STUDY OF LIGHT TRANSMISSION THROUGH THE UNDERWEAR FOR DEVELOPMENT OF A URINARY INCONTINENCE SENSOR

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Abstract: Urinary incontinence is a troubling disease that makes it difficult for patients to live a normal life. Rapid detection of urinary incontinence could allow many patients with this condition to feel more confident about going out. Therefore, our goal is to develop a urinary incontinence detector based on a light-emitting diode and a photodiode. Here, we describe the development and testing of a prototype model. The photosensor is driven by a 9 V battery and consists of an ordinary electrical circuit, a light-emitting diode (lambda max = 950 nm), a photodiode (spectrum 750-1200 nm), a comparator and, a compact motor. Light transmission through the underwear was changed by soaking with liquids. This phenomenon was measured using a digital voltmeter. The urinary incontinence sensor was placed on a dummy. Liquids were drained into the shorts. These increased in voltage from 3.73 V to 8.78 V, which caused the motor to vibrate. These results show that the prototype sensor can be used to detect urinary incontinence.

1 INTRODUCTION

In recent years, Japan is rapidly becoming an aging society. According to the report by the Japanese Ministry of Internal Affairs and Communications, as of August 2011, the number of elderly people in Japan aged 65 or more was 2971 million (23.2%). Of these, aged 65 or older women were 1702 million. It is reported that about 11 percent of women need to have surgery related to urinary incontinence or genital prolapse one or more times, which means about 187 million women are applied (Olsen et al., 1997).

In studies of epidemiology or health screening, lower urinary tract symptoms are highly prevalent (Homma Y, Yamaguchi O, Hayashi K, 2006; Terai A et al., 2004). Currently, about 4 to 5 million people suffer from urinary incontinence in Japan. It is estimated that the number of urinary incontinence patient will increase 10 million people after 15 years.

Cause for urinary incontinence includes, the person who is elderly, patients with dementia, patients who have undergone radical prostatectomy due to cancer, patients who injured spinal cord, patients who have schistorrhachis, females after delivery of a baby or at the menopausal stage, and one in four otherwise healthy women who develop urinary incontinence. Such incontinence decreases quality of life in various situations in society. Patients with chronic incontinence have no urge to urinate, and so it is difficult to use public facilities and continue to work. For example, Spinal cord injury (SCI) patients with normal upper body function have a desire to return to society, but their concern that urinary incontinence may occur at any time often causes patients to avoid going out. Therefore, urinary incontinence disrupts human relationships and increases isolation, and in extreme cases patients may commit suicide because of this condition.

At a hospital, care facility and home, a diaper is commonly used to prevent urinary incontinence.

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Patients with SCI may also use intermittent self-catheterization using a balloon catheter, and male patients can use a condom remodeled as a urine bag. However, these methods have several problems: condoms remodeled as urine bags require a long time to fit, and patients dislike wearing diapers. Furthermore, the artificial urinary sphincter, which is the only definitive therapy for urinary incontinence, is not covered by the Japanese National Insurance system and thus is uncommon in Japan, despite its approval by the Japanese Ministry of Health, Labour and Welfare (Arai et al., 2009).

Several sensors have been described for prevention or detection of incontinence, including monitoring of temperature changes in diapers (Matsushita et al., 1993), detection of conductance changes in diapers after incontinence (Nakajima et al., 1994), and use of the characteristics of radiofrequency that prevent its transmission if water is present on clothes (Tamura et al., 2007). A device that measures urinary volume in the bladder using ultrasound is also on the market (Yuririn, USH-052, Takashiba Electric Ltd., Japan, Retrieved Aug 26, 2011). However, these devices are not commonly used in Japan. In addition, some of the reported sensors are intended for use at the bedside for elderly patients or patients with dementia. In contrast, we have been unable to find a report of practical use of a portable urinary incontinence sensor in normal life situations. Therefore, we have started development of a urinary incontinence sensor that is portable, works on a battery, senses urinary incontinence quickly, is diaper-independent, and has a low cost.

2 METHODS

2.1 Basis and Structure of the Incontinence Sensor

Our sensor is based on the venous needle dislodgement sensor that we have described for use during hemodialysis (Takeuchi et al., 2010). This sensor utilizes light transmission through a cloth and changes voltage after liquid osmosis. We modified the sensor by changing the diode to emit infrared light, adding a monitoring circuit, and using a dry-cell battery to drive the sensor. The sensory module consists of a light emitting diode (LED, lambda max = 950 nm, SFH4110), a photodiode (PD, spectrum 750-1200 nm, BP104FS), and a comparator (LM2903) with a compact motor on a simple circuit (Figure 1). The PD changes its resistance depending on the intensity of the transmitted light. The LED and PD are attached at the edges of a plastic clip and sealed with bonding to avoid a short-circuit that could be caused by urinary incontinence (Figure 2). The voltage across the R2 resistor (12 kohm) increases when the light is bright and decreases when it is dark. The voltage is not changed by background illumination such as that from a fluorescent lamp because the strong LED light is directly targeted to the PD through the cloth. The comparator receives a certain voltage from variable resistors (Rv, 1 kohm) and R2 (variable due to light transmission). When urinary incontinence occurs, the R2 voltage increases to slightly higher than the Rv voltage, and the resulting current drives the transistor (BC373G) and causes the motor to vibrate.

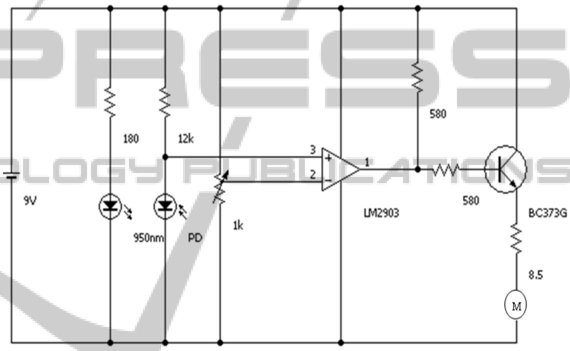

Figure 1: The circuit of the sensor module.

Figure 2: Components of the incontinence sensor.

2.2 Experimental Methods and Statistics

First, to measure the characteristics of the sensor, several liquids were infused and light transmission was measured. The sensor is attached by clipping underwear made of cotton at the bottom of the front surface. Infusion tube is inserted into the inner side of the underwear (Figure 3). The liquids are infused by the infusion pump (SYRINGE PUMP 1235N Atom Medical., Ltd., Japan) at a rate of 200ml per hour. Normal human urine, tap water, or physiological saline were manually infused into the underwear, and the R2 voltage change between dry and wet conditions of the shorts was measured with a digital voltmeter. We measured the interval of time between the infusion of liquid and the beginning of motor vibration. For each liquid, seven independent measurements were performed. The results are presented as a mean ± SD. A probability level of $P < 0.05$ was considered to be statistically significant. To confirm the effect of thickness of the cloth on light transmission we used three kinds of cloth with the thickness of 0.2mm, 0.4mm and 0.6mm. We then tested the sensor using a dummy patient that was set to external underwear assumes incontinence may occur (Figure 4).

3 RESULTS

With a dry underwear, the mean voltage across R2 was 3.58 ± 0.12 V under control conditions. The threshold of the comparator was set at about 8 V by adjusting Rv. Infusion of liquid to wet the underwear caused the R2 voltage to increase from 3.73±0.41V to 8.78±0.31V with unimpaired urine, from 8.78 ± 0.11 to 5.9 ± 0.06 V with tap water, and from 3.46± 0.13 to 9.08 ± 0.05 V with physiological saline. In all cases, the values after liquid infusion were significantly higher (P<0.01) than the Rv voltage which caused the motor to vibrate about 4.5 to 6 seconds after the liquid was infused (Figure.5).

Figure 3: Positioning of the sensor and infusion tube.

By the experiment that changed thickness of cloth, the R2 voltage increased from 5.7±0.2 to 8.38±0.07V with 0.2mm cloth, from 3.41±0.2V to 7.96±0.3V with 0.4mm cloth, and from 1.92± 0.12V to 6.47±0.31V with 0.6mm cloth (Figure 6). In all cases, the changes were statically significant (P<0.01).

Similarly, in testing on the dummy patient, the motor vibrated a few seconds after infusion of tap water.

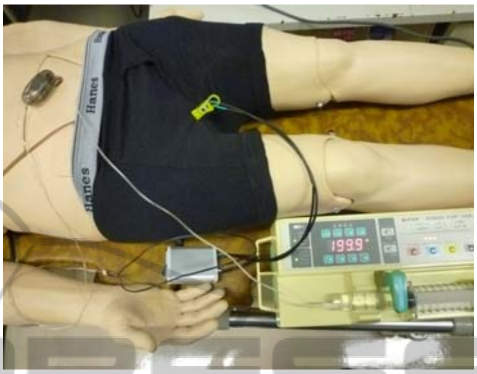

Figure 4: Experimental dummy showing the positioning of the sensor.

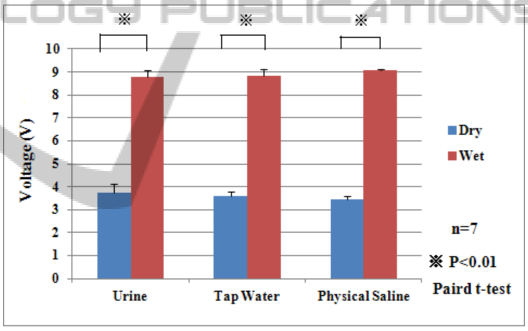

Figure 5: Effect of liquid type on the R2 voltage.

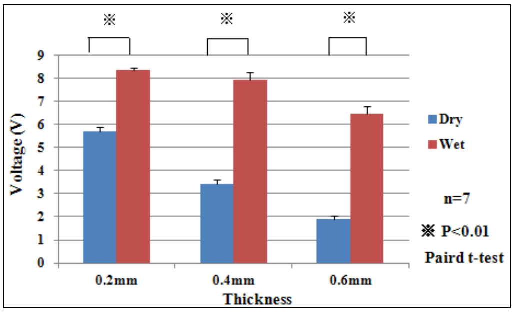

Figure 6: Effect of thickness of cloth on the R2 voltage.

4 DISCUSSION

The prototype sensor described in this work is compact, works on a battery, is suitable for use at the bedside and outside the house, and has a low cost because the sensor is washable and sterilizable. Our

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results show that the sensor can respond to a small amount of urine, which allows detection of incontinence before a flood of urine occurs. We think this sensor is suitable for patients with dementia, patients use a wheelchair such as SCI patients, and training for young patients with enuresis. With use of the sensor, younger patients will be able to avoid wearing diapers and can choose to wear any type of shorts. Soaking of the shorts due to incontinence will drive vibration of the motor, and positioning of the motor on the normal upper body will allow the patient to detect incontinence at an early stage.

From the results, we confirmed that the light transmission through the cloth increased significantly by human urine, tap water and physical saline. When the thickness of the cloth was 0.4-0.6mm, the R2 voltage increased by more than 4V. This indicates that adjusting Rv resistance and setting the threshold properly, this sensor is applicable to detecting urinary incontinence.

In this study we used the underwear made of cotton. The motor vibrated even when the sensor is attached at the thickest position. If we adjust the variable resistors and control threshold voltage, different type of underwear can be used. In the experiment, we used dummy patient, but for practical use it will be necessary to examine the effects of walk and roll-over, etc. Therefore, as the next step in development of the sensor, we will work toward its practical use through testing and evaluation in a patient with urinary incontinence.

5 CONCLUSIONS

In this article, we described development of a urinary incontinence sensor, which utilized light transmission through cloth. This sensor is compact, works on a battery, can be used at the bedside and in ordinary life, and frees the patient from wearing a diaper.

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