Medical Commander uses a tablet/notebook and software running under Android/Windows. Health

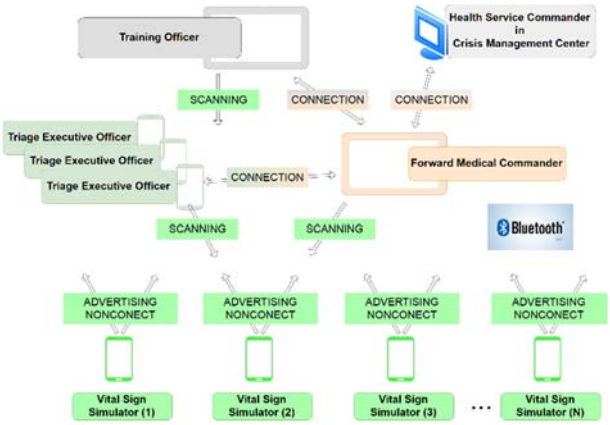

Figure 7: The Communication Structure based on Bluetooth Low Energy 5.1 Standard

Service Commander uses desktop computer and internet or wireless communication channel. Training Officer uses a tablet with bidirectional wireless communication.

In the scope of victim simulations, we propose two options: a simulator based on smartphone either medical phantoms, both providing wireless broadcast of vital human life parameters.

Proposed communication links between the training participants provide; directed one-way and bi-directional as well as broadcast, type connections. The basic variant of the communication is wireless Bluetooth Low Energy (BLE). Another version is the Internet connection with the use of mobile 4G LTE communication networks infrastructure (in the future 5G). Both variants provide sufficient bandwidth and number of channels, alike in rooms and open environment (in range circa120 m).

3.1. Triage Executive Officers software

Current methods of mass casualty incidents victims triage use such categories of optical markers as coloured bands or emergency Triage Tags fasten on the wrist. Triage Executive Officer, after examine the victim's vital signs (obtained from simulator or phantom), decides to which category the victim belongs to, and attaches to it the appropriate colored marker. Preserving mentioned above rules, we equip Triage Executive Officer (trainee) with Android smartphone and software providing the following functionalities:

- enter the trainee ID and triage method ID, once at start of training session,
- determine the GPS position and ID of the triaged victims,
- collect wirelessly broadcasting information about the victim's status,

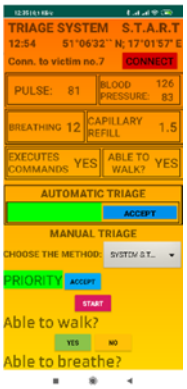

Figure 8: Triage Executive Officers Application, Display Screen, (Burik 2019)

- maintain log for on-site triage activity, stamp in the device memory; time, triage decisions, and life parameters that was the basis for the decision,
- transmit to Forward Medical Commander record with triage results (trainee ID, triage method ID, GPS position, victim's ID, time and triage decision).

The basic requirement for the user interface of Triage Executive Officers application (Fig.8), is to be minimalistic in terms of functionality. Displaying a huge number of different data and information introduces confusion and chaos, which usually is already in excess at the place of the mass casualty accident. Therefore the user interface is simple, transparent and user friendly.

3.2. Forward Medical Commander software

Organisational difficulties of Forward Medical Commander, pertaining predominantly to coordinating actions during mass casualty incidents appears to be largely a result of necessity of two-way cooperation (upwards with Health Service Commander and downwards with Triage Executive Officers), combined with concurrent information processing. The Forward Medical Commander management currently based on paper-used, manual methods of data acquisition.

Preserving mentioned above rules, we introduce Android tablet as smart devices to enhance management process. Proposed software provides the following functionalities:

- enter the trainee ID, his GPS position and triage method ID, once at start of training session,
- maintain log for on-site management activity,
- track the Triage Executive Officer's movement,
- receive from Triage Executive Officers records with triage results (trainee ID, triage method ID, GPS position, victim's ID, time and triage decision),
- present graphically the current triage situation at the place of the mass casualty accident,
- receive from qualified medical staff (working at treatment area located in safe zone, Fig.1) records with re-triage results (staff ID, triage method ID, GPS position, victim's ID, time and triage decision),
- present graphically the current triage situation at the treatment area located in safe zone,
- monitor on-line, the broadcasted vital signs, and collect it wirelessly for all already triaged/re-triaged victims of accident,
- alert the situation of critical changes in vital signs,
- display charts of vital signs, for chosen, already triaged/re-triaged victims of accident,
- transmit information to Health Service Commander about the number and severity of victims,
- transmit periodically to Health Service Commander an aggregative card of the current state of rescue action and information about resources required,
- receive information from Health Service Commander about the number of available EMTs, destinations and medical facilities.

The user interface of Forward Medical Commander application (FMC) is much more sophisticated than it was with the Triage Executive Officers (TEO) application. This FMC application is an intelligent re-transmitter between the Triage Executive Officers (downwards) and the Health Service Commander (upwards), supported Forward Medical Commander.
This application focuses on triage results, the actual condition of the victims, available rescuers, emergency medical service ambulances, and transporting patients to the medical facilities. That's why its appearance of a desktop, consists of many display screens with graphics, decision buttons and the drop down windows.

4. CONCLUSION

Proposed training system provides a structured, simple and practical approach to triage training, for first response paramedic and emergency medical services personnel, as implementation of procedures of the triaging in mass casualty accidents.
Many of emergency medical staff (EMS) (Wilk 2015, argues that about a third) had no real experience in medical rescue at mass casualty accidents. Those EMS,

who had training the triage procedures as well as those who once had acting during realistic response to mass casualty incidents, (it does not happen often) simply forget required procedures. Maintaining of the trained skills efficiency requires their repetition every now and then.

Presented training system increases trainees competence level in executive as well as control and governance skills.

Triage in mass casualty accident is carried out as team work under high psychological pressure for emergency medical personnel. The mobile devices (Windows notebooks, Android smartphones, and tablets) used in training system are exactly the same as had been used during genuine mass casualty incidents. Triage in real conditions, it's just one more varieties. This significantly reduces the level of stress.

Emerging technologies and their potential application yield new contenders. The stick-on sensor called VitalTag (Dolon 2018) is fixed to a victim's sternum and wirelessly transmit real-time vital sign measurements.

A soft, stick-on patch (DGIST 2017) fixed to a victim's sternum, which collects, analyzes and wirelessly, via Wi-Fi channel, transmits a vital signs to a smartphone.

We should not become complacent with this state of affairs. Our system may not be as poor as some currently used systems (e.g. these using booklets, pencils and cardboard tags), which look almost laughable to our modern information technology perspective, but there is still plenty of room for improvement. We intend to provide this training system for emergency medical staff to test and formulate comments that allow to improve this issue.

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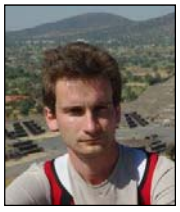

Maciej Nikodem graduated a M.Sc. in Computer Science and a M.Sc. in Control and Robotics from the WUST. Holds Ph.D. in Computer Science at Faculty of Electronics, WUST. He works on Counter-measures to Fault Analysis, Boundary Scan Security, Wireless Sensor Networks.

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Ryszard Klempous holds a PhD and DSc from Faculty of Electronics of WUST. His core research considers an extensive scope of medical systems in engineering practice, including virtual reality rehabilitation platforms.