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The design of an electronic alarming angiocatheter: An intelligent instrument for hospitalized patients

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ABSTRACT

Vessels bloodretrograde into theintravenous tube can cause some problems such as blood clotting, waste of time, interfere with the treatment process and the patient's anxiety. The aim of this study was the design of a device to warn the blood retrograde into the intravenoustube. Designed peripheral intravenous catheter, warns medical staff by alarming blood retrogrades into the intravenoustube. Changes in the blood concentration showed no significant effect on the sensitivity of the device. Certainly this practical angicatheter can be helpful in improvement of treatment process and also helps to patient's calm.

Keywords: Clinicalalarm; angiocatheter; medical device designs; hematophobia; intravenous

INTRODUCTION

1. Background

Vessels blood retrograde into the intravenous tube is one of most common complication of the inpatient treatment process in the various parts of clinics and hospitals that this can follow two types of problems:

A] Corporal and economical: Delay of treatment staffs during blood retrograde could increase the risk of hemolysis and clotting which cause corporal and economic damages:

- Interference with passing drug or fluid through the IV tube with clogging caused by importing blood into the intravenous tube.
- Waste of time for medical staff [Considering the necessity of change serum intravenous set].
- The economic costs related to the replacement of intravenous set and loss of sensitive and expensive drugs during the discharges of blood clots.
- Increase the risk of peripheral vein thrombophlebitis

Inflammation of the vein wall due to mechanical or chemical stimulation or infectious agents [thrombophlebitis] is the commonest complication associated with a PIVC [1-4].

This phenomenon is usually characterized and diagnosed clinically. Common causes of infectious phlebitis are germs that they colonize the catheter center and the skin around the entry point of the catheter. Intravascular catheter-related infections are a major cause of morbidity and mortality in the United States [5]

Blood is a suitable environment for microbial growth, thus blood stasis during clotting in the intravenous tube can provide these situations. The most common route of infection for short-term catheters is the migration of skin organisms at the insertion site into the cutaneous catheter tract and along the external surface of the catheter, also infection of intravenous fluid and hub, or hematogenous dissemination from a contaminated focus elsewhere may involve [2, 6].

There have been many theories on the physiology of peripheral vein infusion thrombophlebitis. The currently accepted concept suggests that catheterization of the vein leads to inflammation and thrombus formation [1].

Totally, prevention of blood clotting in intravenous tube and reducing catheterization can decrease thrombophlebitis.The peripheral intravenous catheterization should be minimized in the ICU&CCU wards and in the diabetic patients [2].

B] Psychological: Blood in the intravenous tube, for most of patients and their relatives is an unpleasant situation. It may even cause anxiety, especially in patients with hematophobia disorder. So design of medical devices which prevents intravenous tube blood clotting is a helpful way to calm patient's by "reducing the likelihood of intravenous set replacement".

Although placing a check valve within the intravenous tube can prevent blood retrograde, but blood flow statics can cause clotting again. [7]

2.Objectives

In the present study, an angiocatheter with relatively user-friendly design was evaluated that does not have mentioned limit.

MATERIALS AND METHODS

According to the transparency of intravenous tube, blood retrograde can detect by electronic eye.

So, this device includes an electronic eye chip which used to detect blood retrograde from veins. Since the extra light (the environment) was an affecting factor on the sensitivity of this device, the circuit design of an infrared receiver (infrared) instead of visible light-sensitive receptors were used.

3.1. Components

Electronic eye could be used in two methods:

A) External model: In this model circuit sensors (receptor and the sender) set up at the end of angiocatheter or PIVC tube and main circuit installed out of PIVC set. (Figure1).

B) Internal: This model includes 2 parts: Electronical and Mechanical. Mechanical part consists of PIVC and Electronical part consists of an Electronical circuit and power circuit (Figure2).

Electronic and power circuit were located over PIVC fins so the two parts of PIVC and circuit are mixed. (Figure3). Internal model was compact and comprehensive form of device.

3.2. Design

Since the majority of the intravenous sets and angiocatheter middle tube are transparent and will not block visible light and infrared rays, an infrared transmitter was placed on one side of the Angiocatheter tube and a receiver on the opposite side (on the end section of angiocatheter, the nearest distance to the vessel)(Figure3).

Normally there is no reaction, but since human blood is dark (red) due to hemoglobin, by exposure of the blood between the transmitter and receptor, the relationship between the receptor and the sender interrupts and this situation felt by the receiver circuit and the circuit is activated.

For reducing battery exchange, PIVC circuit uses Watch Dog mode battery. Aslo potentiometer is used to adjust the sensitivity of this device. Considering the resistance of the potentiometer to changeable then the output voltage is also adjustable.

Alarming circuit via visual signals (LED) or audible (through a small buzzer that is set on PIVC and warns medical staffs at the beginning about blood retrograde). (Figure4)

3.3. Test of the device

The difference of this PIVC with another PIVCs is its electronic chip. In Vitro test was designed by using the external model (figure 5).

Thus, test of device based on seprate electronic chip which was a combination of two internal and external models.

First, the sensitivity was tested by the passage of blood from the intravenous tube that the transceiver was installed on the both sides of tube; the sensitivity of device was adjusted by changing of potentiometer in sensing range, So that the alarm worked when blood crossed.

The most important component affecting the sensitivity of this device is the blood concentration. Returned blood in the intravenous tube may be diluted in contact with the intravenous liquid. Therefore, a high sensitivity is necessary to react with the diluted sample, so the sensor receiver and transmitter of device was installed on both sides of an ordinary test tube (Figure5).

Then a normal blood sample into a tube of the oxalate was used for testing. The blood samples were elected from near the base limit of normal adult hemoglobin that in this experiment was 11.2.

RESULTS

First 0.5 cc of blood was moved into the test tube which the sensor was mounted on it. To dilute the blood, 0.5 cc of normal saline was added to it and then saline was added regularly.

When 0.5 ml of blood was gone into the test tube which sensed by the device and the alarm played. By diluting the blood, the alarm was played again. Then saline was added regularly and the device was sensitive each time, so that the ratio of 1 to 44 (blood: saline) was obtained. The higher degree of sensitivity did not show in the device. The experiment was repeated once again that it was repeatable. At the second time, the ratio was 1 to 47(p-value<0.05).

DISCUSSION

PIVCs are common medical devices that are used for fluid therapy and administration in the treatment of patients in all age groups. There is not any exact information on global consumption. But, in the United States, annually about 25 million pieces of intravenous catheters are used [8] and 15 million central vascular catheter [CVC] days [i.e., The total number of days of exposure to CVCs among all patients in the selected population during the selected time period] occur in intensive care units [ICUs] each year [5]

Among the common problems associated with catheter injections, blood retrograde and clotting has been considered as a significant complication. Research shows that among the 490 IV injections, 22.4% had complications that 10% of total complications were obstruction [9].

Sometimes patients should receive a fixed dose of drug. When clots create in intravenous tube, it is necessary to separate the intravenous tube from the angiocatheter. Clots are washed by exit some of the intravenous liquid, but the amount of the drugs in an intravenous container [micro set] also wastes and can interfere with the treatment process.

On the other hand, unpleasantness to see blood in intravenous set, then anxiety, and in the most severe status, hematophobia [Blood-injury-injection [BII] phobia] are the range of the psychological effects that is discussed more in this context. One of the main symptoms of this disorder is the excessive and unreasonable desire to avoid a feared object or situation like intravenous therapy [10].

BII phobia is triggered by the sight or anticipation of blood, wounds, syringes and similar stimuli [11]. The prevalence of BII phobia among the general population in the United States is estimated about 3% to 4% [12, 13]. The highest prevalence of BII phobia is found in females in reproductive age [% 3.3], while the prevalence rates in men range from 0.7 to 0.8% [14].

On the other hand, hospitalized children often are accompanied by their mothers that are in this age period and an early age of onset at around 5.5 years [12]. Hospitalization of children is fairly stressful for both children and their parents[15].

Out of fear, patients may abstain from necessary medical treatment despite negative consequences for their health [16, 17]. Fainting is a major reason why patients with a blood injury phobia are afraid of confrontation with the feared stimuli, and it is still not fully understood [18].

Although most of the patients were not suffering from hematophobia disorder, but some degree of anxiety or at least unpleasantness could be seen. These patients like other patients, often during the same admission process encounter by intravenous injections, which is inevitable, but installing a device that prevents from entering of blood into the intravenous tube in a relatively long time period of receiving intravenous, can help patients and their relatives to be calm.

Although behavioral therapy, such as exposure to irritants and participant modeling has been used successfully to treat BII phobia [19, 20] and generally for the treatment of specific phobias, exposure therapy is the most common method, but severe cases of hematophobia can cause physical reactions that are unusual in most other phobias, especially vasovagal syncope [fainting]. In the most of the phobias, exposure to fear factor can be result in increased heart rate, but these patients, mostly have a biphasic cardiovascular response, including: initially increased the heart rate, then reduction in heart rate, hypotension, shock, dizziness, syncope, sweating, nausea and rarely systole and death [21, 22].

Also Venipuncture is one of the most routinely performed invasive and time-consuming procedures, especially in condition such as cardiac failure, edema, hypotension.

Hence, if the blood entry into the intravenous tube, the present device warns and prevents from blood clotting within the angiocatheter and it can also result in calm of the patient by "reducing the likelihood of the intravenous set replacement".

To evaluate the impact of changes of blood concentration on the sensitivity of the device, performed experiments in laboratory showed no significant effect on its accuracy. Thus, its use is appropriate in hospitalized patients, especially in the parts that patients are not accompanied by their relatives.

One of the causes of blood retrograde into the intravenous tube is the finishing of the intravenous contents because blood can move within the intravenous container due to increased relatively blood pressure in comparison with the pressure from the gravity of intravenous fluid. Hence, this device will notice the finishing of the contents of the intravenous Container to medical staff.

It seems that simple mechanical medical device developed to electromechanical device. This developing also can be seen in relatively simple tools like a tourniquet [23].

Some research used an optical device to determine the Related Blood Volume in patients undergoing hemodialysis, during the process, but applying this method into the PIVC was innovative [24].

CONCLUSION

The new generation of intelligent angiocatheter designed for detecting blood return and warning of intravenous flow finishing.Also, it is a small step to improve medical ethics in the clinical centers by decrease anxiety andabsorb the patients with hematophobia to this center. Therefore, future study should be conducted to evaluate the psychological and clinical aspect of this instrument.

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Abbreviations:
PIVC = Peripheral intravenous catheter
IV = Intra venous
CVC = central vascular catheter
(BII) phobia = Blood-injury-injection