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Application of Intelligent Blood Temperature and Humidity Monitoring System in Blood Station

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ABSTRACT

Objective: To explore the application of intelligent blood temperature and humidity monitoring system in cold chain management of blood station. Methods: Through the monitoring of fifty sets of cold-chain equipment in the central blood station in Hezhou for 6 months, the differences between the management of the automatic temperature and humidity monitoring system and the manual management were compared in terms of real-time recording, equipment alarm, data storage, historical data traceability and data analysis. Results: Temperature and humidity automatic monitoring system can automatically real-time acquisition, transmission, storage and alarm according to the required time interval; meanwhile, historical data can be quickly exported and traced, data and charts can be analyzed, and the alarm is real-time and effective. Conclusion: The system can effectively monitor the process of blood cold chain in blood stations and play a key role in ensuring blood quality. It can be popularized and used in blood stations.

1. INTRODUCTION

The quality of blood is closely related to the safety and effectiveness of blood transfusion, which directly affects the health and medical quality of patients. Temperature is one of the key links in blood quality assurance; "Blood Storage Requirements" WS399-2012 puts forward clear requirements for blood storage: "When manual monitoring is used for blood storage equipment, the temperature should be monitored and recorded at least once every 4 hours; When using the automatic temperature monitoring and management system for blood storage equipment, manual records should be made at least twice a day, with an interval of more than 8 hours between the 2 records" [1]. At present, cold chain equipment gener-

ally uses traditional manual recording temperature monitoring management, which has many disadvantages: Due to the large number of cold chain equipment, manual inspection and manual recording are time-consuming and laborious, and temperature monitoring cannot be fully monitored in real-time 24 hours; The failure of refrigerator equipment during night shifts and holidays cannot be detected and dealt with immediately; Manually recorded data is difficult to archive and query; and it is difficult to track, analyze and count the operation status of blood storage equipment for a long time [2, 3]. Therefore, the automatic temperature and humidity monitoring equipment networked with the computer will become an inevitable trend which can realize functional applications such as network application control, 24-hour automatic monitoring, automatic recording of temperature and humidity data, statistical summary of temperature and humidity data, etc.; At the same time, it realizes automatic alarm for abnormal temperature and humidity, and timely and automatically notify management personnel to take corresponding measures. Taking the central blood station in Hezhou as an example, the author discusses the effectiveness and practicability of the intelligent blood temperature and humidity monitoring system in the blood cold chain monitoring.

2. MATERIALS AND METHODS

2.1. Hardware and Software

Hardware: wireless intelligent temperature and humidity recorder (temperature probe), which mainly monitors the cold chain equipment and records the temperature and humidity; Wireless intelligent gateway mainly receives the temperature and humidity data of "sensor/temperature and humidity probe/node", converts it into the data format received by "cold cloud platform" and encrypts it, and then transmits it to "cold cloud platform"; Fluke thermometer is mainly used for temperature comparison of fluke thermometer calibrated by measurement; Computers are mainly used for temperature monitoring and recording.

Software: The remote intelligent monitoring platform which has the functions of data acquisition, data storage, data analysis, temperature and humidity upper and lower limit alarms of temperature and humidity sensors. Users can perform equipment management, system configuration, account settings, real-time monitoring, alarm query, historical data query and other functions. The schematic diagram of temperature and humidity data management is shown in **Figure 1** below.

2.2. Methods

2.2.1. Hardware Installation

1) Refrigerator Takes Smart Gateway + Countless schemes of Wireless temperature and humidity recorder; The external probe is mainly located in the middle of the refrigerator. Probe measurement precision ±0.3˚C; ±3%RH. 2) The blood transport box adopts intelligent gateway with GPS positioning + schemes of Wireless temperature and humidity recorder; The wireless temperature and humidity recorder is directly put into the transport box; GPS positioning intelligent gateway is placed outside the transport box.

2.2.2. Temperature and Humidity Setting and Collection

The upper and lower limits of temperature and humidity shall be strictly set according to the requirements of various blood preservation and transportation; Data acquisition 2 minutes/time, data storage 5 minutes/time.

2.2.3. Alarm Setting

When the temperature and humidity exceed the upper and lower limits for 10 minutes, the on-site gateway will give an alarm, the management platform will give an audible alarm, and push the WeChat alarm. It means that after the temperature and humidity of the cold chain exceeds the standard (beyond the range), the "cold cloud platform" will directly push the alarm information to the mobile WeChat of relevant staff/managers through its "WeChat alarm function module", so as to deal with the problem in time. Among them, the smartphone of the staff/Manager receiving the alarm information needs to

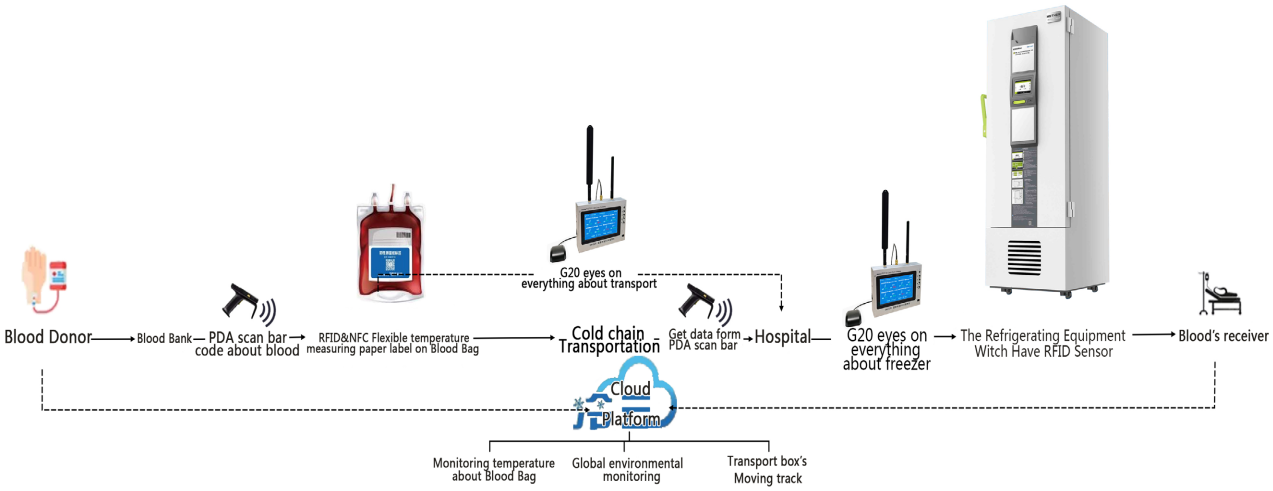

Figure 1. **Flow chart of temperature and humidity data management.**

download and bind the app or official account of the "cold cloud platform". User defined 2-minute interval for push. As long as the equipment is abnormal, the system will push the alarm information to ensure that the abnormality can be found and handled in time.

2.2.4. Data Setting

The data platform is saved for 5 years; Data score value and curve display, setting which can be backed up, saved and exported in any time period.

2.2.5. Accuracy of Temperature Measurement

The fluke thermometer calibrated by measurement is used for comparison.

3. RESULTS

3.1. Real Time Recording; Equipment Alarm Comparison

Measurement accuracy, convenience and time limit; Over temperature alarm mode, timeliness, effectiveness, etc., the accuracy of the automatic temperature and humidity monitoring system has obvious advantages over manual management, See Table 1.

3.2. Comparison of Abnormal Alarms

During the 6-month monitoring of 50 sets of cold chain equipment, a total of 176 cases of abnormal temperature and humidity alarms occurred in automatic monitoring, and 176 cases were effectively alarmed, including 52 cases of equipment sealing problems, 98 cases of human factors, and 26 cases of cold chain equipment failures; There were 36 cases of abnormal temperature and humidity alarm by manual monitoring, and 17 cases were effective alarm, including 3 cases of equipment sealing problem, 12 cases of human factors, and 2 cases of cold chain equipment failure. 17 cases of effective alarm by manual monitoring were identified by automatic monitoring, See Table 2.

3.3. Data Preservation, Historical Data Traceability and Data Analysis

The manually managed paper records of temperature and humidity are inconvenient to save, occupy a large physical space, can not quickly trace the history, and it is difficult to analyze the overall data. The data of the automatic monitoring system platform can be electronically backed up and exported at any time, such as day, week, month, quarter and year; and the automatic monitoring system platform can analyze the data of any time period and equipment, See Figure 2 & Figure 3.

Table 1. Real-time recording, Device alarm comparison.

Accuracy	Convenience	Time-limited	Alarm method	Alarm timeliness	Alarm validity
Automatic monitoring	0.2˚C ± 0.1˚C	Achieve 24 hours unattended	5 minutes	Sound and light, platform, information push	10 minutes Continued alarm reminder
Manual monitoring	0.5˚C ± 0.4˚C	Manual review required	6 hours	Refrigerator with sound and light or without	30 minutes or none Need personnel on site

Table 2. Abnormal alarm comparison.

Monitoring type	Number of alarms	Number of validity alarms	Equipment tightness	Human factor	Equipment failure
Automatic monitoring	176	176	52	98	26
Manual monitoring	98	17	3	12	2

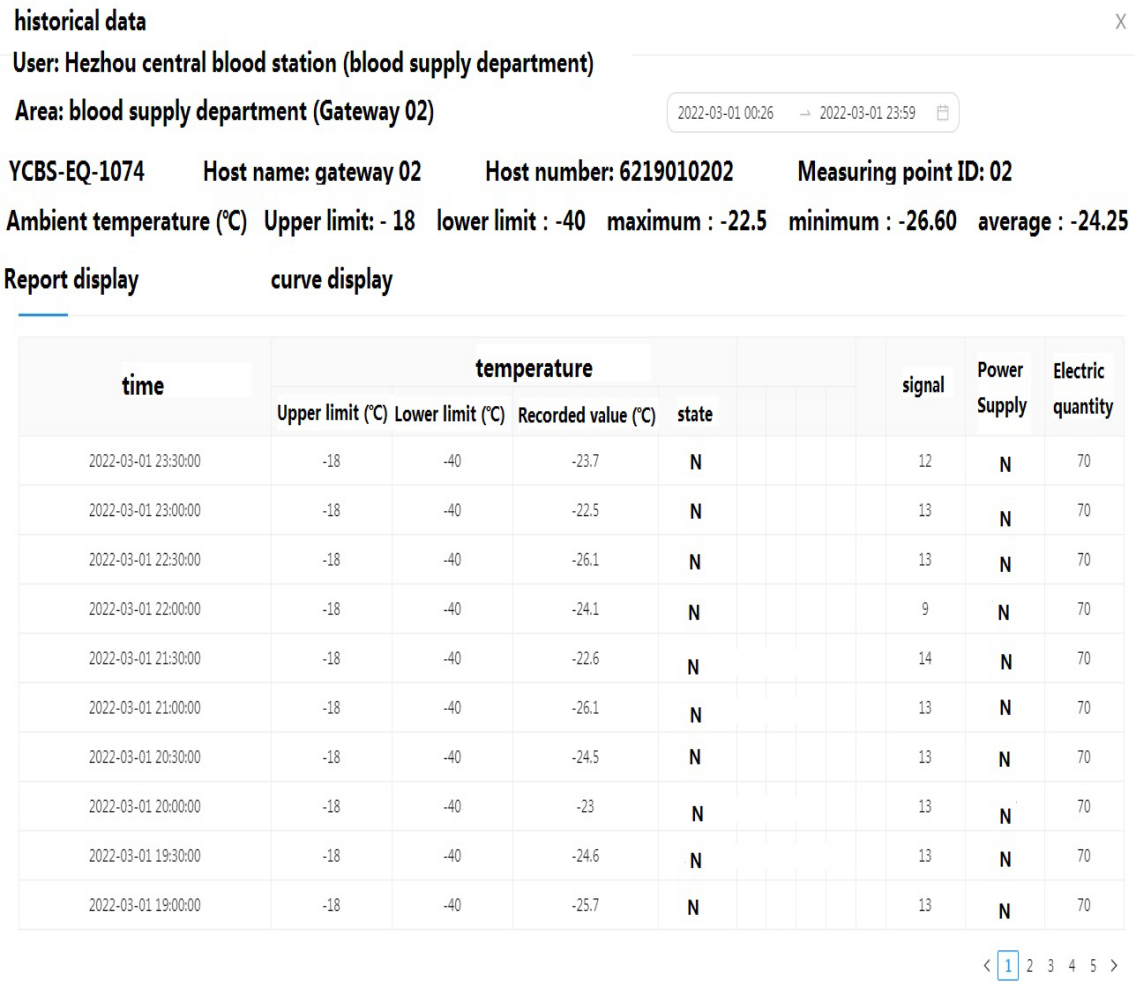

Figure 2. Historical data report display.

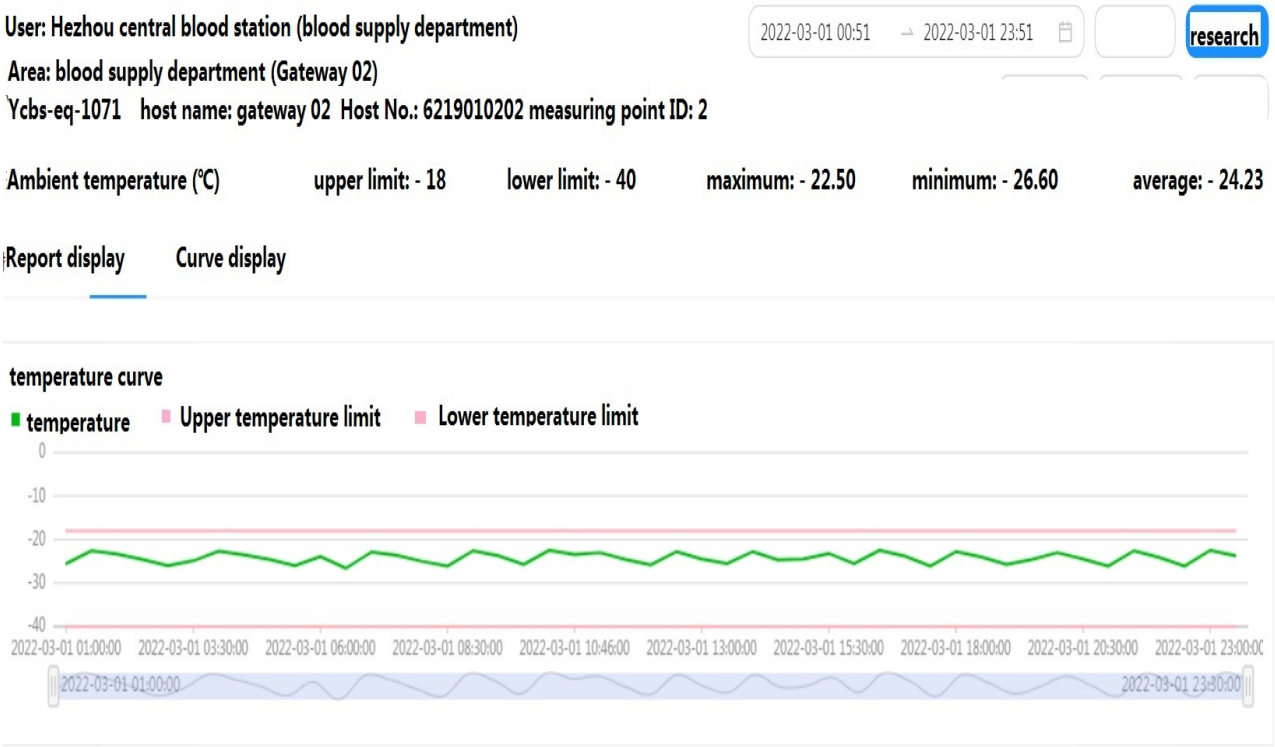

Figure 3. Historical data curve display.

4. DISCUSSION

Blood is an important special resource for the treatment of ischemic patients. The storage and transportation temperature of blood is very important for blood quality, which is not only related to blood storage equipment, but also has a perfect monitoring system. At present, the temperature monitoring of blood collection and supply and hospital blood bank is basically divided into manual monitoring and automatic monitoring. Domestic blood cold chain monitoring mostly adopts manual or chip methods [4], which cannot achieve real-time monitoring, while foreign blood has basically achieved the whole process of cold chain management, and can control the temperature [5]. With the development trend of information technology, many scholars in my country have also carried out research on the standardized quality management model of blood and blood samples throughout the cold chain transportation [6]. Pan Lingling *et al.* [7] have applied research on the cold chain control of the whole process of blood collection and transportation based on Internet+, which proves the feasibility of RFID tags and Internet technology in blood temperature monitoring. There are also scholars who use the Internet of things for real-time total factor monitoring of transportation temperature to solve the problem of timeliness of disposal after the temperature is out of control in the process of blood transportation [8] and the problem of closed-loop management [9]. This paper makes a comparative analysis of manual monitoring and automatic monitoring based on the Internet, and demonstrates its feasibility and practicability.

In terms of real-time recording and equipment alarms, we can see from **Table 1** that manual monitoring still has defects such as low accuracy, relying on personnel on-site operation, relying on the performance of cold chain equipment, inconvenient operation, and low alarm effectiveness, while automatic monitoring systems can realize 24 hours of unattended operation, automatic data recording once every 5 minutes, adjustable abnormal temperature delay alarm from 1 minute to 10 minutes, and continuous push alarm information, so as to achieve real and effective temperature monitoring.

In addition to the cooling capacity requirements of blood storage and transportation equipment, real-time and effective alarms are also important. At present, most of the medical refrigerators used in

blood collection and supply institutions, blood banks and blood transfusion departments are professional medical refrigerators; there are also a small number of ordinary refrigerators, the alarm function is uneven, and it is limited to the on-site sound and light alarm, which cannot realize the real alarm function. As shown in **Table 2**, only 17 of the 98 cases of alarms detected by manual monitoring in this research work are valid, while the 176 cases of alarms detected by automatic monitoring are all valid alarms, which shows that there are large loopholes in manual monitoring, and great risks in blood storage. In 176 cases of effective alarm (including 17 cases of manual monitoring), 98 cases were caused by human factors; the main reasons were frequent opening and closing of refrigerator and long opening time; then, 52 cases of equipment sealing problems which mainly due to the aging of the refrigerator door sealing strip and the staff not closing the refrigerator door according to the specifications. There were 26 cases of cold chain equipment failures; the main reasons were the temperature controller, refrigerator icing, and fan blowing; these problems caused intermittent and periodic alarms in the refrigerator, such as when the indoor temperature was low in the early morning. According to these three problems, the station has improved the operating procedures for the use of refrigerators and strengthened the operation awareness of personnel; The refrigerator of the station has been repaired and maintained, and the management of the cold chain has been further strengthened, so that the alarm problems of the refrigerator have been significantly reduced, and the quality of blood reserve and transportation have been improved.

The automatic monitoring system is used in this station to completely solve the situation of manual statistical data, physical space storage and manual working diagram analysis. As shown in **Figure 2** & **Figure 3**, it can easily call out the data in any time period, and can perform intuitive analysis on digital reports and temperature and humidity curves to further improve efficiency and management.

5. CONCLUSION

To sum up, the system has been officially operated in the station for more than half a year; Combined with the monitoring results of the station on blood temperature, it has fully verified its feasibility, effectiveness and accuracy, and the use of the system further improves the management level of cold chain equipment and personnel operation norms of the station, which plays a key role in ensuring blood quality and the safety of clinical blood use, and can be popularized in the blood station system.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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