STUDY OF LIGHT TRANSMISSION THROUGH GAUZE PAD EFFECTED BY BLOOD OR LIQUIDS TO DETECT NEEDLE DISLODGEREMENT

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ABSTRACT. Objective. Serious 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 for monitoring the needle sites, we studied effects of liquids and porcine blood on light transmission through a thin gauze pad with a basic photo sensor. Methods. The photo sensor consisted of an ordinary electrical circuit, a light emitting diode (LED, lambda max = 645 nm), a photo diode (PD), and a thin gauze pad placed between the LED and PD that were tightly attached to the edges of a plastic clip. The light transmitted through the gauze pad, soaked with liquids or porcine blood dropped on it, was measured with a digital voltmeter. The liquids were reverse osmosis water, physiological saline, glucose in water at 5, 10, 20, 40 and 50%, porcine plasma, and porcine blood (Hct 40, 30 and 20%). Results. The liquids on a tight-weave gauze pad, significantly increased the voltage (light transmission) from 0.412 ± 0.003 V (SD) to 0.794 ± 0.025 V (minimum, by reverse osmosis water) and to 0.945 ± 0.021 V (maximum, by 50% glucose). The porcine blood significantly decreased the voltage from 0.412 to 0.195 ± 0.030 V in Hct 40%, to 0.334 ± 0.035 in Hct 30%, to 0.397 ± 0.007 V in Hct 20%. The higher the concentration of glucose, the more the light transmission increased. The higher concentration of Hct, the more the light transmission decreased. Similar results were also shown for the loose-weave pad. Conclusions. Using two types of gauze pads, we confirmed that liquids significantly increased light transmission through gauze pad, but porcine blood decreased light transmission. This opposite response can be used to distinguish liquids from blood on a gauze pad.

KEY WORDS. venous needle dislodgement, blood sensor, photo sensor, light transmission, gauze pad.

INTRODUCTION

Over the past three decades, hemodialysis has evolved into a safe and less stressful procedure for both patients and caregivers [1, 2]. However, intradialytic complications still cause considerable patient morbidity and rarely, mortality [1]. Venous needle dislodgment (VND) is one of the most serious accidents that can occur during HD [2–4]. The FDA has some statistics on cases of fatal blood losses but the known numbers are probably too low to reflect the real figures [5]. Ahlmén et al. estimate the incidence of venous-needle dislodgements of 0.1% is merely an approximation over a short period [5]. Although certain devices monitoring venous pressure [6], pressure pulse, [7]
and moisture [8, 9] have been developed, tested, and patented, a “VND sensor” has been requested by patients and medical professionals [10]. The European Dialysis and Transplant Nurses Association/European Renal Care Association (EDTNA/ERCA) has produced 12 practice recommendations to help reduce the risk of VND and detect blood leakage as early as possible [4]. A device that uses fiber optic technology to detect blood has been approved (CE marked) as a Class I medical device with the intended purpose of detecting VND in extracorporeal circuits [4, 5]. 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 [4].

Although there was no observed event that led to dislodgement of the needle in most reported episodes [11], the oozing of blood has commonly been noticed on a tape or small gauze at the needle site in hemodialysis [11–13]. 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 a moisture or enuresis detector is not suitable in Japan because the DC 5 V power supply could cause a microshock by ionization in the skin. Processing an optical fiber in a blood sensor is technically difficult in our laboratory. Moreover, the fiber was already used in the above blood loss detection device, STELARA,™ Redsense Medical, Halmstad, Sweden [5]. Although it is easy to imagine that light transmission through gauze might be changed by blood on the gauze, to our knowledge, there is no practical report of light transmission affected by blood or any 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.

MATERIALS AND METHODS

Light sensor module

The sensor module consists of a light emitting diode (LED, lambda max = 645 nm, 55 mcd, HLMP-Q105), a photo diode (PD, spectrum 600–1,050 nm, DIL-BPW34) on a simple circuit that is commonly used in light/dark sensors (Figure 1). A piece of gauze pad is clipped between the LED and PD. The PD changes its resistance depending on the intensity of the light transmitted. The voltage across the resistance R2 (12 kΩ) 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.

Gauze and test medium

Two types of gauze pads were used in these experiments: a tightly woven pad, the “tight-weave pad,” was cut into a 3-cm square from a surgical skin care pad (Multi Fix Pad 3, Alcare Ltd., Japan); and a loosely woven pad, the “loose-weave pad,” was a piece of gauze also cut into a 3-cm square (Blood Ban, L size, Yutoku Pharmaceutical Industry, Ltd., Japan) similar to those used after collecting blood or administering infusions such as the gauze pad in a BAND-AID™. Although the surface of the gauze pad was fully covered with a transparent plastic sheet or a light-brown plastic mesh covering, the back was bare to make contact with the skin. To avoid contamination between the photo sensor and liquids, and to avoid any short-circuits caused by any liquids that might have overflowed onto a pad, an extra-wide edge of the covering was manually folded over to cover the edge of the gauze pad. 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 (RO) water, physiological saline, and glucose in water at 5, 10, 20, 40 and 50%. All of these except the RO water were pharmaceutical products. Porcine plasma and blood (Hct 40, 30 and 20%) were also applied and tested in the same manner. The hematocrits were prepared by adding porcine plasma but not saline. An additional experiment was done for two kinds of porcine blood (Hct 44%) that was