A Heuristic Rule-Based Approach for Monitoring of Hemodynamic Data in Cardiothoracic Intensive Care Unit

Rabiah A.Kadir[1], Abdul Rahman Ali Ali Al Maweri[1] and M. Zamrin Dimon[2]

[1]*Universiti Putra Malaysia, Malaysia, rabiah@fsktm.upm.edu.my, mawertigers@yahoo.com*

[2]*Universiti Kebangsaan Malaysia, Malaysia, drzamrin@gmail.com*

ABSTRACT

Patients in Cardiothoracic Intensive Care Units (CICU) are physiologically weak and require watchful monitoring and support. Such monitoring generates massive amount of data that enable early detection of changes in the patient's condition and provide information that help medical staff to give the treatment and evaluate the response to medical interventions. The countless data gathered from monitoring systems and clinical information systems have created a challenge and are time consuming for clinicians to analyze. This paper discusses the implementation of an intelligent system that has been designed to improve interpretation of clinical data which will then increase the quality and efficiency of the working environment in CICU. The implementation is based on the description state from the cardiologist. This research work extends the cardiologist approach by providing the heuristic rules-based approach to address the treatment. The system is intended to help physicians and CICU staffs to diagnose and track the conditions of patients.

Keywords: Intelligent Computing, Hemodynamic Monitoring System, Decision Support System

I INTRODUCTION

Health care professionals often rely on their knowledge and experience together with observations and measurements to make clinical decisions. A successful decision depends on precise monitoring and effective methodology to detect physiologic events in patient's vital cardiovascular hemodynamic parameters and interpret them into a machine useable form. Cardiothoracic Intensive Care Units (CICU) patients are physiologically weak and require watchful monitoring and support. Such monitoring generates massive amount of data which enable early detection of changes in the patient's condition and provide information that can help medical staffs give treatment, and help evaluating the response to medical interventions.

The countless data which are gathered from monitoring systems and clinical information systems were challenging and time consuming for clinicians to analyze, and the problem of information overloading will become more and more serious (Braga et. al., 2005; Janice, et. al., 1982). Therefore, these factors and others may cause errors in patient care because they cannot assimilate and interpret such large volume of data.

For reducing medical errors and improving the quality, safety and efficiency of health care, CICU data area managed in a more systematic way, and represent the patient's conditions as a set of parameters that will increase the quality and efficiency of the working environment in CICU. Intelligent system has the capability to perform these functions which are normally associated with human intelligence, such as reading and saving data, and prepare them punctually for decision making. Other than that, it can also give suggestions that are helpful and can be optimized through experience. Successful intelligent systems will combine facts, merge them with human knowledge, and are supported by computers to solve the problems.

In this work, an intelligent system was designed and implemented to interpret CICU hemodynamic data and trained to give a list of medicine suggestions. The system is also intended to help physicians and CICU staff to diagnose and track the conditions of patients.

This paper is organized as follows: Section 2 describes the hemodynamic monitoring and related works in this study. The proposed heuristic rule-based system is presented in the following section 3. In section 4, the intelligent suggestion methodology is illustrated based on input of hemodynamic data. Finally, conclusions and future research directions are presented in the last section.

II HEMODYNAMIC MONITORING AND RESEARCH BACKGROUND

Hemodynamic means "blood movement". It is the study of blood flow on the circulation. Hemodynamic monitoring directly measures blood pressure from inside the veins, heart, and arteries. It also measures blood flow and the amount of oxygen in blood. Samples of blood from deep inside the body can be analyzed. The difficulty of evaluating cardiac performance is reflected by the number of hemodynamic parameters, which are thought to be indicators of myocardial function. The heart, vessels and lungs are all actively involved in maintaining healthy cells and organs, and all influence hemodynamic.

Many treatments and medical interventions depend on recognizing small changes in the way the heart works. Changes in blood pressure or blood flow which occur deep inside the human body will take time to become visible. Hemodynamic monitoring helps to predict the state of patient condition either he/she needs blood or fluid transfusions. It shows whether the lungs are getting enough oxygen and checks how well the heart is pumping by measuring the total flow of blood per minute. This is very important for some patients who need to have surgery or critical attention in CICU. Time appears to be crucial for an early diagnosis of hemodynamic catastrophe and earlier therapy appears to improve outcome in this situation.

The most important aspect in monitoring the critically ill patient is the detection of life-threatening derangements of vital functions and evaluating the patient's immediate response to the treatment such as drugs and mechanical support. Therefore, ongoing development in monitoring techniques on knowledge of pathophysiological processes associated with critical illness is needed.

Physicians in CICU may face information overload, in dealing with very large, complex, and ever-changing quantities of clinical data, which often lacks efficient organization. It is often challenging and time consuming for them to analyze such massive information loads. The information overload leads to errors and mishaps in giving a treatment in CICU. There are occasional tragedies, most of it which are due to human error.

There are some medical expert systems that had been done in hemodynamic monitoring such as MYCIN, which was an early expert system developed over five or six years in the early 1970s at Stanford University (Bruce, 1984). MYCIN operated using a fairly simple inference engine, and a knowledge base of 600 rules. It would query the physician running the program via a long series of simple yes/no or textual questions. It provided a list of possible culprit bacteria ranked from high to low based on the probability of each diagnosis, the reasoning behind each diagnosis and also recommended course of drug treatment. MYCIN also list the questions and rules which led it to rank a diagnosis in a particular way. This is then followed by other systems with difference functions, capabilities and different intelligence approaches to solve the problem such as PUFF, developed in 1979 using the EMYCIN shell to interpret measurements related to respiratory and identify pulmonary disorders, ILIAD in 1990s, operates in two modes: as an expert consultant to teach differential diagnosis and as a knowledge-based patient case simulator to teach and test medical problem (Chang, et. al., (1993). In 1999, HELP was the first hospital information system to collect patient data needed for clinical decision-making and at the same time incorporate a medical knowledge base and inference engine to assist the clinician in making decisions (Korsakas, et. al., 2006).

In this research the hemodynamic parameters are used intelligently to predict the state of the patient's condition. Table I shows the hemodynamic parameters and its normal range.

Table 1. Hemodynamic Parameter and the Normal Range.

NO.	Name	Code	Normal Range
1	Systolic Blood Pressure	SBP	90 to 160 mm Hg
2	Diastolic Blood Pressure	DBP	55 to 110 mm Hg
3	Cardiac Output	CO	2.2-6 L/min
4	Stroke Volume	SV	60 to 90 ml
5	Heart Rate	HR	50 to 90 beat per minute
6	Central Venous Pressure	CVP	5 to 12 cm H2O
7	Mean Arterial Pressure	MAP	60 to 90 mm/Hg
8	Cardiac Index	CI	2.2 to 4.4 L/min/m2
9	Stroke Volume Index	SVI	33–47 mL/beat/m2
10	Pulmonary Artery Occlusion Pressure	PCWP	10–15 mm/Hg
11	Systemic Vascular Resistance	SVR	900–1200 dyn·s/cm5
12	Pulmonary Vascular Resistance	PVR	100–200 dyn·s/cm5
13	Oxygen	SP O2	90 to 100
14	Respition	RESP	8 to 22
15	Haemoglobin	HB	11 -18 form male / 9-13 female
16	Rhythm:	RHY	((SR / ST))
17	Suhu - Temp	TEMP	32-37.5
18	BLOOD LOSE	BLood_lose	5ml/kg/hr
19	URINAT	urinat	1ml/kg/hr

Physicians in CICU may face information overload, in dealing with very large, complex, and ever-changing quantities of clinical data, which often lacks efficient organization. It is often challenging and time consuming for them to analyze such massive information loads. The

information overload leads to errors and mishaps in giving a treatment in CICU. There are occasional tragedies, most of it which are due to human error.

Currently, the research is a Fuzzy Decision Support system for therapy administration in Cardiovascular Intensive Care Patients in 2009 (Mouloud, et. al., 2009). A fuzzy logic based decision support system was proposed for the management of post-surgical cardiac intensive care unit (CICU) patients. The decision support system includes an input module to evaluate the patient's hemodynamic status, a diagnostic module which implements the expert decision-making strategies and a therapeutic module which incorporates a multiple-drug fuzzy control system for the execution of the therapeutic recommendations.

In their work, the decision levels were linked to five important components of the cardiovascular physiology which are the systolic blood pressure (SBP), central venous pressure (CVP), systemic vascular resistance (SVR), cardiac output (CO), and heart rate (HR). Their progress was dependent upon the normalization of each physiological parameter to a value pre-selected by the clinician via fluid, chronotropes or inotropes. The decision support system was tested on a physiological model of the human cardiovascular system. This model was able to reproduce conditions experienced by post-operative cardiac surgery patients including hypertension, hypovolemia, vasodilation and the systemic inflammatory response syndrome (SIRS). The proposed CDSS has been designed with a sufficient degree of flexibility to allow future extensions to be made gradually to enhance its functionality and performance. Because of its modular structure, the CDSS can be easily configured to accommodate a larger number of monitored variables.

However, this research analyzes the medical knowledge which is required for formulating decision models in the domain of hemodynamic monitoring data using heuristic rule-based approach (Buchanan and Smith, 2007; Tuncel, 2007) to solve the medical decision problems in CICU. On top of that, the proposed approach is able to determine the best medicine to the patients with the flexibility of parameters and also able to provide alert signal for abnormal cases which is not provided in the previous medical decision support system.

III A HEURISTIC RULE-BASED FOR HEMODYNAMIC MONITORING DATA

The proposed methodology of the decision support system for hemodynamic monitoring data is heuristic rule-based to solve the medical decision problems and to determine the best medicine to the patients, which have much flexibility of the parameters such as BP, HR, MAP, and SPO2. This approach utilizes heuristic rule statements to detect special parameters which can cause low blood pressure. On top of that, we need to evaluate the hemodynamic data, discover all the abnormal parameters, and give the medicine suggestions based on the specific parameter. Whereas, the part routing control system aims to handle an abnormal status.

All the rules are collected from the cardiologist before it can be implemented to the system. This collection of rules will be as a historical rule and being referred by the system before the decision or medicine suggestion has been made. Figure 1 shows the flow of decision support system for monitoring hemodynamic data in CICU.

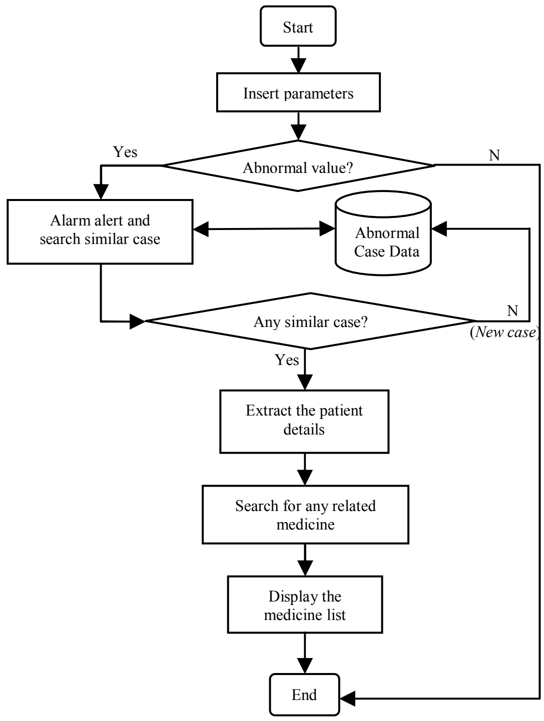

Figure 1. Flowchart Diagram of Intelligent DSS for Monitoring Hemodynamic Data in CICU.

The proposed approach also has been modeled with an alarm system to give an alert signal for low blood pressure. For example, the system will detect if there is any low blood pressure case. If the system discovers any abnormal parameters such as low blood pressure, an alarm will be run automatically and search any similar cases that can be a guideline to provide the medicine. Otherwise, the system accepted all parameters and store to the database.

Then, the objects and rule statements look for the similarity between abnormal parameters and medicines to design the decision support system. A set of production rules in the form of "IF..... THEN....." statements have been constructed based on the heuristics to assign the right medicine to the patients. The matching of rule IF portions to the facts can produce inference actions. Thus, it provides a computerized support to the user so that the decision is taken after checking the normal range of each hemodynamic monitoring data. A production rule, which is means of expressing reasoning links between facts, expresses the condition of patients in the system of interest.

IV GUI OF THE INTELLIGENT SYSTEM FOR HEMODYNAMIC MONITORING DATA

GUI provides interactivity between users and the system. It contains several interfaces such as shown in Figure 2 which is a form to input the hemodynamic data of each patient at specific time intervals. As an intelligent system for hemodynamic monitoring data, by pressing the button 'submit' to insert the abnormal status in the comparison table, then followed by pressing the button 'give suggestion' to get some suggestion using heuristic rule-based, the system is capable of suggesting the medicine that should be given to the patient as shown in Figure 3.

Figure 2. **Form to Input the Hemodynamic Data**.

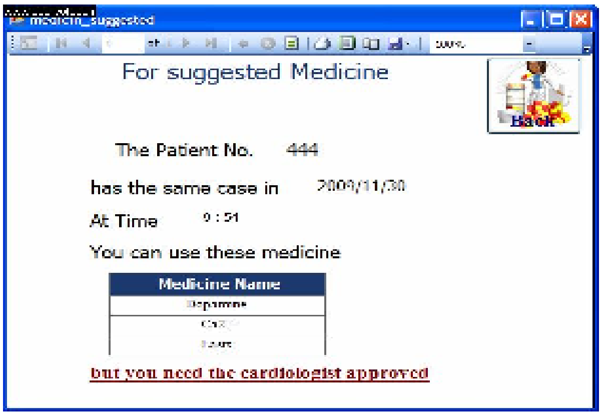

Figure 3. **Suggestions Interface for Abnormal Cases**.

V CONCLUSION

In this work, the system has been developed which provides an option to the users to deal with hemodynamic data by just inserting data, and the system will process all the functions including the suggestion on the medicine to be given. This intelligent system has the potential to improve the efficiency, accuracy and timeliness of clinical decision-making in CICU. The system is also capable of triggering an alarm for abnormal cases and using heuristic rule-based to give suggestion to the CICU staff that they may aid clinicians in optimal care. For further research, the system could be embedded to ECG digital machine in monitoring the state condition of patient in CICU.

REFERENCES

Braga, F., Forlani, C., & Signorini, M.G. (2005). Knowledge based home monitoring system for management and rehabilitation of cardiovascular patients. Computers in Cardiology, pp. 32-41.

Bruce, G.B. (1984) Rule Based Expert Systems: The Mycin Experiments of the Stanford Heuristic programming Project. *Addison-Wesley*,

Janice, S.A.., John, C.K., Edward, H.S., & Kobcrt, J.F. (1982). PUFF: An Expert System for Interpretation of Pulmonary Function Data. Report No. Stan-CS-82-931, Stanford University.

Chang, P.L., Yu, C.L., Wu, C.J., & Huang, M.H. (1993). Using ILIAD System Shell to Create System for Differential Diagnosis of Renal Masses. *Journal of Medical System*, Springer Netherlands, pp. 289-297

Korsakas, S., Vainoras, A., Lauznis, J., Markovitcs, Z., Gargasas, L., Markovitc, I., Poderys, J., Jurkonis, V., Ruseckas, R., Miskinis, V., Juodenas, G., Balodis, G., & Strelcs, V. (2006). The remote mobile monitoring system for patients with cardiac risk.

Mouloud, D., Mahdi, M. & Ross, J. J. (2009). A Fuzzy Decision Support System for Therapy Administration in Cardiovascular Intensive Care Patients. IEEE Xplore.

Buchanan, B. G. & Smith, R. G. (1988). Fundamentals of Expert Systems. Annual Review of Computer Science, 3:23-58.

Tuncel, G. (2007) Multiprocessor Scheduling: Theory and Applications; A Heuristic Rule-Based Approach for Dynamic Scheduling of Flexible Manufacturing Systems. Austria, pp.436-443