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A Model Based Neuromuscular Blockade Control System with Injector

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ABSTRACT: The proper neuromuscular blockade level during surgeries can be attained by providing a substantial amount of drug to patients. Patients differ from each other even if same patient is considered within span of time the same drug given to him/her will result differently under consideration of factors like age, weight, sex and other physical attributes. Apart from the physical attributes of patient, nature and composition of drug is a deciding factor for anesthetist. During the anesthesia, in traditional practice drugs are given to patients on the trial and error basis, this may leads to the patients in risk. The system aims to develop the automatic controller which provides robustness against the variability of patients' response to drug dosage under uncertain circumstances. The proposed system aims to satisfy different important goals as: To calculate the amount of drug considering the physical attributes and to provide drug automatically to the patient. The database of 9 patients is considered under this work.

KEYWORDS: Depth of Anesthesia, Injector, Control System, NMB, ASA.

I. INTRODUCTION

Anesthesia is a temporary state consists of unconsciousness, lack of pain and muscle relaxation the lack of response and recall to noxious stimuli. The control of the neuromuscular blockade provides a good illustration of the main features and inherent constraints associated with the control of physiological variables [10]. Getting muscle relaxation, hypnosis and analgesia is main aim of anesthesia. Absence of muscular movements is required in surgical interventions in the area under consideration. The inhibition of muscle movements can be obtained by providing drugs which block the neuromuscular transmission, therefore producing muscular paralysis [2].

Traditionally, this monitoring is done by anesthetists, the activities of anaesthetists include numerous repeated and isolated tasks. Anaesthetists have to observe and control a great number of different variables of anaesthesia, and also some of the vital functions, with their personal experience decide the proper amount of drug for initial bolus (fast injection given in a short period of time with the aim to reach a high level of relaxation) as well as the appropriate amount of doses so that the patient maintains an adequate level of relaxation during surgery [2]. The major problem with drug delivery systems is the large uncertainty with different patients and within the patient under consideration of factors like age, weight, sex and other physical attributes and metabolism of drugs. Biological systems are non-stationary and nonlinear, and present a high degree of interindividual variability. Therefore, the control of physiological variables is characterized by a very high degree of uncertainty in the systems dynamics, while the nature of the application involved requires a very reliable and robust control system. As a result, the same drug provided to different patients and the same patient after a span of time will result differently [3]. During the anesthesia, drugs are given to patients on the trial and error basis that may leads to the patients in risk. And also the providing at a time drug causes the problem of overdose. Due to this, situations like instability in the level of relaxation and over paralysis may arise in patients. The instability in the level of relaxation have direct implications in the clinical state of the patient while the over paralysis (excessive drug amount given) may result in residual paralysis finally come to delayed recovery. These problems can be overcome by providing antagonist drugs, but this indirectly leads to undesirable over drug consumption.

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The deployment of an automatic control system for infusion of drug dosage in Operation Theater poses several difficulties. Firstly robustness, reliability, and performance of the system are critical in the operating theater. On the other hand, the anesthetist will feel more comfortable with a control system which gives fast explanatory and transparent decisions so that the anesthetist will validate them online and suggest alternatives if and when needed. And also it is clear that the control system will give benefit from the introduction or modification of control rules in an anesthetist-friendly way for allowing her/him to use her/his own clinical knowledge and experience.

A classical tool provided by engineering is control system, a topic that is receiving attention for drug delivery in clinical pharmacology. Control can also significantly contribute for understanding the effects of pharmacology agents and provide progress in drug delivery systems. Automatic control of anesthesia can support the anesthetist in his activities. The automatic control system suppresses the danger of awareness or drug overdoses. A shorter stay time of the patient in the postoperative care unit helps saving money.

A general requirement in anesthesia is to ensure a suitable level of muscle relaxation in the patient. Thus, from a control engineering viewpoint, such a requirement can be considered as a regulation problem where the plant to be regulated is the patient, the output is the patient's neuromuscular blockade level [%] and the input is the drug (Atracurium) infusion rate. In practice the problem is a complicated one, mainly because of undesirable transients caused by the initial ignorance on the relevant patient dynamics [11]. Automatic drug delivery can potentially improve drug therapy by allowing for more efficient delivery, reducing drug usage and costs; permitting health care staff to work more efficiently, providing better care; and allowing the safe use of drugs that are difficult to administer manually. It allows delivery of drug continuously while matching the dose to the patient's needs [12].

II. RELATED WORK

In last decades, many control systems are proposed varying from simple, static to complex and adaptive to overcome the problems (excessive drug consumption and small recovery time). These variations in control loop system are based on the calculation of different parameters (muscle response, depth of anesthesia) which are taken under consideration during anesthesia. Calculation using bispectral index (BIS) is one of the most popular method which is discussed in different papers. [1]This paper discussed the control problems for neuromuscular blockade and depth of anaesthesia. The control system was forced to be used in controlling the main parts of general anaesthesia (muscle response, depth of aneasthesia). The applied measurement techniques to the system with different experimental conditions and control strategies were presented. The combination of an on-off controller and GPC showed the neuromuscular blockade was controlled with a satisfying accuracy. The study was performed on a total of 31, classified in ASA 1-3 (American Society of Anesthesiologists), patients aged 33 to 63 which had to undergo a pancreas operation to achieve control of the neuromuscular blockade at a set point of 90% within a tolerance range of ± 3% using the drug Mivacurium.[2]This paper deployed of a fuzzy controller that was aimed to satisfy two important goals: 1) an optimization of the amount of drug (atracurium) required for inducing an adequate level of relaxation and 2) a compatible ability to explain the undertaken control decision at the level of natural language. This aim was set using the fact during surgeries, patients are subject to a substantial amount of drug dosage required for achieving the required neuromuscular blockade level. This system was explained as: statements of the form " the difference between the target and the current blockade level is near zero, so a small quantity of drug infusion should be currently applied," where "near zero" and "small" are linguistic terms that were represented as fuzzy sets. Hence, this controller was constructed that was human friendly and highly transparent. The effectiveness of the approach was demonstrated through experiments involving 100 simulated patients (used for training) and 500 patients (forming the test set), approving the approach for application in the operating theater.[3]The main problem related with the drug delivery system is variation of factors like age, weight, height, sex, race etc. in patients and moreover, when a same patient is considered after a interval of time the problem related with metabolism of drug arises. A metabolism of same / different drug will depend on the physical and internal attribute of the patients. This paper proposed a way to overcome this problem based on supervised multi model adaptive control (SMMAC). The specific case of neuromuscular-blockade-level control of patients under general anesthesia was considered, and also claimed that the overall procedure can be applied to the control of other physiological variables. Design guidelines for implementation of SMMAC are presented, along with clinical cases of patients undergoing general anesthesia, where atracurium was used as the blocking agent. The important role played by

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the selection of the observer polynomial in the supervisor was also demonstrated.[4] This paper presented an approach for new modeling and identification strategies to obviate many difficulties in the identification of anesthesia dynamics. The most commonly used models for the muscle relaxant effects during general anesthesia comprised of high number (greater than eight) of pharmacokinetic and pharmacodynamic parameters. In the clinical practice, main problem related with identification of the neuromuscular blockade system is that, the input signals / the amount of drug to be infused in patient vary too little to provide a sufficient excitation of the system. A way to solve this problem is presented in this paper.[5]In this paper the recursive estimation of a parsimonious nonlinear Wiener model for the neuromuscular blockade (NMB) in closed-loop anesthesia is presented. In this paper it is also demonstrated that the main source of intra-patient variability lies in the nonlinear pharmacodynamic part of the model with the help of the model parameters that were recursively estimated from clinical data. The distance to a bifurcation phenomenon leading to nonlinear oscillations of the Wiener model under PID feedback is also evaluated.[6] The main objective of this paper was to develop an automatic system for the control of neuromuscular blockade by regularly infusing the non-depolarizing types of atheistic agents (atracurium, cistracurium, vecuronium, rocuronium). To fulfill this objective they used method called as Hipocrates which is based upon classical, adaptable, robust control. This also includes various noise reduction techniques with online adaption to patients characteristics feature. The system proposed is easy to setup and can be used in clinic. The system consists of a portable PC computer, a Datex AS 3NMT sensor and a Braim compact prefusion pump. They proved Hippocrates is extensively validated and also provides an excellent environment for education and training purposes.

III. DESIRED IMPLICATION

A. Algorithm:

According to physical attributes and all other factors under consideration, the database is created. In accordance with database, the amount and composition of drug will be displayed. The signal relevant to amount of drug is passed to the stepper motor. The speed with which we want to inject the drug will be decided according to steps taken by stepper motor.

The system utilizes stepper motor with gear assembly for the motion of injector. As presented in hardware setup each gear assembly is operated by electronic stepper motor driver circuit. The motor driver circuits are in turn controlled by the program through the parallel port interface. The driver circuit comprises of ULN 2003 IC. The driver circuit used to operate the motor has inputs which are connected to the parallel port of the computer.

The main advantage of this system is if stepper motor fails/damaged, we have another mechanical system consisting of gear motor and gear assembly which will work manually with the help of switch.

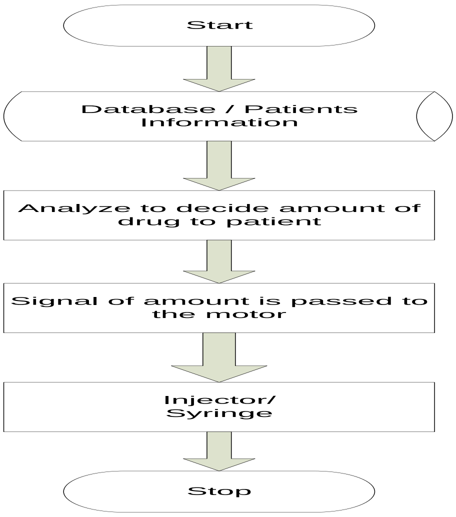

Fig 1: flow chart of the system

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B. Hardware Components and Setup:

- 60mL BD Syringe Luer-Lok
- 12V Step-Down Transformer
- Geared motor-12V and 150rpm
- Gear assembly
- DC stepping motor-3kg
- Switch-6V
- 10mm diameter gear shaft
- 4mm diameter Railing

Fig 2: Hardware setup

IV. RESULT ANALYSIS

By considering all the physical attributes like age, sex, race, operation etc. amount, composition and nature of drug is decided. Signal relevant to amount of drug passed to motor. Speed with which injector should inject is achieved by controlling the steps/rotation of the motor. Back-up mechanical system is present in the project. If stepper motor fails to do the automatic operation or we remove the stepper motor from the system the injector is controlled by the mechanical system (gear motor with gear assembly).

Traditional method for giving drug in anesthesia is direct drug delivery, this administration is done by anesthetists, with their personal experience decide the proper amount of drug for initial bolus (fast injection given in a short period of time with the aim to reach a high level of relaxation) as well as the appropriate amount of doses so that the patient maintains an adequate level of relaxation during surgery. During the anesthesia, drug are given to patients on the trial and error basis. This may leads to the patients in risk. And also the providing at a time drug causes the problem of overdose. Due to this, situations like instability in the level of relaxation and over paralysis may arise in patients. The instability in the level of relaxation have direct implications in the clinical state of the patient while the over paralysis (excessive drug amount given) may result in residual paralysis finally come to delayed recovery. This systems considers all factors including physical attributes and composition of drug. The system can work in fully automatic way in which the motion/speed of injector is controlled by steps/rotation of steeper motor. If the stepper motor fails to do so, the system have another mechanical system in which the motion of injector is controlled by gear motor and gear assembly.

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V. CONCLUSION AND FUTURE WORK

Thus an effective automatic controller system is modelled which decides the amount of drug using pateint's database. System considering the physical attributes and parameters like muscle relaxation, hypnosis (Depth of Anesthesia), analgesia can be developed for optimization of drug. If all above parameters are considered more precise and efficient system can be developed. The system for simultaneous delivering two or three medicines can be developed. Making the system more precise and speed controlled, the same can be used for long-time drug delivery.

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BIOGRAPHY

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etc.