Simulation of the Clinical Interactions Among COPD Patients and Healthcare Staff in the Emergency Department

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***Abstract*—Chronic Obstructive Pulmonary Disease (COPD) has become a major and critical cause of death among the elderly with a history of acute pulmonary exacerbation. The aim of this research is twofold: on the one hand to create a conceptual and computational model of the evolution of COPD patients in treatment at the Emergency Department (ED) and, on the other hand, to model the process of evaluation, diagnosis and intervention, made by the ED nurses and doctors responsible for the treatment of COPD patients. The base of simulation we propose to use is the Probabilistic Finite-State Machines method, which applies the training method for the evolution of COPD patients. This method is in front of patient as an actions/treatment applied by healthcare personnel. In addition, the Delphi method applies expert method reasoning for the decision making process carried out by healthcare staff, in order to decide the treatment to be applied to the COPD patients.**

***Index Terms*—Simulation Model, COPD Patient, Pathologies, Emergency Department (ED), Emergency Medical Service (EMS)**

I. INTRODUCTION

In recent decades, governments / academics have been developing applied technology for treating disease progression to control the prevalence of chronic diseases in order to improve public health and increase life expectancy in developed countries. COPD, with its inherent characteristics and gradual lifelong development, reduces independence, culminating in a high level of dependency on self-care activities in its later stage. The patient's low skill in controlling the disease to preserve their autonomy often leads to exacerbation's and subsequent readmissions, which are more common in older age groups. The world currently has a progressively ageing population. The number of the aged between 40-100+ is 2.87B. In Spain, the ageing process resulting from ever longer life spans has been particularly rapid, to the extent that the number of people aged over 65 has doubled in the space of less than 30 years [1].As populations age and live longer, chronic diseases become increasingly prevalent. Elderly persons with complex pathologies and conditions will require multiple sources of care to meet their healthcare needs. They will need to depend on healthcare decision systems that can adequately address and reliably serve their multiple needs. In this case, Emergency Decision Making (EDM) is an effective way to deal with any emergency situation, insomuch as it plays an alleviating role for the loss of attributes and lives caused by an emergency event. Unexpectedly, those responsible for environmental areas have many unplanned decisions and activities to carry out, which has recently been under the attention of governments and academics. When an environmental emergency occurs, EDM plays a key role in mitigating the loss of life and property facing two critical factors: lack of information and time pressure. EDM has become a remarkable topic in recent years. Normally people make decisions based on the potential value of losses and gains. Normally loss and gain properties in emergency situation distinguishing by reference point which the outcome is respect with attributes. In reference to Kahneman and Tversky, psychological behaviors of decision makers show risk-taking tendencies for profit and risk-taking tendencies for losses, meaning that people are more sensitive to losses that have equal profits [2]. To measure the amount of profit and loss, the S-value function is presented in landscape theory, as shown in Figure 1.

In addition, Kahneman and Tversky's law demonstrated value function where x demonstrated the gains with the shape of $x \geq 0$ and losses with the shape of $x < 0$ also α and β are the key point of the gains and losses which are respectively $0 \leq \alpha, \beta \leq 1$ (Equation 1). λ is the risk parameter which represents the a characteristic. In this equation, the values of α, β and λ are equal to 1 [2].

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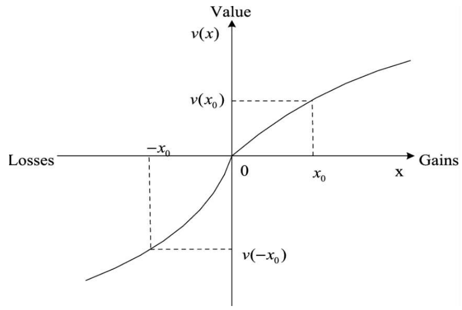

Fig. 1. S-shape diagram as value function according to Kahneman and versky’s law.

$$\upsilon(x) = \left\{ \begin{matrix} x^a, & x \geq 0 \\ -\lambda(-x)^\beta, & x < 0 \end{matrix} \right\} \quad (1)$$

In Spain, the elderly population is increasing rapidly. Simultaneously, the number of COPD patients will continue to rise. So, a large number of COPD patients refers to the medical wards. Reciprocally in EMS and ED, which are highly responsible for managing, caring for treating COPD patients, two major problems are being faced: the first is “resources”, which are very limited in the field of therapy and the second is the “cost function”, which requires more financial resources. The outcome of those challenges impact on COPD patients’ needs as well as on the search for a higher quality of services (QoS). From our point of view, we need to consider two problems: the first is the need for correct time, witch limited in ED and Decision Making capability of the healthcare staff in charge of COPD patients. The second is the need for specific training to acquire these skills. Here is the exact point of problem dominating other services.

This research proposed research objectives in II, the regarding the COPD patients, Exacerbation the COPD. Section III presents the related work. Section IV introduces the decision making support system which is the main part of this article, in order to training nurses and student and help the healthcare personnel to take immediate decisions in front of the patient with high accuracy. The section V, deals with the simulation scenario in the emergency department and nursing activity in an emergency box (triage). Finally, in section VI, we present our conclusion and future work.

II. Research Objectives

The objective of our research proposal is divided into the two important problems described below: 1) The Conceptual Model, which is concerned with the evolution of the COPD patient in the ED, defining several variables which are most relevant to our conceptual model, such as heart rate, blood pressure, skin color (Cyanosis), etc. These variables make up the condition of the COPD patient (cyanosis, accessory muscle, heart rate, oxygen saturation, pulmonary auscultation, x-ray, sputum, temperature, ECG and arterial blood gas).
2) The Computational Model, which is for the decision making carried out by the healthcare staff in training. The target is for training and/or improving the nurse/student’s knowledge

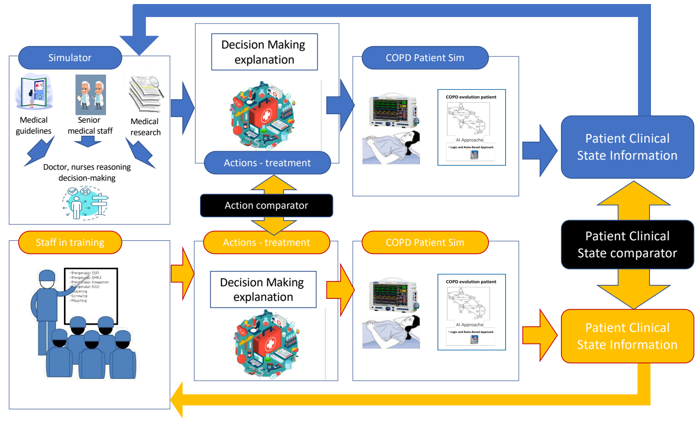

Fig. 2. Decision Making Support System.

in a critical situation, such as in an emergency box, real patient analysis feedback from the simulator, improving the medical knowledge of a junior student, nurse or doctor without much experience in EMS in an ED [3]. For the development of the simulator, the Iterative Spiral Development Model (IDMS) will be followed [4]. Considering the importance for advanced training for healthcare staff working in emergency departments as well as the significance of COPD disease, we propose the design and implementation of a complex system where it would be possible to decide and virtually apply the selected treatment for COPD patients in the ED. This is carried out in two different ways: The first one interactive, for the healthcare staff in training (Area A in Figure 2). The second one involving an automatic decision- making process (an expert and experienced healthcare staff simulator), based on the cooperation of different sources of knowledge (Expert doctors and nurses’ knowledge, scientific publications, medical guides) (Area B in Figure 2).

III. Related Work

Simulation can help us to quantify our model and what we design; we can evaluate our system numerically and it even enables us to reevaluate the system after we obtain feedback from of it. As we work with a conceptual model regarding the COPD patient, we have possibility of considering probabilities in all matters [5]. Clinical simulation is a participant-centered learning technique or method offering better curves than classical learning. Thus, the main limitation for its generalized application is the high cost derived from training in teaching methodology, infrastructure, and the excess time by participants in each clinical activity. On the other hand, computational simulation is a genre that aids student self-evaluation, providing feedback in real-time [3]. This method can carry out simulations at any time and place without a teacher on site, thanks to the possibility of sending messages throughout. The simulation will design for specific COPD patients and our research defines the other exacerbation pathologies which can cause and severity of the COPD pathology as an extensible system. COPD can occur as a result of two matters (Environmental and Genetical). The

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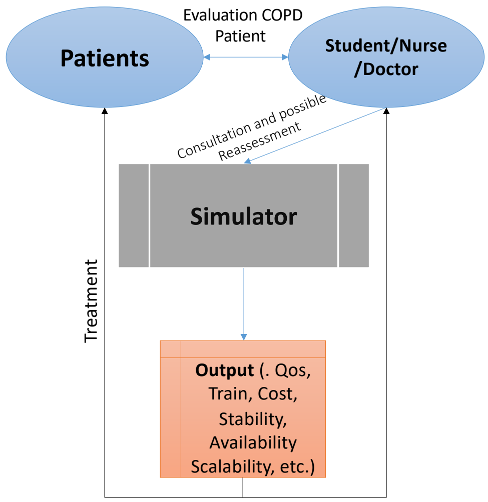

Fig. 3. Evaluation COPD Patient.

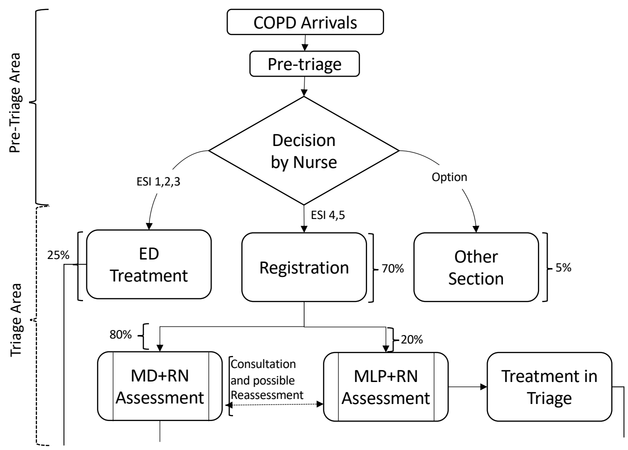

Fig. 4. Pre-Triage and Triage areas.

environmental factor include (defensive cell alternation, alternation anti protease and alternation in the cell that repair the lung). the environmental factor such as (smoking, air pollution and Lung irritants) are a pre-existing diseases background. Our intelligent system can be adopted to all these pathologies and the condition of the healthcare artificial system requirements and regarding the other pathologies as future research work. Figure 3 below shows the connectivity and hierarchy of the target research. The key point of the simulation can be the patient's evaluation, which captured and gathered by the nurse at the level of entry in the ED such as Heart Rate: (59, 60-99, 100), Breath Rate: (11, 12-19, 20) Oxygen Saturation: (80, 81-89, 90-95, 95), Temperature: (36-37.4, 37.5-37.9,38). This data departure to the simulator and user in front of the simulation system can learn and used in cooperation with a comprehensive data base, which regards the patient's various variables and can assist simulation to achieve better decision-taking for the COPD patient's treatment.

In short, a learning process which facilitates online training for both students and professionals is a unique idea which is intended to design a training simulator for students/professionals which can further enhance the learning curve. It also takes into account the fact that today we are living in a pandemic where capacity limitations, mobility, etc. are moving academic training towards a more digitized environment given that clinical simulation is affected by the difficulty of carrying it out.

IV. Decision making support system in ED

The objective of the proposed" Decision-Making Support System" is to simulate the technical behavior of the experienced (highly-trained) healthcare staff of the Emergency Department (doctors/nurses), for the diagnosis and treatment of COPD patients. Our "Decision-Making Support System" is an Expert System (ES) designed with the abilities to reason and think like experienced healthcare staff, using rules, in the diagnosis and treatment of COPD patients. As an Expert System, in our" Decision-Making Support System" we can identify the following main components:

- Knowledge Base
- Inference Engine
- Explanation Facility

The Knowledge Base includes and integrates different sources of knowledge, as well as experience of doctors and nurses, COPD related scientific publications and COPD medical guides.

V. Proposed method and simulation

This section introduces a new simulation scenario based on a proposed theory that can consider decision, triage area, simulation area and treatment area. Pre-triage and Triage areas are shown in Figure 4. Whenever the COPD patient arrives in the Pre-triage area, the duty of Triage Nurse (TN) is to classify the patient into one of five levels of the Emergency Severity Index (ESI), depending on pathology exacerbation [5]. The TN and Medical Doctor (MD) then fully reassess the treatment for the patient. In the simulation area, the base information to simulate will be the patient evaluation data taken on arrival at the ED.

This simulation has two critical aspects in relation to the training part and the expert part. Figure 5 shows the simulation area and the treatment area in the ED.

Training Part: the Triage Nurse (TN) has to classify the patient into one of five ESI levels, depending on the pathology's exacerbation [6]. In this section there can be active/interactive COPD patient simulator. This activity is based on the conceptual model formed by:

Input: patient condition / Actions – treatment.

Output: patient condition after Actions-treatment.

Operation: Evolution of the patient's condition.

Expert Part: We propose using a Rule Based Approach for modeling the patient's condition analysis and the decision process for the treatment to be applied, the reasoning for the decision making process of the healthcare staff, for deciding/elaborating the actions/treatment applied to the COPD patients. The simulation is based on the "Delphi method" for "integrating" the expert's knowledge. Whenever the user has

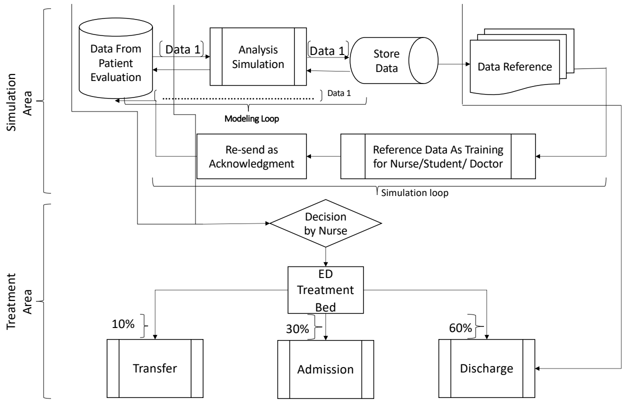

Fig. 5. Simulation and Treatment Area.

any doubt, they can use the data reference as a simulation loop. The data can be transferred as a pull notification. The Input variable of the simulation is the patient's clinical condition information and the output can be actions/ treatment, whose operation is based on the "Data base knowledge", processing the "Input" to generate the "Output".

VI. Conclusion and Future work

This research is based on the conceptual model (Qualitative) and the computational model (Quantitative) which explores the conditions for the implementation of simulating, based on COPD intervention. As initial work, and to guarantee the suggested model runs well, implementing a computational model in the near future. In addition to this, we would implement the conceptual model in order to generate a model as complex and as realistic as possible, in a long term professional period, we would use such a simulator to help and improve the quality of the medical services, in order to enhance student/nurse knowledge. This research could have an interesting potential in gathering/connecting some pathologies relevant to COPD and testing by healthcare professionals for stability, scalability and reliability of the system.

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