2012 International Conference on Advanced Computer Science Applications and Technologies

An Intelligent Hybrid Hemodynamic Data Monitoring for Post-Cardiac Surgical Patients

Abdul Rahman, A.[1], Rabiah, A.K.[1], Md. Nasir S.[1], Lilly S.A.[1], Zamrin, M.D.[2], Joanna O.S.M.[2]

[1] Faculty of Computer Science and Information Technology, University Putra Malaysia
[2] Cardiothoracic Intensive Care Unit, University Kebangsaan Malaysia Medical Centre.

Abstract

Cardiothoracic Intensive Care Units (CICU) patients require vigilant watchful and very strict monitoring of their conditions in real time. Accurate observation is required through bedside monitoring devices which generates massive amounts of data. Such a countless of data which reflect the cardiovascular system and its physiological components pose a lot of difficulties, challenges and is time consuming to the clinicians and health care professionals who are required to interpret and analyze such an overload of information which could cause errors in patient care which could prove fatal. Patients admitted to CICU are characterized by periods of hemodynamic instability and management of these patients requires prompt and accurate therapeutic diagnosis in order to avoid serious complications. This paper describes the design and implementation of an Intelligent Hybrid Hemodynamic Data Monitoring (IHHDM) to overcome such difficulties and to help medical experts in making appropriate decisions. The system has the capability to perform the functions which are normally associated with human intelligence in providing accurate diagnosis and to determine the suitable therapy and specific dosages of drugs administered to the patients. This will increase the quality and the efficiency of the working environment in the CICU, reduce medical errors which may result in suboptimal patient care, and enhance the usefulness of medical sciences.

Keywords

Intelligent Hybrid Hemodynamic Data Monitoring (IHHDM), Cardiovascular System (CVS), Cardiothoracic Intensive Care Units (CICU), Hemodynamic Data, Case Base Reasoning(CBR), Data Minig (DM), Case- Base Memory.

I. INTRODUCTION

The role of knowledge-based systems and computing has been historically marked in the field of medicine because of recent advances in technology, and the spread of knowledge over data. Not only this but also our understanding of medicine and diseases has grown along with the emergent challenges in effective diagnosis, planning, and treatment consists of a proportionate integration of domain knowledge and data. The main goal of expert system technology is to realize the integration of human expertise into computer processes. This integration not only helps to preserve the human expertise but also allows humans to be freed from performing the more routine activities that might be associated with interactions with a computer-based system.

The scope of IHHDM is in the medical field especially in cardiovascular system. Cardiovascular disease has long been the leading cause of death in advanced countries, and quickly became the number one killer in developing countries. Depending on the problem at hand, this integration is harnessed through the science of "intelligent computing" to enhance the quality of care for a selected group of CICU patients.

A. HEMODYNAMIC MONITORING

Hemodynamic is defined as the study behind the forces involved with blood circulation. Hemodynamic means "blood movement". It is the study of blood flow on the circulation [1]. Hemodynamic monitoring directly measures blood pressure from inside the veins, heart, and arteries. It also measures the blood flow and how much oxygen in blood. Monitoring hemodynamic data helps predict if you will need blood or fluid transfusions. It shows whether the lungs are getting enough oxygen or not. It checks how well the heart is pumping by measuring the total flow of blood per minute [2]. Hemodynamic studies require techniques that provide accurate data. Using bedside monitoring devices like Electrocardiogram (ECG), invasive hemodynamic monitoring, minimally invasive and non-invasive hemodynamic monitoring devices generate a massive amount of data which reflect the cardiovascular system and its physiological components and provide the most commonly used hemodynamic parameters which are used in making clinical decisions.

The difficulty of evaluating cardiac performance is reflected by the number of hemodynamic parameters, which are thought to be indicators of cardiovascular system functions [3]. Clearly 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 occur deeply inside the human body. It may take some time to show the changes to appear at the body surface. Correcting problems early may prevent complications. This is very important for some patients who need to have surgery and for some patients in CICU. So, it is a very important aspect, in monitoring the critically ill patients, is detection of life-threatening

978-0-7695-4959-0/13 $25.00 © 2013 IEEE
DOI 10.1109/ACSAT.2012.83

derangements of vital functions, and then to interpret, and be able to make best decisions. The most commonly used hemodynamic parameters which are used in making clinical decisions are serial hemodynamic parameters (blood pressure, heart rate, central venous pressure, etc.) and laboratory blood tests (arterial blood gas, haemoglobin, coagulation profile, renal profile, and liver function test, etc.) which included in Table 1 which shows the most common variables and their normal range in our research. These variables are the necessary requirements and data which are needed in our study. By liaising with physicians, experts in University Kebangsaan Malaysia Medical Center, and CICU staff, these parameters along with the demographic data of the patient are considered enough to achieve all the demanded objectives.

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	Mean Arterial Pressure	MAP	60 to 90 mm Hg
4	Heart Rate	HR	50 to 90 beats/min
5	Central Venous Pressure	CVP	5 to 12 cm H_2O
6	Oxygen saturation	SpO_2	90 to 100%
7	Temperature	Temp	36.5 - 37.5 (^{o}C)
8	Haematocrit	Hct	39 – 52 (%)
9	Haemoglobin	Hb	Male: 11 - 18 g/dl Female: 9 -13 g/dl
10	Platelet count	Plt	150 – 400 X10^9/L
11	Prothrombin time (INR)	PT(INR)	2.4 – 4.0 (ratio)
12	Activated Partial	APTT	0.89 – 1.32 (ratio)
13	Random Blood Sugar	RBS	4.0 – 7.8 mmol/L
14	Urea	Urea	2.5 – 6.4 mmol/L
15	Creatinine	Creat	Male: 62 – 106 µmol/L Female: 44 – 80 µmol/L
16	pH	pH	7.350 – 7.450
17	Partial pressure of carbon	PCO_2	35.0 – 48.0 mm Hg
18	Partial pressure of oxygen	PaO_2	83.0 – 108.0 mm Hg
19	Base excess	BE	(-5 to +5) mmol/L
20	Bicarbonate	HCO_3	22 – 26 mmol/L
21	Oxygen saturation	SaO_2	95 – 99 %
22	Blood loss	Bld loss	> 5ml/kg/hr
23	Urine output	Urine	> 1ml/kg/hr

Table 1 shows the parameters and their normal range.

B. EXPERTS AND EXPERT SYSTEMS

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 abnormal physiologic events and changes in patient's vital cardiovascular hemodynamic parameters. These changes and events reflect the amount of data which need to be interpreted and analyzed by experts. So, these changing, constantly, and countless data has created a challenging and time consuming for clinicians, and health care professionals in patient care. The problem of information overloading will become more and more serious, and may cause errors in patient care because the health care workers cannot assimilate and interpret such large volumes of data. This data (hemodynamic parameters values) enables early detection of the patient's condition and provides information that contributes to the management of patients and evaluation the response to medical interventions. For this reason, CICU data should be managed in a more systematic way to help physicians and CICU staff to track the conditions of patients, and represent the patients' conditions as a set of parameters in an intelligent system. The system should have the capability to perform the functions which are normally associated with human intelligence. The medical knowledge which is required for formulating decision models in the domain of hemodynamic monitoring data is analyzed. Based on such analysis, an Intelligent Hybrid Hemodynamic Data Monitoring (IHHDM) is developed. The system is able to make decisions and give suggestions that can help and optimize through experience. The knowledge base of the research is obtained and still in updating and renewing according to the objectives and improvements that the domain environment toward to accomplish. Any abnormal case would insert into the data base, would be a helpful and useful case for the system through which it can learn and give suggestions or advise that they may aid clinicians in optimizing care or they can help in save one's life.

II. RELATED WORK

In 2002, Saeed, M., et al., a multi-parameter intelligent monitoring for intensive care [4] (MIMIC II) database was developed. MIMIC II was a massive temporal database which archived from intensive care patients. It is a relational clinical database that could be important resource to provide detailed information for intelligent patient monitoring researches and could support efforts in discovering knowledge by using data mining techniques.

In 2003, Bauernschmitt, R., et al., a Fuzzy-Logic Based Automatic Control of Hemodynamics [5] was constructed to build multiple-input-multiple-output fuzzy-logic controller, which is able to match the process of clinical decision making. In their work, all possible combinations of four standard hemodynamic parameters (mean arterial pressure, on-line cardiac output, central venous pressure and systemic vascular resistance) and four treatment regimens (fluid administration, noradrenalin, dopamine and nitrates) were linked by knowledge-based rules in a fuzzy-logic system. The system proved to be able to observe and handle any cardiocirculatory disturbances in circulatory models and animal experiments. The system remained stable throughout any observation period. Hemodynamic changes and therapeutic interventions were documented in an electronic experimental record. In several attempts for automatic therapy control in the past, failures were mainly due to insufficient computer capacity, inadequate sensors and the lack of appropriate mathematical models. Case-Base Reasoning (CBR) technique will be used to avoid the lack in the mathematical models which is considered one of the main disadvantages. CBR solves new problems by adapting solutions that were used to solve old problems. CBR is attracting attention because it does not require an explicit domain model and so elicitation becomes a task of gathering case histories, and implementation is reduced to identifying significant features that describe a case, an easier task than creating an explicit model.

In the late of 2008, Denai, M., et al., a fuzzy logic-based decision system [6] used along with genetic algorithm in design an expert system to designate the appropriate therapeutic actions and for adjusting the fluid drug infusion rates to maintain the hemodynamic variables at specified target band. In his work, he had depended on 5 hemodynamic components of the cardiovascular system which are SBP, CVP, SVR, CO, HR. Not only this, but also their progress was dependent upon the normalization of each physiological parameter to a value pre-selected by the clinicians who enter the target value for every abnormal component via fluid, chronotropes or inotropes. Their 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 septic shock the systemic inflammatory response syndrome (SIRS). The fuzzy system did not put in consideration the demographic data of patients, and assumed all patients to weight 75 kg. For all these reasons, the Intelligent Hybrid Hemodynamic Data Monitoring (IHHDM) is developed to be able to match the process of clinical decision making very closely and to give the possibility to include additional physiological components and their rules (more than 24 parameters) which would be also able to handle any form of cardio circulatory disturbances in CICU. And the need of clinician's interactions will be to approve the suggestions and dosages.

III. DATA AND INTELLIGENCE TECHNIQUES

Data was collected for every patient admitted to CICU. Each patient record commenced with the demographic data and ended with final discharge from CICU. Every record is consisted of objects which are more than 55 attributes at the moment the data collected. They can be grouping in different group such as demographic data (patient No., Age, weight, height, etc), hemodynamic or physiologic parameters (systolic blood pressure (SBP), diastolic blood pressure (DBP), main arterial pressure (MAP), central venous pressure (CVP), heart rate (HR), etc), laboratory tests (haematocrit (Hct), random blood sugar (RBS), Urea, bicarbonate (HCO3), etc), blood products (Whole blood, Fresh frozen plazma, Platelet concentrate, etc), medications (actrapid, dobutamine, GTN, KCL, Morphine, etc) and their dosage, but when they present the case they come in one record or considered as one case. These objects (their values) were originally sourced from bedside monitoring devices and from the related documents. With the assistance and cooperation of the CICU staff, all the fields ware filled and missing values were avoided. This data was then transmitted to the case-base memory. In such way our case-base memory was seeded with significant problems and their solutions. By utilizing nurse-verified measurements, records or cases were interested with their successful solutions into the system's case-base memory. These measurements are recorded every 15, 30, or 60 minutes depends on the time of the patients admit to CICU. These objects are recorded every 15 minutes for the first 4 hours, then they were recorded every 30 minutes for the 5th and 6th hours, finally they were recorded hourly for the rest of time during the length of patient stay in CICU. Because clinicians are depend on their prior experience in the absence of strong guidelines to make their decisions, a case base reasoning will be used to fulfill this purpose.

These data and information will be processed by using Data Mining (DM) techniques to extract the association rules among all these attributes to discover the more significant attributes and to enrich the knowledge base in our system. the post-operative patients in CICU are an ideal population for clinical data mining investigating because the relationship between the treatment interventions that patients receive and the clinical out-come still unproven, and this will lead to find out the association rules that will help in enhancing the intelligence of the system.

IV. SYSTEM COMPONENTS & METHODS

The Intelligent Hybrid Hemodynamic Data Monitoring (IHHDM) includes two building blocks: a classification module and a therapy module which interact with the patients' data and clinicians as shown in fig 1. The conceptual topology of the IHHDM shows that the interaction between these two modules is coordinated depends on the current case which is generated in classification module.

A. CLASSIFICATION MODULE

This block receives the patient data, the input variables are classified into linguistic levels for each variable (low, medium, and high). Medium means the input numerical data is within the normal range of physiological component. Decision rules (rule-base approach) will be applied to determine the level of each variable as it is shown in fig 2.

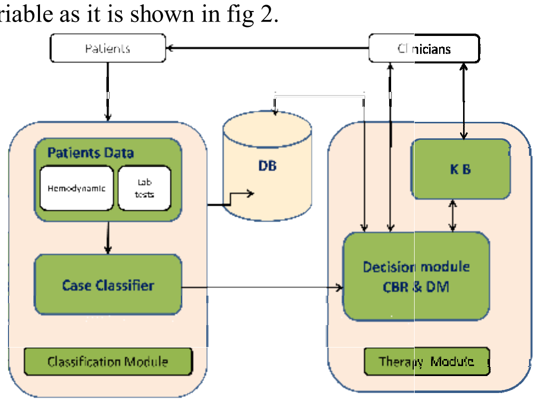

Fig 1 The topology of (IHHDM)

Next, the linguistic terms for each hemodynamic parameter can be combined with all other abnormal ones to generate a case. The current case will include information for the patient (e.g. demographic, hemodynamic parameters, and laboratory measurements) which include just the abnormal range (high or low) for each variable. The indices are assigned to the case to facilitate their retrieve depends on the variable itself and its level, and they are abstract enough to allow widening use in future. The case will be generated regularly and automatically every time input data received. Then the case will be send to the therapy module to make the suitable decision. An example for the case which represents the problem case is shown in fig 3.

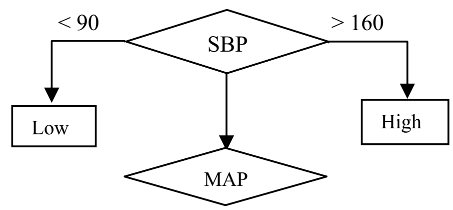

Fig 2 decision rules related to SBP

Patient's demographic data	Indices assigned to the case

Fig 3 shows represented problem case

B. THERAPY MODULE

Base on the current case received from the case classifier in the classification module, this block performs the process of finding the suitable solution. Because of the lack of sufficient information for the mathematic model the Case Base Reasoning (CBR) technique is applied in this block to find the similar case and to suggest solutions depends on the history of similar cases. The new problem which is considered the current case might be matched against the cases in the case-base memory, and one or more similar cases are retrieved by different retrieving algorithms (knowledge guided induction & template retrieval which combined into hybrid retrieval strategies) using the indices in the case memory to match the indices in the current problem. The solutions will be suggested by the matching cases, unless the retrieved case is closely similar. The retrieval algorithm relies on the indices and the organization case-base to lead the search to the most useful cases which is best similar to the current case. In such cases, the solution will probably have to be approved, disapproved, or modified from the specialists to be retained in the case-base as a new solution, or to be avoiding in future when the solution is disapproved. Database technique can be used to find exact similarity and giving the accurate solution. Fig 4 shows the cases which comprise problems and their solution in the case-base memory.

Patient's demographic data	Indices assigned to the case	Solutions	Approved / Disapproved

Fig 4 shows cases with solutions

V. Conclusion

Postoperative intensive care patients are facing periods of hemodynamic instability because of the volume shifts from intravascular to the extravascular space, generation of vasoactive mediators, myocardial reperfusion, or hypertension. Usually all these problems can be solved easily if they are diagnosed early, but often the attention of the intensive care physician and continuous medical support are required for unstable patients.

Clinician decision-making in the absence of the good interpretation and analysis for the hemodynamic data where there is no strong guidelines is frequently driven by prior experiences which particularly common phenomenon in medical side. The proposed IHHDM in this paper is developed to support intensive care by anticipating and counteracting alterations of the hemodynamic parameters before circulatory instability occurs. It is intended to improve the quality of medical decision making and to remove the workload from nurses and specialists to give them more time to treat the critical conditions and to reduce the human errors.

The proposed IHHDM 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 IHHDM can be easily configured to accommodate a larger number of monitored variables.

VI. References

[1] Belloni, F.L. Teaching the principles of hemodynamics. in Advances In Physiology Education. 1999.

[2] Donald L. Warkentin, M. Hemodynamic Monitoring. 2010 [cited 2012 14 July]; Available from: http://actilean.healthinformatics.net/docs/english/aha/hemodyna.car.asp.

[3] Boldt, J. Clinical review: Hemodynamic monitoring in the intensive care unit. in Critical Care. 2002.

[4] Saeed, M., C. Lieu, G. Raber, and R.G. Mark. MIMIC II: a massive temporal ICU patient database to support research in intelligent patient monitoring. in Computers in Cardiology. 2002.

[5] Bauernschmitt, R., J. Hoerer, E.U. Schirmbeck, H. Keil, G. Schrott, A. Knoll, and R. Lange. Fuzzy-logic based automatic control of hemodynamics. in Computers in Cardiology. 2003.

[6] Denai, M., M. Mahfouf, and J. Ross. A Fuzzy Decision Support System for Therapy Administration in Cardiovascular Intensive Care Patients. in Fuzzy Systems Conference. FUZZ-IEEE. IEEE International. 2007.