LIGHT TRANSMISSION THROUGH GAUZE PAD SOAKED WITH BLOOD OR LIQUIDS TO DETECT VENOUS NEEDLE DISLODGEMENT

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Abstract: Accidents during hemodialysis such as a large amount of blood loss are often caused by venous needle dislodgement. To develop a bleeding sensor based on a photo sensor, we studied effects of liquids and porcine blood on light transmission through a thin gauze pad. The photo sensor consisted of an ordinary electrical circuit, a light emitting diode (lambda max = 645 nm), a photo diode, and a thin gauze pad placed between the diodes. The light transmitted through the gauze pad soaked with liquids or porcine blood was measured with a digital voltmeter. The liquids on a gauze pad, significantly increased the voltage (light transmission) from 0.33 +/- 0.004 V (SD) to 0.63 +/- 0.02 V (minimum, by reverse osmosis water) and to 0.70 +/- 0.03 V (maximum, by 50% glucose). The porcine blood significantly decreased the voltage from 0.33 V to 0.21 +/- 0.02 V in Hct 40%, to 0.27 +/- 0.02 in Hct 30%, to 0.30 +/- 0.02 V in Hct 20%. We confirmed that liquids significantly increased light transmission through the gauze pad, but porcine blood decreased light transmission. This opposite response can be used to distinguish liquids from blood on a gauze pad.

1 INTRODUCTION

Over the past three decades, hemodialysis has evolved into a safe and less stressful procedure for both patients and caregivers (Sarkar, Kaitwatcharachai and Levin, 2005; Hawley, Jefferies, Nearhos and Van Eps, 2008). However, intradialytic complications still cause considerable patient morbidity and rarely, mortality (Sarkar et al., 2005). Venous needle dislodgment (VND) is one of the most serious accidents that can occur during HD (PMID9859033, 1998; Hawley et al., 2005; Van Waeleghem, Chamney, Lindley and Pancírová, 2008). The FDA has some statistics on cases of fatal blood losses but the known numbers are probably too low to reflect the real figures (Ahlmén, Gydell, Hadimeri, Hernandez, Rogland and Strömbom, 2008). Ahlmén et al. estimate the incidence of venous-needle dislodgements of 0.1% is merely an approximation over a short period (Ahlmén, et al., 2008). Although certain devices monitoring venous pressure (Hertz, Joensson, Sternby), pressure pulse (Goldau, Fresenius Medical Care Deutschland GmbH) and moisture (Pierratos and Lugonzo, 2009) (DRI Sleeper® Dr. Page. Retrieved Aug 20, 2009) have been developed, tested and patented, a “VND sensor” has been requested by patients and medical professionals (European Dialysis and Transplant Nurses Association/European Renal Care Association (EDTNA/ERCA, 2005) has produced 12 practice recommendations to help reduce the risk of VND and detect blood leakage as early as possible (Van Waeleghem et al., 2008). A device that uses fiber optic technology to detect blood has been approved (CE marked) as a Class I medical

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device with the intended purpose of detecting VND in extracorporeal circuits (Ahlmén J et al., 2008; Van Waeleghem et al., 2008). The device has also been granted FDA approval and is now available for sale in the United States. However, other detection systems are still under development at the present time (Van Waeleghem et al., 2008).

Although there was no observed event that led to dislodgement of the needle in most reported episodes (Sandroni, 2005), the oozing of blood has commonly been noticed on a tape or small gauze at the needle site in hemodialysis (Lindsay, Burton, 1972; Salaman, 1971; Sandroni, 2005). The oozing may be due to a brittle vessel and skin in chronic renal failure patients. The oozing decreases the adhesiveness between the tape and skin and could lead to needle dislodgement. A small piece of gauze is used to absorb the oozing blood at a needle site and to avoid bloody soiling of clothes and bed sheets.

We attempted to sense the small amount of blood on a small gauze pad that covers the needle site. A direct electronic sensor such as moisture or enuresis detector is not suitable in Japan because they could cause micro electrification. Processing an optical fiber to a blood sensor is technically difficult for our laboratory, and the fiber is already used in the convenient device above. Although it is easy to imagine that light transmission through gauze might be changed by blood, we could not find a practical report of light transmission affected by blood or other liquids.

To detect an accidental bleed in hemodialysis, we made a photo sensor module to measure light transmitted through gauze pad and studied the effects of blood and liquids on a light transmission.

2 METHODS

2.1 Light Sensory Module

The sensory module consists of a light emitting diode (LED, lambda max = 645 nm, 55 mcd, HLMP-Q105), a photo diode (PD, spectrum 600-1050 nm, DIL-BPW34) on a simple circuit that is commonly used in light/dark sensors (Figure 1). The

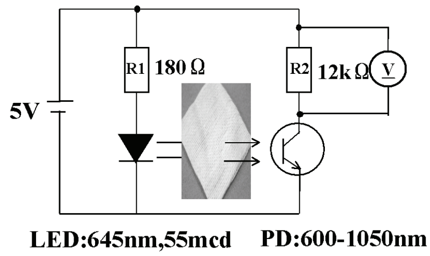

Figure 1: The circuit of photo sensor module.

PD changes its resistance depending on the intensity of the light transmitted. The voltage across the resistance R2 (12 k ohm) increases when the light is bright and decreases when it is dark. The voltages are measured with a digital voltmeter. The LED and PD are attached at the edges of a plastic clip and sealed with bond to avoid any short-circuits that could be caused by the liquids. The voltages were not changed by any background illumination such as that from a desk lamp because the strong LED light was shown directly through the gauze pad to the PD.

2.2 Gauze Pad and Test Medium

Loose weave pads was a piece of gauze (Blood Ban, L size, Yutoku Pharmaceutical Industry, Ltd., Japan) used after collecting blood or administering infusion such as a “BAND-AID.”

Test mediums in the amount of 0.3 ml were manually dropped in the center of the gauze pad (Figure 2). The applied liquids were a reverse osmosis water, physiological saline, and glucose in water at 5%, 10%, 20%, 40% and 50%. Porcine plasma and blood were also applied and tested in the same manner. The hematocrits (40%, 30% and 20%) were prepared by adding porcine plasma but not saline. The porcine blood was obtained from a slaughterhouse (Tokyo Shibaura Zoki Ltd., Tokyo Japan).

2.3 Statistics

For each liquid, seven measurements were collected and presented with a mean and SD. For each porcine blood, five measurements were averaged as one value. Nine values were collected for each blood sample and presented with a mean and SD. They were statistically compared with the control values using unpaired Student’s *t*-test. A probability level of $P < 0.05$ was considered to indicate statistical significance.

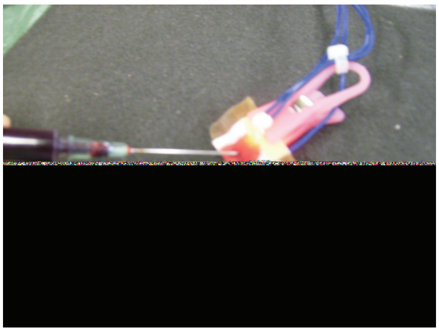

Figure 2: Experiment of dropping porcine blood on a tight weave pad thin gauze pad.

3 RESULTS

Mean voltage was 0.332 +/- 0.004 V under control condition. Liquids and porcine plasma increased the voltages from 0.332 +/- 0.004 V to 0.634 +/- 0.018 V (minimum, by a reverse osmosis water) and to 0.703 +/- 0.027 V (maximum, by 50% glucose) (Figure 3). The light transmitted through the gauze pad was increased by liquids or plasma. There was a higher concentration of glucose the more the light transmission increased. Porcine blood decreased the voltage from 0.332 V to 0.214 +/- 0.019 V in 40% Hct, to 0.271 +/- 0.023 in 30% Hct, to 0.304 +/- 0.019 V in 20% Hct. The higher the concentration of Hct, the more the light transmission decreased.

4 DISCUSSION

Studies of incidents showed that the typical scenario of VND episodes happened in apparently routine treatments and with fully staffed units (Sandroni, 2005). Although a needle and needle tubing are stabilized with an adhesive fabric and the "chevron" technique (Van Waeleghem et al., 2008), VND occurs in hemodialysis. In the present state, medical staffs are required to find accidents as quickly as possible.

Liquids or plasma increased light transmission through gauze pad. It may be the same effect as when light is seen through a wet shirt. A part of the light from a light source, the LED, was scattered outward in the gauze as a bulk scatter. The residuals hit the PD. The liquids dropped on the gauze pad could reflect the light traveling inward. The light transmissions increased proportionally to the glucose concentrations. The relationship is probably due to the Beer-Lambert's law.

Porcine blood clearly decreased the light transmission through the gauze pad. The decreases were related to their hematocrits. The absorbance of light at a wavelength 645 nm was interpreted by a higher concentration of haemoglobin. The opposite response of light transmission caused by liquids or blood may be used in theory to distinguish blood from liquids such as sweat, infusion drip, urine, saliva, or leaching solution. Although we have attempted to develop a monitor tool to detect bleeding in hemodialysis, the device may be used for monitoring VND during a continuous intravenous infusion for a relatively long time. In such a case, even if venous blood flows and mixes at the needle site, the infusion volume may be larger than that of venous blood. It would be more desirable if the device could quickly detect any change from the control level rather than an absolute value of the light transmission.

Although the optical device of Ahlmén et al. (2008) can find a minute amount of blood (about 1 ml), it may be difficult to distinguish oozing from bleeding. Our procedure may control the sensing volume by an arbitrarily set gauze volume or distance between the needle site and the sensor on a gauze pad.

This study proved that the light was absorbed in gauze pads with hemoglobin and that light transmission increased in wet gauze pads without hemoglobin. Although we should confirm that the phenomenon is ordinary shown in other kinds of gauze pad, more thin or thick, this fundamental study will promote the development of simple practical bleeding sensors to monitor hemodialysis and continuous infusion. In a future plan, we will consider a disposable or re-usable LED and PD device to completely avoid any infection and short-circuits, a power supply for four-hour hemodialysis a day, three times a week, and how to alarm an event to notify medical staffs.

5 CONCLUSIONS

We confirmed that liquids on a gauze pad significantly increased light transmission through the gauze pad, but porcine blood decreased light transmission. These opposite effects of light transmission through the gauze pad can be used to distinguish liquids from blood on the gauze pad with the bleeding sensor.

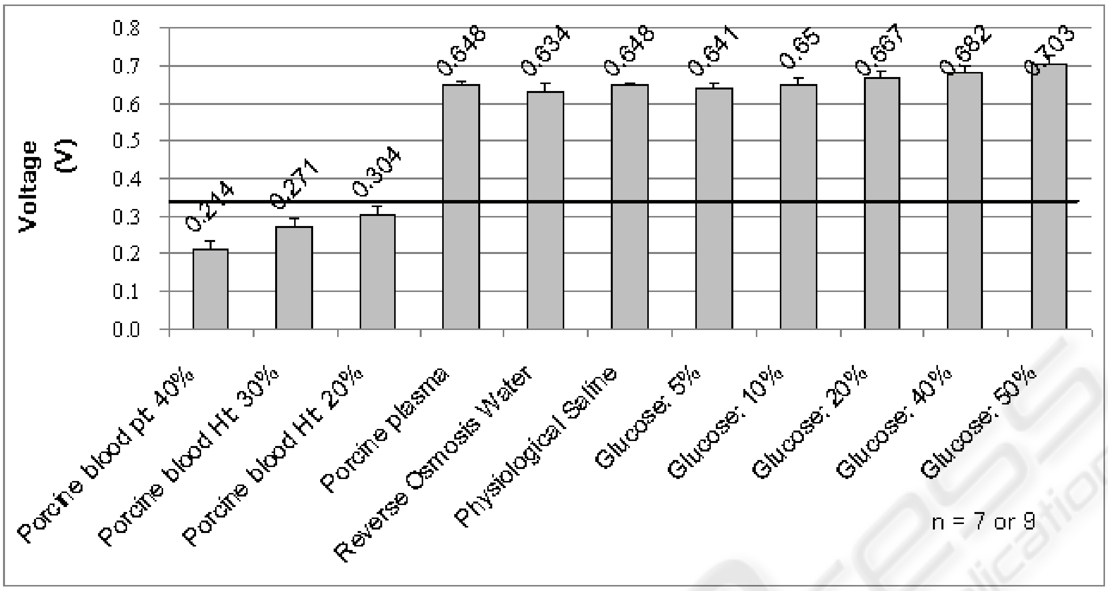

Figure 3: Voltages across R2 with porcine blood and liquids in the gauze pad. Horizontal line 0.332 V shows the value at the control condition.

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