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Application of Sensors Used to Detect Degree of Anesthesia during Surgery

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Abstract. Medical sensors act as an important role in modern surgeries. They help operation become safer and easier to operate. This paper goes into sensors made of electronic plastic design specially for detecting degree of anesthesia during surgery. Determine degree of anesthesia is a crucial part during surgery. Serious consequences may be caused if depth of anesthesia is not precise. The paper begins by introducing electronic plastics—such as polypyrrole and polythiophene, which are conjugated polymers with alternating single and double covalent bonds enabling electrical conductivity. Detecting method according to BIS index and concentration of propofol in patient blood are two ways used in surgery. Structure of the device is also included. Due to the interference in the blood, the two methods combined to work better. One example of clinical trials in The First Affiliated Hospital of Chengdu Medical College has validated its efficiency in improving surgical safety and anesthesia quality. In the future, such electronic plastic sensors are expected to be further optimized to provide more convenient technical support for surgical anesthesia monitoring.

Keywords: Bispectral index, plastic electronic plastic, medical sensors, depth of anesthesia

1. Introduction

As an up-coming technology, electronic plastic is becoming more widely used. In the medical field, this kind of material is widely used for its excellent abilities to acquire external environment information and adapt to changes of the surrounding. Most sensors are made based on this kind of material. Stage of surgery is observed by human eye in traditional open surgery, which is not accurate. Depending on device with sensors, medical staff are able to get a better idea of the surgery. Medical staff can response to emergences faster and more properly thanks to the real-time reflection by the sensors. Therefore, it is easy to come to the conclusion that research in sensors used in surgery allow doctors to do operation in a safer and more efficient way. The primary goal of general anesthesia is to render patient unable to feel painful stimuli while controlling autonomic reflexes. Intravenous (IV) anesthetics, inhalational anesthetics are two ways of anesthesia included in five total method. Each way of anesthesia has drawbacks to the patient. Knowing these drawbacks is proved to be effective to surgeons. How to choose the way of anesthesia depends on patient preference and type of surgery [1]. Detection of depth of anesthesia has two widely used ways, detecting with BIS and propofol concentration. The Bispectral Index (BIS) is a quantitative metric derived from processed electroencephalogram (EEG) signals, ranged from 0 to 100. Stable propofol

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concentrations help overdosing (risk of awareness) or underdosing (hypotension, respiratory depression). These two methods work together to provide a more efficient way of curing for surgeons.

2. Electronic plastic

Electronic plastic like polypyrrole and polythiophene are conjugated polymer which physically and chemically act well so it receives great attention these years. Conjugated polymer represents a polymer has alternative double and single covalent bond (shown as the Figure 1). As a result of that, it forms a structure that conducts electricity.

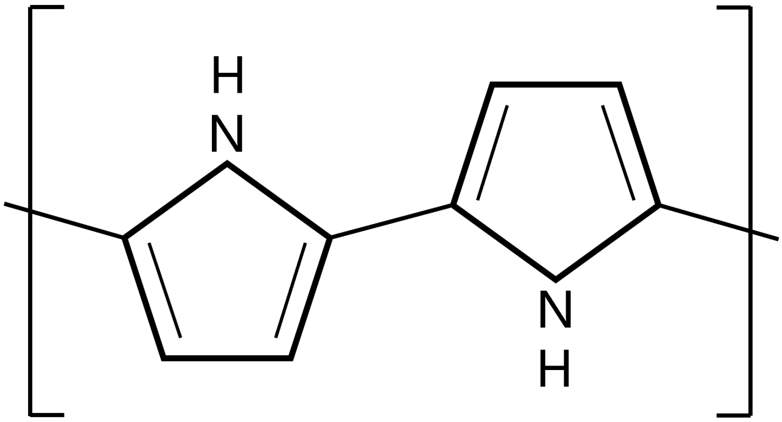

Figure 1. Structure formula of polypyrrole

Nevertheless, this kind of conductivity is not strong enough to be used. Doping is another essential process. The process of intentionally adding small amounts of impurities to a material to change its electrical conductivity or other properties. Elements like sulfur and phosphorus are often chosen to be the source.

Polythiophene is a man-made electronic plastic. It is red insoluble solid before doping and becomes green after doping. This color change can be applied to electrochromic devices. This kind of material has great strength, even greater than metal while produce with specific producing process. With these properties, polythiophene is widely used as organic solar cells, chemical sensing, electroluminescent devices [2]. PEDOT, the by-product of polythiophene is an important hole transport layer material in the preparation of organic electroluminescent devices. Electrochemical polymerization method is a way to produce polythiophene. The production realization of conductive polythiophene films is often prepared by electrodeposition. The polymerization produced has good mechanical properties but this method costs too much and is low-efficient. Chemical oxidative polymerization method is another method. This method is high-yielding but the product cannot be used in sensors directly. The products need further manufacturing process.

3. Application for medical sensor

3.1. Medical sensor

Medical sensers are device designed for detecting all sorts of data of the patient for doctors. Traditionally, the data are collected by human eye or by large, heavy and complicated sensors. These

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ways are out-of-date as they are not accurate. Therefore, a new flexible sensor is in need which is made from electronic plastic. Its affordable price and low weight quickly take the majority of market. Nowadays, electronic plastic sensors are used for measurement of sweat or blood, detecting cells like glucose or hemoglobin. Bioelectric electrodes for electrocardiogram, electroencephalogram and electromyogram signal are main working part of these electrochemical sensors. Besides electronic plastic, conductive paste and carbon material are also included in the raw material of medical sensers[3]. More and more researches have done about medical sensors. Medical sensors are developing into a cheaper and more precise way.

3.2. Detecting method

Detecting degree of anesthesia acts as a crucial part in surgery. Any overdose or misoperation will lead to serious consequences to the patient. As a result, automatic clinical test for the degree of anesthesia is important. Basically, two ways of detecting will be introduced in this paper. The one detects with electroencephalogram (EEG) signals will be introduced first.

BIS is a common index for anesthesia. As the patient's anesthesia depth level changes, the characteristics of their electroencephalogram signals will also change significantly. According to a specific pre-weighting method, the frequency of the signal will translate into BIS index [4]. The BIS anesthesia depth monitoring system consists of sensor electrodes, a signal collector, a processing host, a display, and cables [5]. According to the relevant process, a workflow diagram has been integrated and produced, as shown in Figure 2.

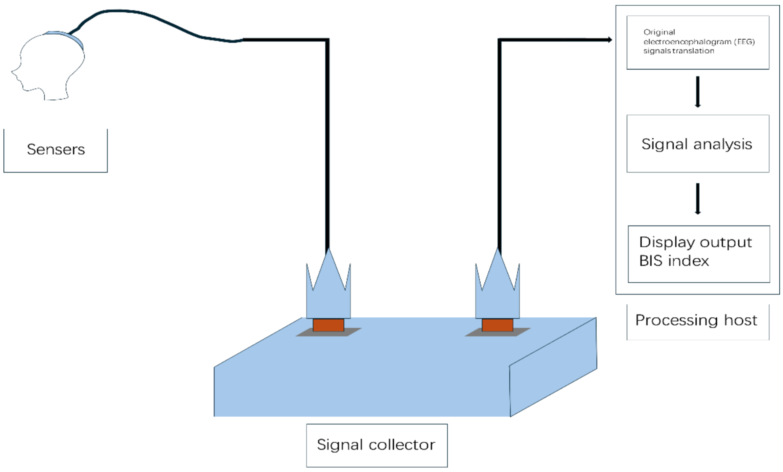

Figure 2. The whole structure of BIS detecting device

EEG electrode pads which stick on the surface of the head collect the signal from the brain. There are two more types of pads which are EEOG and SEEG. The two pads are injected deeper in the brain so collects more accurate data. However, they cause greater damage to the brain. The signal collector is made of metal to block external interference. The processing host is the key part of the whole structure. Through the cables, the signal transfer to the processing host. There, the signal will translate into BIS index for the operators to identify the degree of anesthesia.

Identifying the concentration of propofol in the blood is also a way to figure out the degree of anesthesia. This is a way that not that efficient as the first one so it just assists to identify depth of anesthesia. Propofol is a normal anesthetic to help patient stay calm. Its clinical features include rapid onset of action, short duration of effect, quick and smooth recovery, and few adverse reactions. In recent years, this drug has been widely used for anesthesia in various clinical departments and

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sedation of critically ill patients [6]. One way to detects it is using electrode sensor. Basically, this kind of sensor has working electrode and reference electrode. Propofol will reacts with working electrode and forms voltage difference with the reference electrode. When the difference occurs, the sensor will send signal to the device that deal with the data. This cannot be very precise as there are interfering substance in the blood. Moreover, blood acts differently with patient of different ages. Therefore, it is hard to determine the exact concentration of propofol in blood[7].

3.3. Examples of medical sensing applications

A case of 80-year-old man highlights the value of continuous electronic monitoring. He underwent laparoscopic partial hepatectomy under combined general and epidural anesthesia. Pressure alarm was triggered in two minutes at the start of the surgery and capnography showed an obstructive pattern as ventilation became difficult. The operators suspected it was severe asthma so injected drug at once. The old man was safe on postoperative day one. Therefore, it is obvious the sensors acts as a significant role in surgery [8].

BIS test is used in real cases and proved to be efficient. In the First Affiliated Hospital of Chengdu Medical College, tests have been done on clinical trials. Compound sodium lactate is injected to the patients at the start of the surgery. The working electrode is placed on right temple and the reference electrode is placed behind right ear. BIS monitor detects the BIS index continuously. The result shows that BIS has better indication than HR index. BIS index has good relationship with the depth of anesthesia. With the help of BIS, operators can do anesthesia in higher quality [9].

4. Conclusion

BIS monitoring reflects a medication’s actual effect while propofol concentration detection shows the specific amount of this drug in the blood and these two tools offset each other’s shortcomings with consistent propofol concentration sometimes leading to varying BIS values and BIS monitoring ensuring the medication functions as intended.

BIS monitoring results usually appear earlier than propofol concentration detection results in the blood due to blood circulation and this time difference lets clinicians adjust medication infusion rate promptly to maintain stable anesthesia depth.

Combined BIS and propofol concentration monitoring prevents patients from regaining consciousness during surgery and enables precise medication dosage control to avoid both overdose and insufficient dosage. Together establish a comprehensive anesthesia monitoring system whose individualized real-time and high-safety features support wide application in modern surgical procedures and contribute to more stable hemodynamic status and faster postoperative recovery.

Medical sensors as a core component of this monitoring system are expected to capture larger market share with their cost-effectiveness appealing to healthcare institutions and such sensors can be applied in AI-assisted surgeries in the long run making them boast broad development prospects worthy of in-depth research and providing a stable safe environment for surgeries to stand as a typical representative product in modern medical technology.

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