Wound Drainage Monitoring and Warning System

Tong-Jin Chou*, Wei Wang†, Chia-Hui Chin†, Hsiu-Chuan Wu†, Young-Ching Chou*,
Yu-Chee Tseng*, and Cheng-Kuan Lin*
* Department of Computer Science, National Yang Ming Chiao Tung University
† Department of Nursing, Shin Kong Wu Ho Su Memorial Hospital

***Abstract*—A patient's wound healing status can be characterized by the amount, type, color and smell of wound drainage fluid. Typically, patients undergo the removal of the drainage tube within a time frame of 24 to 72 hours following surgery. This early removal of the drain aims to reduce the risk of retrograde infection and enhances the overall comfort during the recovery process. Based on monitoring and analyzing the flow and color changes of drainage fluid, we proposed a timely early warning system for wound drainage. This system can inform the medical staff of the patient's wound status in real time, and assist the medical staff to analyze the patient's wound healing degree.**

***Index Terms*—color of wound drainage, wound drainage monitoring , warning System**

I. Introduction

Most postoperative patients in the surgical ward have wound drainage tubes, the purpose of which is to remove air, blood or exudate from the wound to promote healing and avoid infection. Information such as the color, shape, flow rate, and flow rate of the drainage material can provide medical personnel with the ability to determine whether there is infection, leakage, or bleeding in the surgical wound. The drainage tube is the predominant device utilized for surgical drainage. It offers benefits such as a simple structure, affordability, safety, minimally invasive nature, and effective drainage [1], [2]. It used to drain accumulated fluids (such as hematomas, bile, and pancreatic fluid) out of the body or into other parts of the body to prevent infection, reduce inflammation, prevent compression and irritation of surrounding skin tissues, accelerate wound healing, reduce complications, and promote wound healing [3], [4].

However, the drainage tube can become blocked due to bending or the presence of foreign objects such as pus, blood clots, stones, tissue fragments, floccules, and lung tissue. If proper remedial measures are not taken in time, it may cause water accumulation and infection at the drainage site, and even threaten the life of the patient. Furthermore, by observing the color change and flow change of the drainage fluid, it can be used to judge the wound healing status of the patient.

The healing status of a patient's wound can be assessed by evaluating the quantity, type, color, and odor of the wound drainage fluid [5]. The color of drainage can offer insights into the healing process and potential complications such as clear or pale yellow indicates healthy, healing wound, red indicates fresh bleeding (see Fig. 1(a)); cloudy, yellow, or tan indicates the wound is becoming colonized (see Fig. 1(b)); brown indicates older or dried bloods; white or milky-colored drainage indicates infection; and blue-green color indicates Pseudomonas infection. Significant drainage can be indicative of an infection, while a decrease in drainage may suggest a resolving infection or insufficient arterial circulation.

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(a) (b)

Fig. 1. Two types of wound drainagea, (a) normal and (b) colonized.

In this paper, our task is to realize a timely early warning system for wound drainage by monitoring and analyzing the flow and color changes of drainage fluid. We have developed a monitoring system based on weight sensors and color sensors. This system allows real-time monitoring and early detection of abnormal flow rates and color variations in the drainage fluid of patients. By analyzing the sensing data, we can promptly identify any anomalies in the flow rate or color of the drainage fluid. This approach offers the advantage of not requiring any modifications or alterations to the existing drainage tubes and bags. Additionally, it enables accurate measurement of the flow rate of the patient's drainage fluid.

II. Related Works

Drainage monitoring is an aspect of patient care that is frequently underestimated, and the care provided for drainage is often inconsistent and insufficient [6]. The timing for removing various types of postoperative drainage tubes may differ, a common practice is to consider removing them when the drainage fluid decreases to around 100cc per day and becomes clear with no signs of leakage. While there are some guidelines for interpreting color changes in the drainage fluid, there is currently no standardized criterion. Essentially, healthcare professionals rely on their subjective judgment when assessing the color [5]. It has been proved feasible in several studies [7]–[9] that patients uploading images of their wounds to hospitals or medical centers, followed by online evaluations by medical professionals and prompt responses regarding the patients' wound conditions.

III. Method

While there are several methods available for measuring fluid flow, such as ultrasonic flow meters, thermal mass flow meters, and optical flow meters, the current challenge lies in effectively measuring postoperative drainage in patients. This is due to the fact that postoperative drainage bags are typically soft and flexible, and the drainage tubes are characterized by their thin walls, short length, low flow rates, and higher viscosity. Moreover, postoperative patients require a solution that is portable. As a result, existing approaches are not suitable for accurately measuring postoperative drainage in patients. Meanwhile, there are privacy concerns associated with using cameras to capture images of the patient's drainage fluid. Therefore, we propose a monitoring system based on weight sensor and color sensor. By analyzing the data from the weight sensors, we can calculate the flow rate of the drainage fluid over a specific time period, allowing us to assess the healing status of the patient's wound. Additionally, by analyzing the data from the color sensors, we can obtain the color values of the drainage fluid, enabling us to analyze whether the patient's wound is prone to suppuration or infection. This approach addresses privacy concerns while still providing valuable insights into the condition of the patient's wound.

The weight sensor and color sensor will periodically measure the weight and color of the patient's drainage bag. Those sensing data will be returned to the server of hospital in the following format:

$$[\textit{sensing\_time, ID, drainage\_weight, drainage\_color}]$$

where "*sensing_time*" is the timestamp of the data sensing, "*ID*" is the patient's ID number, "*drainage_weight*" is the weight of drainage measured by the weight sensor during that particular measurement, and "*drainage_color*" is the color values measured by the color sensor during that particular measurement.

Assume that $t_2 > t1$. The average flow per hour is $d_f = \frac{(w_2-w_1)\times d_{dra}}{t_2-t_1} \times 60$ where w_i is the weight of drainage is time t_i for each $i \in \{1,2\}$, and d_{dra} is the density of drainage. The flow chart of drainage warning system is shown in Figure 2 where ε_u and ε_l are the normal flow upper bound per unit time and the normal flow lower bound per unit time, respectively. Table I illustrates the range of RGB values obtained from our testing for various types of drainage using TCS34725 RGB Color Sensor.

TABLE I
THE RANGE OF RGB VALUE OF DIFFERENT TYPE DRAINAGE USING TCS34725

Type	R	G	B
Normal	$27.96-35.19$	$11.13-13.39$	$4.78-6.28$
Sanguineous	$23.05-32.97$	$7.97-11.96$	$6.85-9.68$
Colonized	$11.96-19.69$	$12.57-17.98$	$7.97-11.96$

IV. Simulation Results

Shin Kong Wu Ho Su Memorial Hospital provide 10 wound drainage samples collected. Under those samples, The early

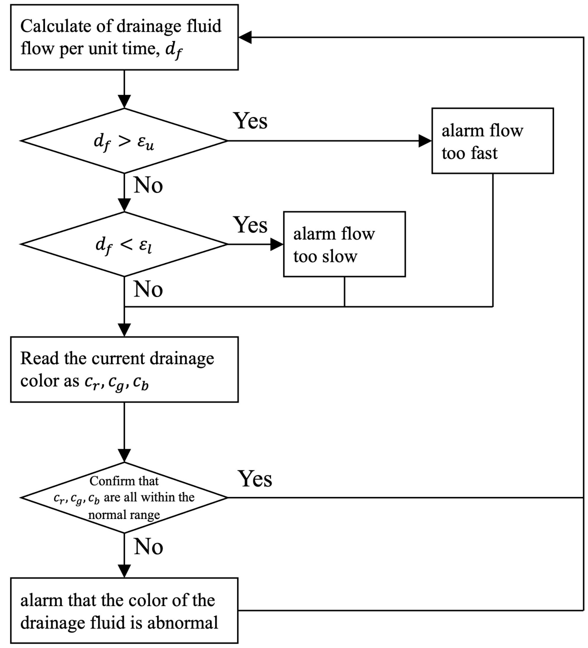

Fig. 2. The flow chart of drainage warning system.

warning accuracy rate of our system's flow and color reaches 98%. Limited by the accuracy of the weight sensor and the influence caused by the pulling of the drainage tube, after we filter out the abnormal detection value, the accuracy of converting the flow rate per 2 hours based on the weight measurement can reach 95%. Therefore, this system has the potential for practical application. In the future, we will continue to optimize various measurement data to reduce the system's error rate.

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