Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

An integrated System supporting Training in medical and administrative Decision Making in the Emergency Department

B. Spyropoulos, A. Tzavaras, M. Botsivaly, M. Moschidis, K. Koutsourakis

Abstract— **The aim of the present project was the development of an integrated computer-based system supporting Training in medical and administrative Decision making in the Emergency Department. The system comprises of, first, a module supporting on-line acquaintance with Emergency Medical Guidelines, second, a vital-signs monitoring and processing module, and finally an administrative module organizing the most relevant facts about a patient's health status in compliance with the ASTM E2369-0 Standard Specification for Continuity of Care Record, in order to be employed after discharge from the Emergency Care to a hospital ward or to homecare.**

I. Introduction

CONTINUING Medical Education (CME) constitutes a specific kind of education, and nowadays it is a requirement among practicing physicians and nurses to promote continuous enhancement of clinical knowledge to reflect new developments in medical care. Lifelong learning is critical to current physicians who are being held to high levels of accountability to patients, health-care payers, and society at large.

The developed application, aims to support, first, emergency health-care personnel training, through the on-line display of the appropriate medical guidelines for the treatment of a patient in the Emergency department of a hospital, according to the patient's condition.

Second, the system is supporting emergency patient's well-being observation, by performing vital-signs monitoring, and, by employing software means for the processing, the evaluation, and the targeted transmission of the acquired health-data.

Finally, an administrative module is organizing the most relevant facts about a patient's health status in compliance with the ASTM E2369-05 Standard Specification for Continuity of Care Record [1], in order to be employed after discharge from the Emergency Care to a hospital ward, to homecare, or elsewhere.

Thus, all the important issues concerning an Emergency Department Patient, from the triage procedure until the patient's transition to another point of care or discharge, are addressed and appropriately supported.

Manuscript received March 31, 2006. This work is part of a project co-funded by 75% from European Union and 25% from the Greek Government under the framework of the Education and Initial vocational Training Program "Archimedes". This work was also supported in part by the research program "Athena" of the Research and Education Committee of the Technological Education Institute of Athens.

All the authors are with the Medical Instrumentation Technology Department, Technological Education Institute of Athens, 12210 Athens, Greece (Corresponding author's phone: +30 210 5385335; fax: 30 210 5385335; e-mail: basile@teiath.gr).

II. The Emergency Medical Guidelines Module

Commonly accepted European and American Emergency Medical Guidelines [2], [3] are employed in this module that defines the minimum standard of care provided to patients by the First Responders. These protocols define the minimum standard of care to be provided in the Emergency department of a hospital, and the user interacts with the program through its main menu, which gives him the ability to switch to up to thirteen different screens, each one of which reflects a distinct emergency aspect. The first six screens represent the following major emergency categories:

Cardiopulmonary	*Obstetric-Neonatal*
Medical	*Pediatric*
Trauma	*Behavioral-Environmental*

Each screen is divided in three parts. The first part comprises of the *Basic Life Support protocols* for the most common incidents, as a list, from which the user can choose the desired one. The second part encompasses *Advanced Life Support protocols*, to be employed for the advanced life support of a patient. The last part of each screen includes instructions about *specific emergency operations* such as endotracheal intubation, AED etc. Some of these operations are also demonstrated through videos.

The next seven screens support the following important issues:

A. Primary survey of an adult patient through a table that displays the ABCDE assessment *(Airway, Breathing, Circulation, Disability, Exposure)* and the proper management of the patient.

B. Evaluation of the patient status based upon the medical signs and indications and their classification into four categories that is *CPR, unstable patient, potentially unstable patient and stable patient*. The classification is accordingly color encoded (red, orange, yellow and green).

C. Secondary survey of an adult patient *(Head, Neck, Chest, Abdomen, Pelvis, Assessment of the level of consciousness, Extremities, Back)*.

D. Automatic External Defibrillation (AED). The basic screen displays the AED guidelines and gives to the user the

possibility to be informed through a pop-up window with pictures and notes about the proper placement of the paddles of the defibrillator and to watch through another pop-up window the video of an on scene defibrillation.

E. The Simple Treatment And Rapid Transport (S.T.A.R.T) flow diagram, which is used in the event of a Multiple Casualty Incident (MCI). This plan allows for the triage of patients, according to respiration, circulation, and mental status observations. The patients can be are marked with colored tags (Black, Red, Yellow, Green) depending on the severity of their condition.

F. An *interactive drug management screen* based on MS Access 2000 *allowing* for drug administration.

G. The last screen constitutes a typical powerful *patient-record data-entry menu*.

I. The Monitoring and Processing Module

The hardware of the system comprises of, first, a custom-made ECG acquisition module, equipped with a RF link between amplifier and PC, second, a Nellcor finger pulse oximetry probe for typical plethysmography based Oxygen Saturation (SpO2) measurements and the estimation of Heart Rate (HR) and Respiration Rate (RR), and third, another custom-made Carotid Sounds (CS) acquisition module, for the extraction of Heart Rate (HR) and Respiration Rate (RR).

A. The ECG module

The ECG module is designed to acquire Eindhoven I, II or III leads [4]. The system comprises of preamplifier circuit, a band pass active filter in the range of 0.5 -150 Hz, an amplifier, an analog to digital converter, and a microcontroller circuit that collects and transmits digitally and wireless the ECG. The receiver end is composed of a Radio Frequency (RF) digital receiver tuned to transmitter frequency, and a controller that translates digital data to RS232 communication protocol.

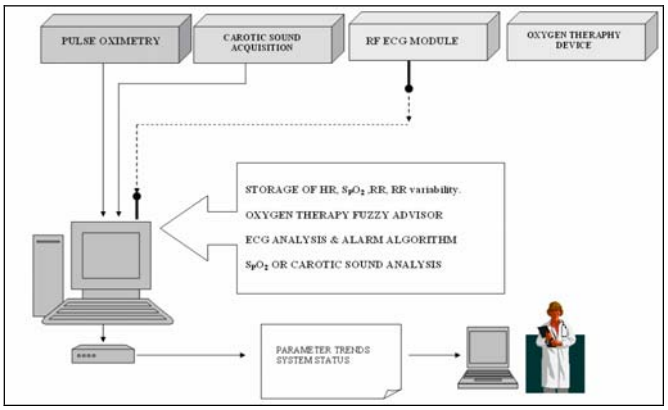

Fig. 1. The overall monitoring hardware block diagram.

B. The Pulse Oximetry module

The Pulse Oximetry module measures non-invasively light absorbance of arterial blood as a basis of determining arterial oxygen saturation. It measures absorbance at two distinct wavelengths: Red light (660nm) and Infrared light (990nm), and distinguish the concentrations of two different absorbers (Hb and HbO2 respectively), as shown in equation 1:

$$S_pO_2 = [HbO_2] / ([Hb] + [HbO_2]) \times 100 \qquad \text{(Eq. 1).}$$

The Ratio of Ratios (R_{OS}) is a variable used in calculating oxygen saturation based on the said two-wavelength Arterial Blood absorbance, and is presented in equation 2:

$$R_{OS} = \ln(R_L / R_H) / \ln(IR_L / IR_H) \qquad \text{(Eq. 2).}$$

Here, R_L and R_H are the maximal and minimal readings of the Red-light intensity, and IR_L and IR_H for the Infrared-light intensity accordingly. The Oxygen Saturation module returns the data to the computer for further processing.

C. The Carotid Sound Acquisition module

The Carotid Sound Acquisition module is based on the arterial blood flow sound waveform, acquired by the stethoscope. The sound is captured with the aid of a microphone fitted to the stethoscope acoustic path, and then directed to the PC sound card input, as shown in Figure 2. Although the system's architecture is simple, and the implementation cost is minimal, the performance is very good, allowing for not only the acquisition of Heart Rate and Respiration Rate waveforms, but, furthermore, full-scale tele-auscultation, in quasi real time mode. Obviously, other irrelevant bodily sounds and external noises may influence the recording.

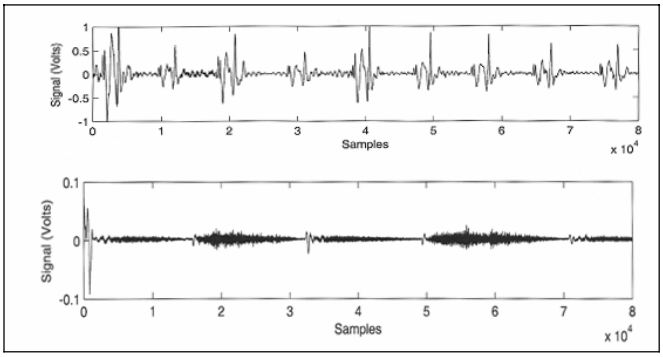

Fig. 2. Heart Rate and Respiration Rate waveforms acquired through the Carotid sound acquisition module.

D. Processing and transmission of the acquired data

The acquired row data are appropriately processed to produce decision supportive data, while they can be easily stored in the home computer and/or transmitted to another location.

The *ECG waveforms* and the corresponding *Heart Rate (HR)* are directly acquired from the ECG module, while the HR can be obtained also directly from the Carotid Sound acquisition module. *Respiration Rate* can also be reproduced directly from the Carotid Sound acquisition module, or be extracted by employing frequency analysis and filtering of the original Photo-plethysmography [5] signal (PPG). PPG taken from finger tip extends from 0.001Hz to 6Hz, with DC

content removed, and the range 0.5 – 2.0 Hz is related to the mean heart rate.

A Fuzzy logic algorithm [6] was designed and implemented, by employing MatLab software, to support Oxygen Therapy management, accepting as input Oxygen Saturation (S_pO_2), the Heart rate (HR), and the Respiration Rate (RR) data, acquired by the described system. As internal indicator of the efficiency of oxygen therapy, Oxygen Saturation over time (dS_pO_2), has been considered, serving as an evaluative factor of the patient's condition. The pulse oximetry module and the associated decision support are employed only if the patient is in need of Oxygen.

The detection of shockable Ventricular fibrillation (VF) and malignant ventricular tachycardia (VT) and the closest responder alerting, for high risk patients, is achieved by employing two different techniques, introduced earlier by some of the authors [7], first, the Image Analysis Technique, according to which the ECG record is considered to be an image and is divided into a number of equal regions of interest (ROI), and second, the Cumulative Probability Distribution Function (CDF) and the coefficient of Skewness (SKEW) CDF-SKEW techniques.

The data transmission can be achieved through wireless point-to-point links, modem and telephone lines on both, landlines and mobile cellular telephone lines, by a designated location through secured paths over the internet and, finally, through satellite communication links.

II. The Administrative Module

The developed system consists of two sub-modules. The first module allows for the creation of a typical Continuity of Care Record (CCR) that contains the appropriate demographic and administrative data, as well as the relevant clinical information, while the second module enables the creation of a care plan which will be included in the Care Plan section of the CCR. The system is intended to be used upon the transition of a patient from the Emergency Department to a ward or to homecare, although the first module alone could actually be used in any case of transition or referral.

The CCR could be described as a standard for an electronic form for patient transfer, referral, and discharge. Rather than a complete patient record, the CCR is designed to provide a snapshot in time containing the pertinent clinical, demographic, and administrative data for a specific patient. It is a way to create flexible documents that contain the most relevant core clinical information about a patient, and to send these electronically from one provider to another or to provide them directly to patients.

The sections forming the CCR include, first, patient and provider information, second, insurance information, and third, the patient's health status that is the recent care provided and recommendations for future care (care plan).

The CCR is designed to be technology and vendor neutral for maximum applicability. It must be developed on the extensible mark-up language (XML) platform in order to offer multiple options for its presentation, modification, and transmission. Through XML, CCR can be prepared, transmitted, and viewed in a browser, in an HL7 - CDA compliant document, in a secure email and in any XML-enabled application.

The widespread use of the CCR will improve continuity of patient care, enhance patient safety, reduce medical errors, reduce costs, enhance communication and exchange of health information and standardize patient care information across healthcare providers. It is actually anticipated that CCR will facilitate and stimulate more rapid Electronic Health Record (EHR) development, as an essential and simple building block. The typical–CCR module can either collect the necessary data from an already installed EHR system, or can allow for the user to enter the data manually by filling special forms. In any case, the user decides which parts of the patient's medical record (electronic or paper) are the most significant ones or are the necessary ones for the description of the current health status of the patient and should be included in the CCR.

The second sub-module allows for the creation of the care plan by creating a structured subset of data, containing the diagnostic, monitoring, treatment, and nursing activities that should be employed during the post-discharge period.

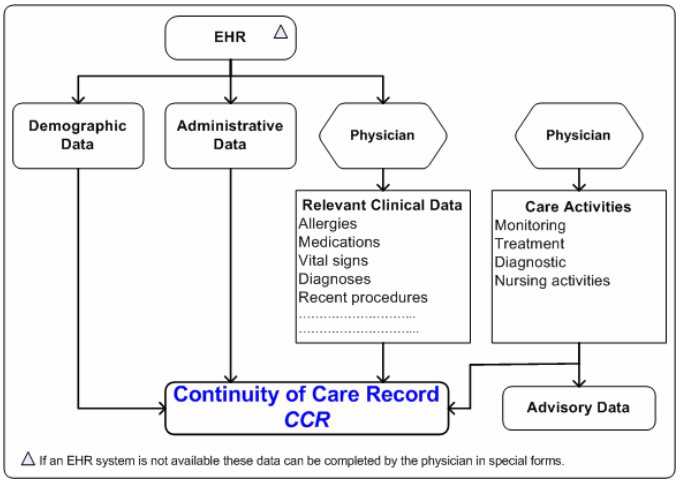

Fig. 3. Flow-chart of the developed system

The developed model allows for every user, i.e. every physician responsible for discharging a patient from the Emergency department, to individually assign an appropriate set of care activities to specific diagnoses codes that are coded according to Diagnosis Related Group (DRG) codification. These activity sets consist of diagnostic, monitoring and treatment activities that can be actually performed in an out – of – emergency – department environment.

During the formation of these profiles the user can attach to each activity a set of nominal fees. This set of fees consists, first, of the official Insurance Agencies reimbursement amount, and, second, by a currently valid financial rate. This later is estimated by a software tool that we have already developed and allows for a rational approximation of the effective mean cost for several

elementary medical activities, over different medical specialties [8], [9]. Thus, the developed system ignites, when relevant, the corresponding revision of an implicitly associated latent financial record that allows for an approximation of the individual case-cost.

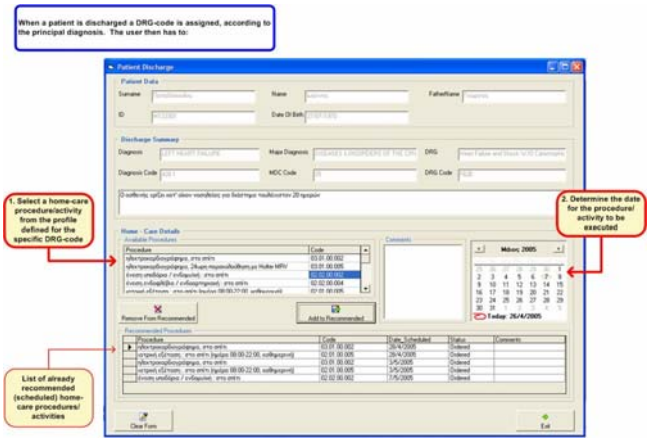

Fig. 4. A typical menu of the developed system allowing for the Care-plan activities selection for a specific patient.

Upon the actual discharge of a patient the physician can use one of the predefined profiles, create a new one or modify an existing one in order to adapt his care profiles to specific instances and to emerging new demands. The scheduled procedures are automatically inserted in the CCR in the section of Care Plan.

In the case of discharge of a patient to home-care, the system, apart from producing, electronically or in paper – format, the CCR, also produces a number of additional forms, including advisory and informational notes for the patient himself or for his relatives and diagrams of physiologic measurements, such as glucose, blood pressure etc. that the patient should monitor. The system also provides for the production of forms that will be filled by the nursing personnel during the care visits in order to document their activities.

The filled forms, both the ones regarding the nursing activities and interventions and the ones regarding the monitoring of physiological parameters, are returned to the responsible physician who evaluates them and, depending on his evaluation, can modify the care – plan of the specific patient in any suitable way.

The structure and data of the produced CCR are complying with the ASTM E2369-05 Specification for Continuity of Care Record, while XML is used for the representation of the data. The XML representation is made according to the W3C XML schema proposed by ASTM [10]. The CCR that is produced by the system is currently automatically transformed to HTML format, using the Extensive Stylesheet Language (XSL), in order to be viewable and printable.

It should be mentioned here that the diagnostic and treatment activities are classified according to International Classification of Diseases Version 9 (ICD9), while the Australian Refined DRGs (AR-DRGs) have served for the case codification, since DRGs are not yet been introduced in the Greek National Health System and the Nursing Interventions taxonomy of the Clinical Care Classification (CCC) system [11] was used for the documentation of nursing activities.

III. Conclusions

The first of the developed modules facilitates the acquaintance with Emergency Medical Guidelines, and offers a simple and helpful method to support the training of emergency personnel. It allows for the retrieving of information necessary during the patient treatment, and finally, provides means for the recording of the incidences.

The on-going testing of the vital-signs monitoring and processing module shows that it is able to contribute to emergency care training, enhancing, also the Emergency Nursing care, through a well-structured Patient Supervision and Treatment approach.

Finally, the introduction of the administrative module based on the ASTM E2369-05 Standard Specification for Continuity of Care Record, and the XML technology, will, first, stimulate the intra-hospital departmental communication and, second, will improve the creation of a structured subset of data, concerning the most relevant facts about a patient's health status.

References

[1]. ASTM www.astm.org : E2369-05, Standard Specification for Continuity of Care Record.

[2]. European Resuscitation Council. www.erc.edu: ERC GUIDELINES AND RESUSCITATION PRACTICE.

[3]. New York State, Department of Health, Bureau of Emergency Medical Services: Guidelines for Basic Life Support First Response (BLSFR).

[4]. Webster J. G., "Design of Pulse Oximeters", Medical Science Series, 2003.

[5]. Kamal A. A. et al., "Skin photoplethysmography – a review", Comp. Methods & Programs in Biomedicine, vol.28, (1989) p 257-269.

[6]. Tzavaras A., Spyropoulos B., Botsivali M., Gatsios K., Koufakis A. Multivariable Fuzzy Logic Advisory System. Proc. of EMBEC 2005 - 3rd European Conf. on Medical & Biological Engineering, Prague, Czech Republic, 2005.

[7]. Botsivaly M., Koutsourakis K. Spyropoulos B. A quasi real time Biosignal Acquisition processing and Transmission System. 4th European Symposium on Biomedical Engineering, Patras, Greece 2004.

[8]. Botsivaly M., Spyropoulos B., Marinis M., Tzavaras A., Koutsourakis K., Sarantakis P. A Software-Tool allowing for Departmental Hospital Operational Cost Estimation. Proc. of EMBEC 2005 - 3rd European Conf. on Medical & Biological Engineering, Prague, Czech Republic, 2005.

[9]. Spyropoulos B, Botsivaly M, Tzavaras A, Nikoloudakis G, Balabanis I, Karagiannis N, Limnou I Acquisition of cost-data for Surgery and Intensive medicine to be employed for drafting a DRGs hospital reimbursement system in Greece. Proc. of EMBEC 2005 - 3rd European Conf. on Medical & Biological Engineering, Prague, Czech Republic, 2005.

[10]. Astm www.astm.org : ADJE2369- Adjunct to E 2369 Continuity of Care Record (CCR).

[11]. Saba VK. Home Health Care Classification of Nursing Diagnoses and Interventions. Washington, DC: Georgetown Univesity, 1994.