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A Review of the Application of Sensors in the Field of Biomedicine

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ABSTRACT

In modern times, various sensors have been widely used in biomedicine. Humans have been using multiple physical parameters to identify physiological and pathological signals generated in the body for a long time. The relationship between physical parameters of various parts of the human body and diseases has long been known in medicine in multiple countries, such as heartbeat, the relationship between pulse wave (pulse diagnosis) in traditional Chinese medicine and human health. In recent years, biomedicine has continuously promoted the progress and innovation of sensors. Sensors for *in vivo* physiological information and the development status of these sensors is introduced.

Keywords: Sensor; Intracranial Pressure Detection; Heart Sound Detection; Pulse Wave

Abbreviations: TCD: Transcranial Doppler; f-VEP: Flash Visual Evoked Potentials; CSF: Cerebrospinal Fluid; AFP: Anterior Fontanel Pressure

Introduction

Pressure and sound are widespread parameters in the field of biomedicine and clinicalmedicine, and intracranial and intracranial pressure measurement is a vital reference data in neuroscience and brain surgery; heart sounds are also widely used in clinical medicine diagnosis and treatment; pulse diagnosis has vast application experience in traditional medicine in China, India and Egypt. Doctors sense the pulse beat with their fingers and use the pulse information as the basis for clinical diagnosis.

Heartsound Sensor

Since the invention of the single-ear wooden stethoscope by Laennec in Paris, France, in 1816, until the 1960s [1], the stethoscope has made significant progress in terms of acoustic performance and wearing comfort but its functions are both The sound is transmitted directly to the human ear. Stethoscopes at this stage are traditional stethoscopes, and it is difficult to detect subtle heart sounds, such as heart murmurs. Unlike traditional stethoscopes, electronic stethoscopes convert sound into electrical signals, which can then be used for further processing and transmission through analogue-to-digital conversion [2].

In the 1950s, in order to address the limitations of traditional stethoscopes, the idea of connecting an electronic amplifier and microphone to a traditional acoustic stethoscope to amplify some imperceptible heart sounds was first proposed. In the 1960s, the 3M Company in the United States acquired Dr Littimann's stethoscope project. In 1995, 3M started its electronic stethoscope research and development program and developed an electronic stethoscope that can amplify sound similar to traditional acoustic stethoscopes in appearance, feel and operation. After continuous improvement, the electronic stethoscope produced by 3M has become the gold standard in the stethoscope industry [3].

At present, the Littmann 3200-type electronic stethoscope of 3M company and the heart sound visualization software "3M Littmann StethAssist" developed by 3M can record the heart sound signal and perform simple time domain and frequency domain analysis on the recorded heart sound signal. As the core of the stethoscope, the sensor determines the stethoscope's performance [4]. Xue et al. proposed a novel MEMS bionic vector hydrophone based on the principle of fish lateral line organ sensing water flow pressure and velocity. It can be well applied to underwater detection with good frequency response in terms of low frequency and sensitivity [5,6]. After that, Zhang et al. optimized and improved the model [7,8], and Liu et al. proposed a lollipop-shaped hydrophone to improve sensitivity [9]. Li et al. applied cilia-shaped and lollipop-shaped hydrophones for heart sound detection and compared their performance [10]. Zhou proposed a fish-ear structure medical acoustic sensor based on MEMS technology and verified it experimentally. The results show that the sensor has good acoustic performance and can be used to detect human heart sound signals [11].

Flexor Artery Detection

Modern medical theoretical research shows that human arterial pulsation comes from the heart's regular and periodic contraction and relaxation. The generation and propagation of arterial pulsation. signals will be affected by other factors such as the state of human organs, arterial wall elasticity, and blood viscosity. Therefore, the physiological and pathological information related to various functions of the human body will be indirectly hidden and reflected in the changes in the shape of the human arterial pulsation signal. The world's first wrist radial artery signal recording device was developed in 1860. This spring lever radial artery signal recorder mainly draws the wrist radial artery signal by tracing points through mechanical principles, which is affected by the device's defects. the signal waveform drawing result is distorted [12]. Seong-Ki Yoo and other researchers sequentially arranged multiple piezoresistive pressure sensors of the same size and electrically connected them to the PCB through wire bonding and then added a special material coating to form protection to collect the radial artery axis and the upward multiplex signals. signal [13].

Researchers such as Peng J Y used a flexible printed circuit board and integrated a CMOS switched-capacitor readout circuit to measure the radial artery signal at the wrist using a flexible tactile sensor [14]. Xu et al. used the photoelectric reflection method to integrate the photoelectric sensor on the PDMS film and attached it to the surface of the human skin to obtain the arterial signal [15]. The ZMH-I wrist arterial signal acquisition system developed by the Shanghai University of Traditional Chinese Medicine using semiconductor strain gauges as sensing elements can well acquire human wrist arterial signals. After that, the Shanghai University of Traditional Chinese Medicine designed and developed an upgraded version of the new ZM-300 wrist arterial signal acquisition system based on the ZMH-I wrist arterial signal acquisition system [16,17]. Researchers such as Zhou Peng of Chongqing University used capacitive pickup sensors and combined virtual instrument technology to develop a wrist radial artery signal acquisition system, which achieved good results in collecting arterial signals [18]. Researchers such as Wang Xuemin and Yang Cheng from Tianjin University of Traditional Chinese Medicine used flexible array sensors and arterial signal transducers developed with silicone cavities toachieve multi-channel measurement of signals [19].

Intracranial Pressure Monitoring

Intracranial pressure monitoring has important guiding significance for clinical treatment. According to different monitoring methods, it is divided into invasive detection and noninvasive detection. Invasive detection requires the monitoring device to be directly implanted into the patient or the pressure of the patient's measured area to be drawn out by means of ventricle drainage, and then the pressure measurement is performed directly by the pressure sensor. It has been used clinically for decades. There is much practical experience; noninvasive detection does not need to implant monitoring equipment into the patient, so it will not cause complications caused by trauma such as infection and bleeding. It is an ideal intracranial pressure monitoring method. In the 1990s, a micro-sensor device that can monitor intracranial pressure appeared. Its core sensor principle is based on fibre optics and piezoresistive effect. The principle of a fibre optic pressure sensor is to use the propagation characteristics of light in fibre materials and act on photoelastic elements. The relationship makes the pressure sensor The relationship makes the pressure sensor of pressure. The size of the optical fibre sensor is tiny. For example, the diameter of the ordinary single-mode optical fibre is only 125um; the principle of the piezoresistive pressure sensor refers to the change of the energy band caused by the stress when the semiconductor is under stress as well as the energy movement of the energy valley, the phenomenon of changing its resistivity and using the micro-mechanical electronic system (MEMS) technology, the size of the internal bridge reaches the micrometre level.

The volume of the sensor reaches the millimeter level. Noninvasive intracranial pressure monitoring includes Transcranial Doppler (TCD), Flash Visual Evoked Potentials (f-VEP), tympanic membrane displacement, and anterior fontanel using low-frequency ultrasonic transducers. Pressure), etc. Ultrasonic has excellent penetration ability to liquids and solids, especially in solids that are opaque to sunlight. It can penetrate to a depth of tens of meters. When the ultrasonic wave encounters impurities or interfaces, it will produce significant reflection to form an echo, and when it encounters a moving object, it can produce the Doppler effect.

Gaab et al. 1989 proposed tongue-shaped Epidural pressure sensors, which have lower rates of infection, bleeding, and seizures compared to EVDs, but have the disadvantage of not allowing therapeutic cerebrospinal fluid drainage (CSF) [20]. Camino and the Codman Micro Sensor are the current market leaders. The Camino Innerspace equipment launched in 2006 uses an optical fibre pressure sensor, which needs to ensure the straightness of the optical fibre, so the equipment has high requirements for the packaging of the optical fibre. The miniature sensor device launched by Codman in 2007, its built-in sensor chip adopts piezoresistive pressure sensor, which reduces the difficulty of packaging and solves the problem of sensor zero drift.

Transcranial Doppler ultrasound utilizes the principle of Doppler effect of fluid, uses a low- frequency ultrasonic sensor to scan the blood vessels at the base of the skull, and indirectly obtains intracranial pressure information through calculation. In 1982, Aaslid reported the TCD technique and theoretically explained the relationship between TCD and cerebral perfusion pressure. Bhatia and Gupta proposed the clinical application of TCD in 2007 [21]; in 1989, Marchbanks proposed the Tympanic membrane displacement method, which also uses a pressure sensor to measure the eardrum pressure indirectly and then calculate the intracranial pressure [22];Popovic et al. 2009 pointed out that the direction and magnitude of tympanic membrane displacement depend not only on the initial position of the stapes but also on many other factors that affect the acoustic impedance or the strength of the acoustic reflection. In 1959, Davidof et al. changed the Schiotz tonometer to measure ICP by Anterior Fontanel Pressure (AFP). Over the past 40 years, AFP has gradually improved and has replaced invasive ICP monitoring to a certain extent in neonates and infants [23]. The development of technology has promoted the integration of multiple disciplines. High- performance sensors provide strong technical support for biomedicine. In the future, sensors need to develop in the direction of miniaturization, high precision, pertinence, and long-term stability.

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