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DEVELOPMENT OF AN AUTOMATIC BLOOD SAMPLING SYSTEM: CONTROL OF THE PUNCTURING NEEDLE BY MEASURING FORCES

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***Abstract*- For automatic blood sampling to occur, a needle must stop automatically once it is introduced to the blood vessel. Medical technologists can confirm, by the changes in puncturing force, the moment at which the tip of the needle enters the blood vessel. To achieve automatic blood sampling, we have attempted to measure the force required to puncture a blood vessel.**

A device with a force sensor installed inside was developed to measure the force acting on the needle. Experiments involving puncturing of the vena mediana cubiti of 10 volunteers and a rabbit ear vein were performed. A medical technologist was asked to puncture the vena mediana cubiti. In the rabbit experiments, the measuring device was set on an electric-driven linear stage, which was controlled by a personal computer.

In the rabbit experiments, a typical peak was observed in the wave form of the puncturing force, and in the volunteer experiments, two typical peaks were observed. It was considered that just after the last peak appeared, the tip of the needle was inserted into the blood vessel. These results have shown that measuring the force at the time of puncturing a blood vessel will be applicable to achieving automatic blood sampling.

I. INTRODUCTION

Blood sampling is performed frequently in clinical settings. As there is a fear of infection when the needle pricks the operator, the development of an automatic blood sampling system has become an expectation. We are therefore trying to develop a safe, simple and easy-to-operate automatic blood sampling system [1]. There are some problems associated with developing such a system, including the choice of the blood vessel, the angle and speed of the needle's insertion into the blood vessel, and the method used to put the tip of the needle inside the blood vessel without piercing both walls of the blood vessel. This study aims to develop a method for introducing the tip of a needle into a blood vessel, and to perform automatic blood sampling experiments.

II. FORCE MEASUREMENT DEVICE

A device that can measure the force acting on the tip of the needle was developed. As shown in Fig. 1, the device was similar in shape and size to a syringe, with a diameter of 22 mm and a length of 55 mm. A force sensor and a tube were installed inside the device. Changes in the puncturing force were measured with the force sensor, and the tube connected to the needle led the blood to a suction syringe. The output of the force sensor was sampled and recorded by a personal computer.

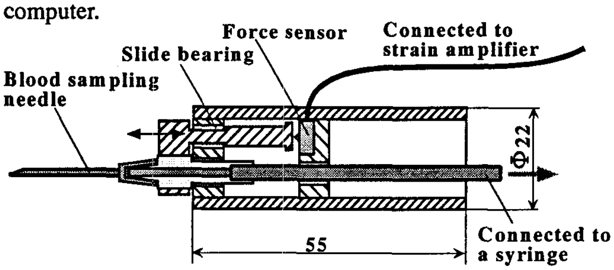

Fig. 1. The device for measuring the force on puncturing

III. EXPERIMENTS

The device was used in three experiments involving the puncturing of a rabbit ear vein and of the vena mediana cubiti on the forearm of human volunteers.

Experiment 1 Puncturing a rabbit ear vein

Puncturing experiments were performed on a rabbit ear vein, which was fixed with a bandage. The diameter of the rabbit ear vein is about 1–2 mm. The diameter of the needle was 0.4 mm. The measurement device was set on an electric-driven linear stage, which was controlled by a personal computer. The experimental setup is shown in Fig. 2. The speed of puncturing was 2.5 mm/s. The angle of puncturing was about 15–30 degrees. The electric-driven linear stage was stopped when we confirmed that the tip of the needle had entered the rabbit ear vein. We judged whether puncturing of the vein was successful by observing the blood flow in the device's tube. The puncturing lasted for about three seconds.

Almost reproducible results were obtained in 10 trials. The maximum force of puncturing was 0.11 ± 0.01 N(ϕ0.4mm needle) for the rabbit ear vein. When the tip of the needle touched the skin of the rabbit's ear, the puncturing force increased gradually. Before the device stopped, the puncturing force decreased. One typical peak was observed in the wave form of the puncturing force. It can be considered that this peak appeared when the needle pierced the vessel wall, and the tip of the needle was then inside the vessel.

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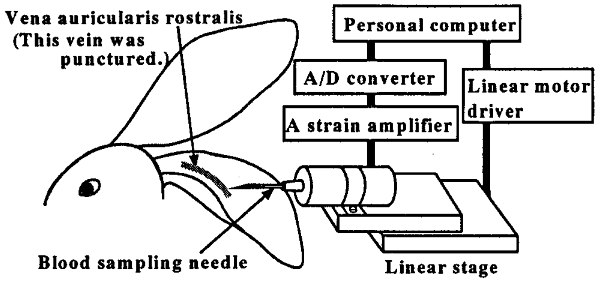

Fig. 2. Experimental setup with the animal

Experiment 2 Automatic puncturing of the rabbit ear vein

Under the same conditions as Experiment 1, the device on the electric-driven linear stage was stopped by a computer immediately after the peak in the puncturing force wave form appeared. An example of the results is shown in Fig. 3. In this experiment, automatic puncturing of a vein was successful on 11 occasions in 14 trials.

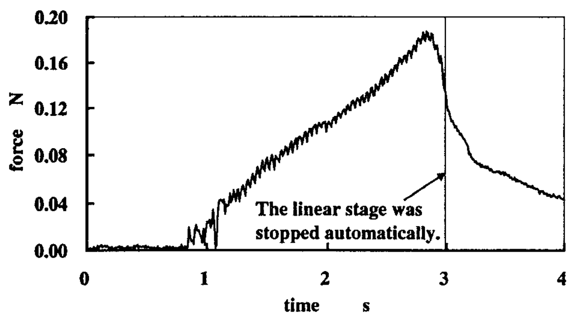

Fig. 3. An example of a puncturing force wave form in the puncturing of a rabbit ear vein

Experiment 3 Puncturing the vena mediana cubiti of volunteers

Using a simulator as shown in Fig. 1, experiments of puncturing were performed using the vena mediana cubiti of volunteers, and the force of puncturing acting on the tip of the needle was measured. The subjects were nine healthy male volunteers and one healthy female volunteer (24.6 ± 4.4 years old). The experiment was performed with the subjects' consent. A medical technologist punctured the vena mediana cubiti. In this experiment, two types of needle, which had diameters of 0.8 mm and 0.4 mm, were used. The speed of puncturing was about 15 mm/s and the needle was moved in a straight direction. The angle of puncturing was about 15 degrees. As a comparison with normal blood sampling, the medical technologist also punctured the skin of three male volunteers under which there were no blood vessels. The puncturing lasted for about one second.

An example of the results is shown in Fig. 4. In this experiment, the maximum force of puncturing was 0.64 ± 0.23 N (ϕ 0.8mm needle) and 0.23 ± 0.09 N (ϕ 0.4mm needle) for the vena mediana cubiti. When the 0.8 mm diameter needle was used, two typical peaks were observed in the puncturing force wave form. This tendency was shown in 7 of 10 volunteers. In the case of puncturing the skin, only one peak was observed in the puncturing force wave form. This tendency was shown in 2 of 3 volunteers, and the two typical peaks could not be confirmed in the other volunteer. From these results, it can be considered that the first peak corresponds to the force of puncturing the skin, and the second peak corresponds to the force of puncturing the vessel wall. However, when the 0.4 mm diameter needle was used, there was not any obvious wave form feature. Since the peak value of the puncturing force using the 0.4 mm diameter needle was smaller than that using the 0.8 mm diameter needle, the movement of a technologist's hand has a great influence on the puncturing force.

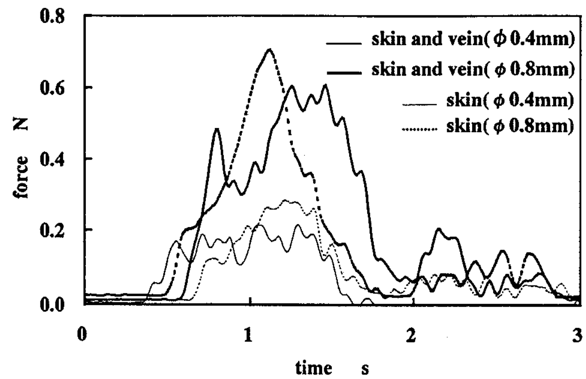

Fig. 4. Puncturing force wave forms on the vena mediana cubiti and the skin of a volunteer

IV. DISCUSSION

By measuring the puncturing force wave form in the experiments involving puncturing a rabbit ear vein, the blood sampling needle could be stopped automatically before it pierced the blood vessel. In addition, in the experiments involving puncturing the vena mediana cubiti, the puncturing force wave form was similar to that observed in the rabbit ear experiments. After the second peak was observed, the tip of the needle was inside the blood vessel. Therefore, it can be considered that the needle will be stopped automatically in the vein in the same way that occurred in the rabbit experiments. These results have shown that measuring the force on puncturing the blood vessel will be applicable to the achievement of automatic blood sampling.

REFERENCE

[1] H. Komine, O. Takahashi, H. Saito, T. Togawa, K. Tsuchiya. "Less invasive blood-sampling system mimicking the mosquito." World Congress on Med. Phys. and Biomed. Eng., vol. 39a(1), pp. 42, 1994.