Results in Physics 25 (2021) 104320

Contents lists available at ScienceDirect

Results in Physics

journal homepage: www.elsevier.com/locate/rinp

The ZigBee wireless information medical monitoring for bacterial infections using filter mathematical model

Maocheng Cao [a], Junjing Wang [b,*], Chunfeng Wu [c], Aseel Takshe [d], Bishr Muhamed Muwafak [e]

[a] *Information Center, The People's Hospital of Bao'an Shenzhen, Shenzhen City 518101, China*
[b] *Performance Office, The People's Hospital of Bao'an Shenzhen, Shenzhen City 518101, China*
[c] *Human Resources Office, The People's Hospital of Bao'an Shenzhen, Shenzhen City 518101, China*
[d] *Department of Environmental Health Sciences, Faculty of Communication, Arts and Sciences, Canadian University Dubai, Dubai, United Arab Emirates*
[e] *Department of Accounting and Finace, Faculty of Administrative Sciences, Applied Science University, Al Eker, Bahrain*

ARTICLE INFO

Keywords:
ZigBee technology
nCD64
Filter mathematical model
Computer information
Bacterial infections

ABSTRACT

the study drew attention to the application of ZigBee wireless sensor network system based on digital filter mathematical model in the post-chemotherapy monitoring of hematological tumor patients, and the diagnostic value of the average fluorescence intensity of peripheral blood neutrophil CD64 (nCD64) for bacterial infections. In this study, 128 patients with hematological tumors who underwent chemotherapy in hospital were selected as the research subjects. The ZigBee wireless sensor network system based on digital filtering mathematical model was used to monitor the physiological indicators of patients in real time. The subjects were divided into the infected group and the non-infected group according to clinical characteristics and imaging examination results, and dynamic monitoring was performed on patients of long hospital stay but without fever. The two groups were compared for the average fluorescence intensity of neutrophils and the expression of C-reactive protein (CRP), and the ROC curve (Receiver Operating Characteristic Curve) was used to judge the cut-off value, sensitivity, and specificity of PCT, CRP, and nCD64. It was found that, under the ZigBee wireless sensor network system based on digital filtering mathematical model, the patient's ECG frequency of the mixed baseline drift was relatively low, and the system filtered through the 0.5 Hz sine shock chill superposition. The detection accuracy was high; the subgroups of the infection group (the increased group, the normal group, the decreased group, and the deficient group) showed higher nCD64 average fluorescence intensity versus the non-infection group ($P < 0.05$). Dynamic monitoring points 1 and 3 showed higher nCD64 average fluorescence intensity versus the control group, non-infection group, and dynamic monitoring point 2 ($P < 0.05$).The ROC curve revealed that the sensitivity and specificity of average fluorescence intensity of nCD64 (in the infection group and the dynamic monitoring group) were 90.4 and 86.7, 79.6 and 79.6, respectively, in the diagnosis of hematological tumor patients after chemotherapy, higher than PCT and CRP. It suggested that ZigBee wireless information medical monitoring based on digital filter mathematical model can effectively diagnose bacterial infections in patients with hematological tumors after chemotherapy, together with nCD64 average fluorescence intensity.

Introduction

Medical monitoring is the monitoring of the physiological status of patients with relevant medical equipment. Medical personnel can obtain the physiological parameters of the monitor and analyze them at any time, which is helpful to take corresponding measures to treat the patients effectively in time. Traditional medical monitoring system usually needs to connect a lot of cables to the patient for monitoring, which is not conducive to the free movement of patients, and these devices are expensive [1]. With the rapid development of computer information technology, sensing technology and communication technology, wireless sensor network technology has been widely applied in environmental monitoring, industry and agriculture, medical treatment, national defense, and military fields [2]. ZigBee wireless sensor network has the advantages of large network capacity, small size, low power consumption, low cost, short time delay, etc. [3]. It mainly carries out real-time monitoring of physiological indicators such as body temperature, pulse, heart rate, blood pressure, etc., and provides instant

* Corresponding author.
E-mail address: wang_junjinggoup12@163.com (J. Wang).

https://doi.org/10.1016/j.rinp.2021.104320
Received 25 March 2021; Received in revised form 9 May 2021; Accepted 10 May 2021
Available online 16 May 2021

monitoring for patients with related diseases, so as to reduce the harm caused by diseases to patients [4]. YANG et al. (2017) proposed a ZigBee cloud system based on a digital filter mathematical model to monitor the patient's heart rate, pressure, and body temperature. The data was then fed back to the doctor and the patient's family [5]. Abdulhamid and Victor (2019) proposed a wireless sensor network based on the ZigBee communication protocol to continuously monitor the physiological conditions of patients, including body temperature and pulse rate. Medical staff can remotely monitor multiple patients at the same time [6].

Blood tumors include leukemia, lymphoma, multiple myeloma and myeloproliferative diseases. Currently, combined chemotherapy is the main blood tumor treatment method, but while killing tumor cells, combined chemotherapy is also lethal to normal blood cells, and bleeding or infection symptoms often occur [8]. After chemotherapy, patients with blood tumors are prone to leukopenia, especially neutropenia, which can lead to bacterial, invasive fungal, or viral infections. Since the immune function of the body is reduced after chemotherapy, the inflammatory manifestations of the patients are not obvious enough, and some of the patients only have fever symptoms, and the infected site is not clear, which affects the formulation of treatment methods. Therefore, the patients with chemotherapy for blood tumor often get worse or die because of the infection [7]. Neutrophils CD64 has been a hotspot in the diagnosis of bacterial infection in recent years with high sensitivity and specificity. Groselj-Grenc et al. (2019) showed that CD64 index was an effective diagnostic marker for bacterial ventriculitis in pediatric patients with ventricular drainage [8]. Qin et al. (2017) used a combination of neutrophil CD64 and PCT to determine bacterial infection in neonates [9. At present, the research subjects of nCD64 diagnosis of bacterial infection are mostly patients with normal hematopoietic system, and there are few reports on the diagnosis of bacterial infection in patients with blood tumor after chemotherapy.

Physiological signals mainly include blood oxygen saturation, ECG, and blood pressure. Blood oxygen, ECG, and blood pressure can reflect the basic vital characteristics of the human body. By detecting these signals, the patient's health status can be grasped in a timely and effective manner. This is of great significance for long-term monitoring of the disease condition and the formulation individualized treatment plans.

To explore the application of the ZigBee wireless information medical monitoring system based on the digital filter mathematical model, the ZigBee wireless network based on the digital filter mathematical model was used to monitor patients with hematological tumors after chemotherapy, and computer biological information equipment was used to determine the average fluorescence intensity of nCD64, and the expression of PCT and CRP. The ROC curve was used to compare the specificity and sensitivity of the diagnosis of bacterial infections. The results provided a theoretical basis for the diagnosis and treatment of bacterial infections in patients with hematological tumors after chemotherapy.

Materials and methods

Wireless information medical monitoring system based on ZigBee technology

The physiological signal monitoring system realizes physiological signal remote sensing by virtue of the wireless communication network. The appropriate signal detection unit, processing unit, and communication unit must be selected in terms of system cost, power consumption, and real-time acquisition. As the core unit of the monitoring system, the processing engine is evaluated regarding the operating speed, power consumption, and scalability of the processor. Mainstream microprocessors now mainly include ARM and DSP. DSP has higher computing power, but its power consumption is higher than ARM. ARM has abundant internal resources, and only a few peripheral devices are needed to build the smallest system [10]. In contrast, the scalability of DSP is somewhat insufficient. Therefore, using ARM as the core processing engine can reduce the development cycle and system consumption.

The Zigbee communication unit can be implemented in two ways: (1) ZigBee protocol processor and RF chip. (2) Design with integrated Zigbee protocol chip. Method 1 can choose different processors and radio frequency chips according to needs, and the design is flexible. However, because many companies have not transplanted the Zigbee protocol suitable for their own processors, designers need to transplant independently. Method 2 avoids the heavy migration work in Method 1, because it serves as a processor, so it can directly cooperate with the detection circuit, and solve the calculation and data transmission work at the same time.

Above, out of consideration of the design difficulties and flexibility, the blood oxygen probe and the integrated analog front end are selected as the units to detect blood oxygen saturation, with the integrated ECG module as the ECG monitoring unit, and the digital three-axis acceleration sensor as the descending signal detection unit. For the processing unit, based on power consumption, scalability, and cost considerations, the ARM processor is selected as the core of the processing unit. The Zigbee communication unit adopts the Zigbee protocol integrated chip as the Zigbee communication unit.

Wireless medical monitoring system usually includes wireless communication module, terminal information acquisition module, and upper computer control display module. The upper computer mainly processes and analyzes the data information collected by the terminal to diagnose the current status of the monitor; the terminal information acquisition module collects the physiological indicators of patients, including temperature, ECG, blood pressure and other sensors; the wireless communication module transmits data between the upper computer and the terminal node. The structure of ZigBee wireless information medical monitoring system based on the filtering mathematical model is shown in Fig. 1. The wireless medical monitoring system usually includes a wireless communication module, a terminal information acquisition module, and an upper computer control display module.

Construction of filtering algorithm

The human body's ECG signal, pulse, and other data can be directly transmitted to the digital filter model through ZigBee wireless communication, but there is interference of the circuit and other random noise, and filtering is needed before subsequent calculations can be performed [11]. The digital filter model is divided into infinite impulse response (IIR) and finite impulse response (FIR) filters [12]. FIR filters have strict linear phase characteristics, can always meet the stability conditions, and are widely used.

There are two ways to design FIR filter, namely, window function method and frequency sampling method. The window function method must constantly change the shape and length of the window function to

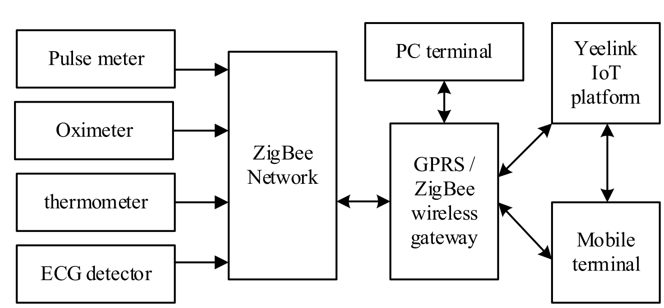

Fig. 1. ZigBee wireless information medical monitoring system based on digital filtering mathematical model.

achieve the best filtering. In contrast, the frequency sampling method is more direct and convenient. The basic principle of using frequency sampling method to design FIR filter model is to sample the ideal frequency response at equal intervals from the frequency domain to approximate the frequency response function of the filter model. $A_i(y^{er})$ represents the expected filter frequency response function, and then the equation below is obtained.

$$|A_i(y^{er}) = A_{ik}(r)y^{e\theta i(r)} \tag{1}$$

With r = 0 ~ 2π, N electrical sampling is performed on $A_i(y^{er})$ at equal intervals, and then equation below is obtained.

$$|A_i(h) = A_i(y^{er})\,|r = 2\pi h|N \tag{2}$$

With $A_i(h)$ as the unit impulse response of the filter model, filter model system functions A(s) and $A_i(y^{er})$ are expressed as follows.

$$A(s) = \frac{1 - c^{-N}}{N} \sum_{k=0}^{N-1} \frac{A_i(h)}{r^{2e\theta i} b^{-1}} \tag{3}$$

$$A_i(y^{er}) = c^{-g^{\frac{(N-1)}{2}}\theta} \sum_{k-0}^{N-1} A_i(h) \frac{1}{N} c^{g^{\frac{\pi h}{N}}(N-1)} \frac{sin[N(\theta/2) - \pi/h/N]}{sin(\theta/2 - \pi h/N)} \tag{4}$$

Frequency sampling of $A_i(y^{er})$ is to extract N equally spaced frequency response values on the unit circle of the c-plane. The frequency response at each sampling point in the filtering model is equal to the ideal frequency response, and the frequency response between each sampling point is obtained by superimposing weighted interpolation functions.

For transmission band $A_i(y^{er}) = 1$and stop band $A_i(y^{er}) = 0$, to reduce the fluctuations caused by the abrupt change of the sampling point at the edge of the passband, it is necessary to increase the transition band between the transmission band and stopband to improve the approximation quality.

Main instruments and reagents

Disposable EP tubes, microliter pipettes, cryopreservation boxes, etc. were purchased from Beijing Biomedical Co., Ltd., BD flow cytometry tubes, immunochemiluminescence instrument, protein analyzer supporting reaction cups were purchased from BD in the United States, high-speed desktop centrifuge , Low-temperature refrigerator, and flow cytometer were purchased from Beijing Times Beili Co., Ltd., and the automatic immunochemiluminescence instrument was purchased from China Medical Device Factory. CD45 fluorescent antibody, CD64 fluorescent antibody, and hemolysin were purchased from BD in the United States, and three distilled water, PCT diagnostic kits, etc. were purchased from Jiangsu Medical Instruments Co., Ltd.

Research subjects

128 cases of blood tumor patients undergoing chemotherapy in hospital from October 2016 to October 2018 were selected as the research object. Among them, there were 68 males and 60 females, ranging in age from 30 to 55 years, with an average age of 42.67 ± 14.82 years. This experiment has been approved by the ethics committee of our hospital, and all the patients included in the study have signed the informed consent.

Continuous dynamic detection group: at the same time, patients with no fever and long hospital stay were selected for dynamic monitoring, their conditions were recorded, and the fluorescence intensity of nCD64 was measured every two days using the computer biological information equipment. If there was fever and the diagnosis was bacterial infection, the fluorescence intensity of nCD64 measured at the first and second time before fever and at the time of fever were recorded as dynamic monitoring group 1, 2 and 3, respectively. The control group was free of bacterial infection during the monitoring, and their CRP and PCT values were detected.

ECG signal acquisition

(l) Before the test, the patient's fingers, especially the nails, should be cleaned. If there is too much dirt, it will hinder the transmission of light and affect the measurement results. (2) It should be noted to avoid strong external light irradiating the blood oxygen probe, which may cause the photoelectric receiving device to deviate from the normal working area and affect the measurement results. (3) During the measurement process, the subject should try to stay calm, breathe evenly, and avoid strenuous exercise, which will cause the extracted signal to drift drastically, resulting in inaccurate measurement. (4) Try to avoid measuring under conditions of shock and low finger temperature, because when the peripheral circulation is not good, the arterial flow of the measuring part will decrease, resulting in inaccurate measurement. (5) During measurement, the blood oxygen probe should be placed in the correct position according to the probe instructions.

The biochemical and imaging tests

(1) The number of neutrophils was recorded and there were four groups based on the number of neutrophils: the increase group, the decrease group, the normal group, and the insufficient group. The effect of neutrophils on CD64 expression was then analyzed.
(2) Infection-related indexes should be collected as much as possible within 1 to 2 days before and after the blood sample collection, such as ESR, CRP, PCT, bacterial culture, mammogram, and CT results, to determine whether infection occurred.
(3) Close attention should be paid to researchers who collect blood samples. When a clinical bacterial infection was diagnosed, the therapeutic effects of antibiotics were monitored. If the symptoms improved quickly after using antibiotics, it can be judged as a bacterial infection. Then, the test data was saved, and a statistical analysis was conducted after the experiment. If there was no significant improvement after using antibiotics, antiviral drugs or antibiotics were further administered. When the condition improved, all relevant information and data on the topic would be excluded.

Diagnostic criteria for bacterial infection

Patients with hematological tumors who have been diagnosed with bacterial infections and clinically diagnosed with bacterial infections after chemotherapy were selected. The diagnostic criteria were as follows.

Sepsis is blood penetration caused by the bacterial infection, accompanied by symptoms of bacterial infection. If pathogenic bacteria were found in blood culture or bone marrow culture, the possibility of contamination was then eliminated. The bacterial infection of local organs or tissue is confirmed if there were symptoms the bacterial infection.

Bacterial infection clinical diagnostic indicators: meeting the following non-specific biochemical diagnostic criteria by at least 2. The total number of white blood cells $> 10 \times 10^9$/L and the number of neutrophils $> 7 \times 10^9$/L. CRP increases by ≥ 8ug/ML after 6–8 h of inflammation, which is a commonly used and sensitive detection index for acute protein. PCT is the precursor of hormone-free calcitonin secreted by neuroendocrine cells under physiological conditions, demonstrating higher sensitivity and specificity than CRP and white blood cell count. The diagnostic cut-off value is ≥ 0.5 ng/mL, but if the PCT concentration fluctuates between 0.05 and 0.5 ng/mL, it may be local inflammation or local infection. Chest radiograph: respiratory tract infection is common in patients with hematological tumors after chemotherapy. If chest x-ray images show thickened lung texture thickening, ground-glass opacity, and spot shadows, it provides certain guidance. The efficacy of antibiotics, etc.

Collection and storage of blood samples

(1) The nurses of the Department of Hematology in our hospital collected peripheral blood for routine monitoring under strict aseptic conditions, and 3 mL of peripheral blood was drawn in EDTA anticoagulant tube and stored at 4 °C.
(2) Of the 3 mL of peripheral blood in this tube, 1 mL of whole blood was stored at 4 °C for subsequent detection of the average fluorescence intensity of nCD64. The remaining 2 mL of whole blood was centrifuged for 5 min (3000 rpm), with the supernatant transferred in a 1.5 mL EP tube using a 1000 μL pipette. The patient's name and sampling date were marked on the EP tube, and it was stored at −20 °C. The data was sorted and analyzed every three months, and sera of some subjects were randomly selected to test their PCT and CRP.

The grouping

Infected and non-infected groups: patients were divided into the infected group (68 cases) and the non-infected group (60 cases) according to whether they were infected or not. The judgment method of whether the patient has bacterial infection was as follows: clinical symptoms, experimental test results (CRP, PCT, bacterial culture), imaging examination (chest radiograph), and follow-up monitoring of the disease were evaluated. According to the absolute value of neutrophils, NEUT was divided into 4 subgroups: normal group (2×10^9L ≤ NEUT ≤ 7×10^9L), increase group (NEUT > 7×10^9L), decrease group (0.5×10^9L ≤ NEUT ≤ 2×10^9L), lack group (NEUT ≤ 0.5×10^9L).

Continuous dynamic detection group: at the same time, patients with no fever and long hospital stay were selected for dynamic monitoring, their conditions were recorded, and the fluorescence intensity of nCD64 was measured every two days using the computer biological information equipment. If there was fever and the diagnosis was bacterial infection, the fluorescence intensity of nCD64 measured at the first and second time before fever and at the time of fever were recorded as dynamic monitoring group 1, 2 and 3, respectively. The control group was free of bacterial infection during the monitoring, and their CRP and PCT values were detected.

Flow cytometry

The mean fluorescence intensity of nCD64 in peripheral blood was measured by flow cytometry. 100 μL blood samples were taken and mixed with CD45 and CD65 fluorescence antibodies, 20 μL each, and incubated for 15 min in dark. After adding 300 μL PBS for resuscitation, the detection was performed by up-flow cytometry. 1000 cells were counted in each sample, and Cellquest software was used for numerical analysis to obtain the average fluorescence intensity of nCD64 (nCD64 MFI).

Statistical analysis

The experimental data were analyzed by SPSS20.0 software, and the measurement data were represented by mean ± standard deviation. The *t* test was used for inter-group comparison, and the Kruskal Wallis rank sum test was used for multi-group comparison. $P < 0.05$ was considered statistically significant.

Results

Basic information and imaging images of the patient

In this study, 128 patients with hematological tumors were selected as the research subjects. There were 82 leukemia patients, 22 lymphoma patients, and 24 multiple myeloma patients under the ZigBee wireless information medical monitoring based on the digital filtering mathematical model. There were 6 cases of sepsis, 49 cases of lung infection, 12 cases of perianal abscess, 21 cases of purulent tonsillitis, and 36 cases of unclear infection. As shown in Fig. 2, the pneumococcal infection exhibited patchy and multifocal consolidation shadows, and the Staphylococcus aureus infection exhibited uniform or patchy multifocal consolidation. shadows, and Klebsiella infection exhibited uniform consolidation of non-segmental distribution.

In this study, 128 patients with hematologic tumors were selected, including 82 patients with leukemia, 22 patients with lymphoma and 24 patients with multiple myeloma. There were 6 cases of sepsis, 49 cases of pulmonary infection, 12 cases of perianal abscess, 21 cases of suppurative tonsillitis and 36 cases of unclear infection foci. Fig. 2 were images of patient's bacterial infection part. After pneumococcal infection, patchy and multifocal consolidation shadows were observed; after staphylococcus aureus infection, uniform or patchy multifocal consolidation shadows were observed; after klebsiella infection, uniform consolidation shadows of non-segment distribution were observed. The processing of patients' ECG signals by wireless information medical monitoring system based on computer ZigBee technology was shown in Fig. 3. In general, the ECG frequency of mixed baseline drift was relatively low, and the system was filtered by sinusoidal chill superposition of 0.5 Hz.

Expression levels of nCD64 in the infected and uninfected groups

Under the ZigBee wireless information medical monitoring based on the filtering mathematical model, the computer biological information equipment was used to measure the average nCD64 fluorescence intensity of the infection group and the non-infection group. In the infected group, the expression levels of nCD64 in the of subgroups (increase group, normal group, decrease group, lack group) were 165.23 ± 54.65 (MFI), 134.35 ± 54.65 (MFI), 183.63 ± 48.64 (MFI), and 188.56 ± 34.67 (MFI), respectively. The nCD64 of the normal group in the infected group was lower than that of the other three groups. In the non-infected group, nCD64 levels of subgroups of neutrophil granulocyte (increase group, normal group, decrease group, lack group) were 50.23 ± 13.61 (MFI), 56.23 ± 15.65 (MFI), 46.23 ± 12.35 (MFI) and 48.23 ± 16.67 (MFI), respectively. There was no statistically significant difference in nCD64 expression between the four subgroups of the infected group ($P > 0.05$); there was no statistically significant difference in nCD64 expression between the four subgroups of the non-infected group ($P > 0.05$); the nCD64 level of the infected group was significantly higher than that of the uninfected group ($P < 0.05$). According to the results in Fig. 4, the expression of nCD64 on the neutrophil surface was independent of the number of neutrophils, so the subsequent experiments need not be divided into subgroups for discussion.

The expression levels comparison of nCD64 in each group

The expression levels of nCD64 in the infected group, the uninfected group, the control group, the dynamic monitoring site 1, the dynamic monitoring site 2, and the dynamic monitoring site 3 were measured using the computer biological information equipment. The results are shown in Fig. 5. There was no statistically significant difference in nCD64 expression between the uninfected group and the dynamic monitoring site 2 ($P > 0.05$); the nCD64 level of the uninfected group was significantly higher than that of the normal control group ($P < 0.05$); the nCD64 level of the dynamic monitoring site 2 was significantly higher than that of the control group ($P < 0.05$); the nCD64 level of dynamic monitoring point 1 and 3 was significantly higher than that of control group, non-infected group and dynamic monitoring point 2 ($P < 0.05$); there was no significant difference in nCD64 level between the dynamic monitoring point 1 and the dynamic monitoring point 3 ($P > 0.05$); the expression level of nCD64 in the infected group, the

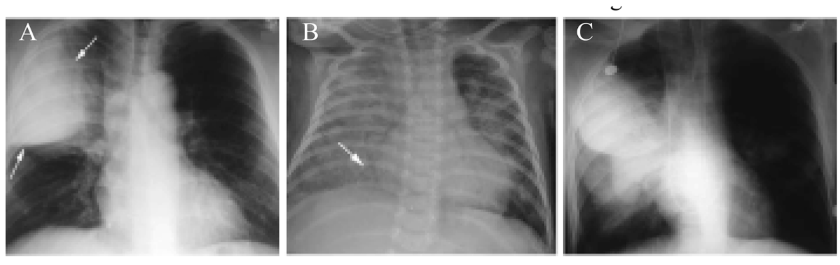

Fig. 2. (A: pneumococcal pneumonia infection, chest anterior film showed uniform consolidation of the upper lobe of the right lung (arrow), accompanied by air bronchus sign; B: staphylococcus aureus infection, chest anterior film showed bilateral consolidation accompanied by air bronchial sign (arrow); C: Klebsiella pneumoniae infection).

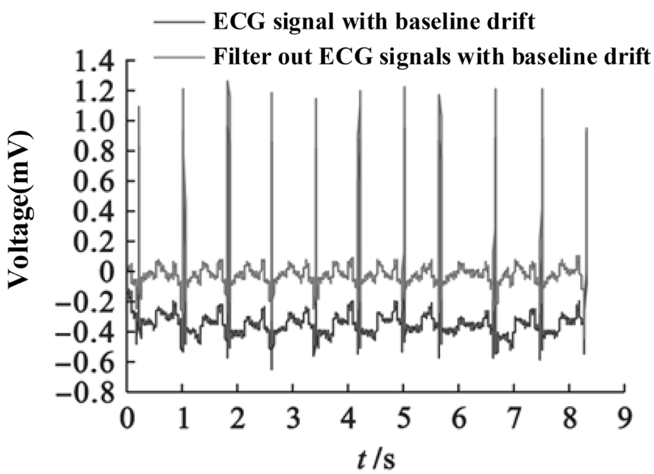

Fig. 3. Real-time monitoring of ECG signals in patients.

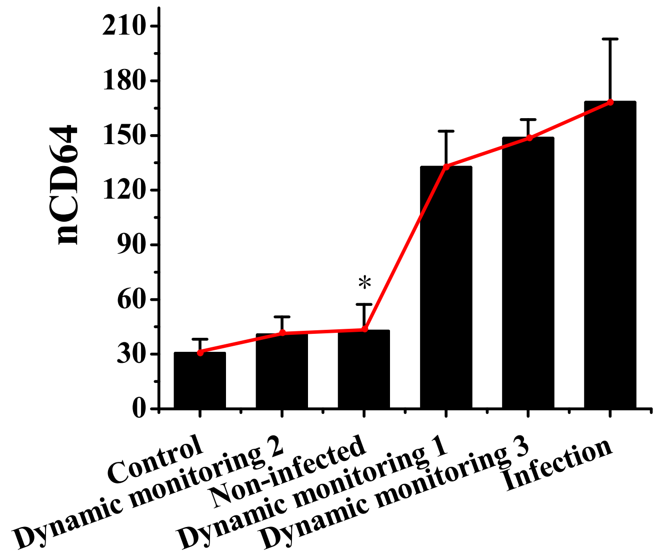

Fig. 5. The expression levels comparison of nCD64 in each group.

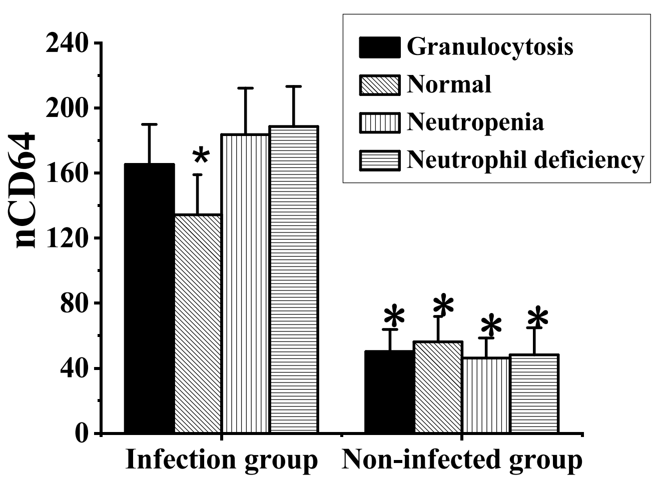

Fig. 4. Expression levels of nCD64 in the infected and uninfected groups * indicated a notable difference between the normal group with the other groups, P < 0.05.

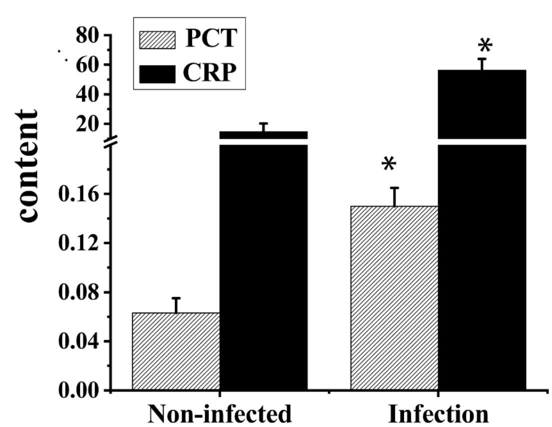

Fig. 6. PCT and CRP measurement in the infected and uninfected groups.

uninfected group, the control group, the dynamic monitoring site 1, the dynamic monitoring site 2 and the dynamic monitoring site 3 showed a trend of gradually increasing.

PCT and CRP measurement in the infected and uninfected groups

The PCT and CRP measurements of the infected and uninfected groups were shown in Fig. 6. The PCT and CRP contents of the infected group were 0.15 ± 0.068 (ng/mL) and 56.23 ± 7.76 (mg/L), respectively. The contents of PCT and CRP in the non-infected group were 0.063 ± 0.012 (ng/mL) and 14.62 ± 5.65 (mg/L), respectively. PCT content in the infected group was significantly higher than that in the uninfected group ($P < 0.05$), and CRP content in the infected group was significantly higher than that in the uninfected group ($P < 0.05$).

ROC analysis of nCD64, PCT, and CRP detection of bacterial infection

The critical value, sensitivity, and specificity of PCT, CRP, and nCD64 (infected group and dynamic monitoring group) in detecting bacterial infection in blood tumor patients after chemotherapy are shown in Fig. 7 and Fig. 8. The critical values of PCT, CRP, and nCD64 (infected group and dynamic monitoring group) for bacterial infection were 0.092, 18.6, 56.18 and 56.26, respectively; the sensitivities of PCT, CRP, and nCD64 (infected group and dynamic monitoring group) to bacterial infection were 78.5, 82.6, 90.4 and 86.7, respectively; the specificity of PCT, CRP and nCD64 (infected group and dynamic monitoring group) were 75.6, 76.8, 79.6 and 79.6, respectively. The sensitivity and specificity of nCD64 level in diagnosing bacterial infection in blood tumor patients after chemotherapy were higher than that of PCT and CRP.

Discussion

After chemotherapy, the immune function of patients with blood tumor is weak and they are prone to infection, and bacterial infection is the most common type of clinical infection [12]. Generally, doctors will use antibiotics for treatment, but antibiotics have a large toxic and side effect on the human body. Improper use of antibiotics will also cause treatment delay, resulting in increased mortality from infection. Therefore, it is of great significance to find the detection index for the early diagnosis of bacterial infection.CD64 is a membrane glycoprotein that plays an important role in the immune response of the body [13]. In the study, a ZigBee wireless information medical monitoring system was constructed first based on a digital filter mathematical model, and then the computer biological information equipment was used to monitor bacterial infections. The results found that, the wireless information medical monitoring system based on the computer ZigBee technology processed the patient's ECG signal. The ECG frequency of the mixed baseline drift was relatively low. The system filtered through the 0.5 Hz sine chill superposition. The filter was found to suppress the limit deviation, leaving the waveform of the electrical signal clearer, and the detection accuracy was heightened; The number of neutrophils in hematological tumors patients after chemotherapy had nothing to do with the expression level of CD64, indicating that the average fluorescence intensity of nCD64 can be used as an index of bacterial infection in patients with hematological tumors after chemotherapy. CD64 was less expressed in normal neutrophils, and its expression increased rapidly within 60 min after infection. Guo et al. (2018) found that the leukemia with bacterial infection group showed higher CD64, CRP, and PCT versus the non-combined infection group [14]. Dai et al. (2017) pointed out that in patients with hematological malignancies and bacterial infections, the CD64 index, CRP, PCT, and NC (neutrophil count) levels of the infection group were higher than those of the non-infection group

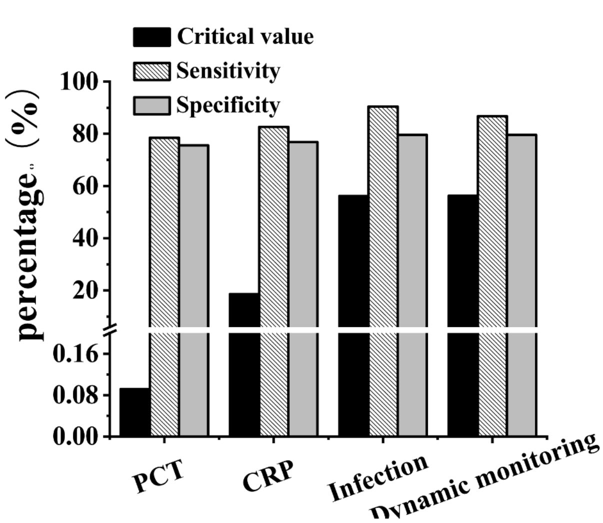

Fig. 7. Comparison of thresholds, sensitivities, and specificities in different bacterial infections detection.

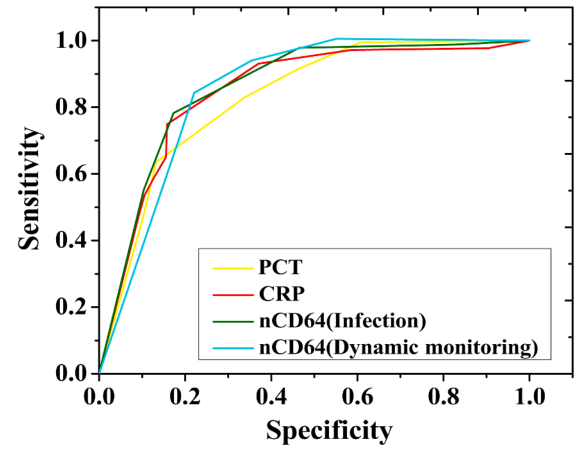

Fig. 8. ROC analysis of PCT, CRP, and nCD64 detection.

before and after antibacterial treatment [15]. In the study, the ZigBee wireless information medical monitoring system based on the digital filtering mathematical model was constructed, and the computer biological information equipment was used to measure the average fluorescence intensity of nCD64 in the infection and non-infection groups. It was found that the average fluorescence intensity of nCD64, and the content of PCT and CRP in the infection group were higher ($P < 0.05$). This was consistent with the research results of Guo et al. (2018) and Dai et al. (2017), who found that the ZigBee wireless information medical monitoring system under the filtered digital model provided guidance for the monitoring of bacterial infections.

Since bacterial infection occurs in blood tumor patients after chemotherapy, the infection foci are not obvious or even absent in some patients, and fever may be the only clinical symptom [16], a dynamic monitoring test was designed in the study. Patients with no fever and long hospital stay were selected to detect the fluorescence intensity of nCD64 before and after the occurrence of fever symptoms. It was found that the nCD64 level in the dynamic monitoring site 1, the dynamic monitoring site 3 and the infected group showed a gradually increasing trend, indicating that the expression level of nCD64 increased with the increase of infection severity. Muzlovic et al. (2016) showed that the area under the ROC curve (AUC) of sepsis with ventilator-associated pneumonia diagnosed by CD64, CRP and PCT were 0.929, 0.869 and 0.909 [17]. Qin et al. (2017) used neutrophil CD64 and PCT to determine bacterial infection in neonates, and found that the areas under the ROC curve (AUC) of neutrophil CD64, PCT and CRP in the diagnosis of bacterial infection were 0.818, 0.818 and 0.704, respectively, and the combined AUC of neutrophil CD64 and PCT was 0.926 [18]. In this study, the sensitivity of PCT, CRP and nCD64 (infected group and dynamic monitoring group) to detect bacterial infection was 78.5, 82.6, 90.4 and 86.7, respectively, and the specificity of PCT, CRP and nCD64 (infected group and dynamic monitoring group) were 75.6, 76.8, 79.6 and 79.6, respectively; the sensitivity and specificity of nCD64 in the diagnosis of bacterial infection in blood tumor patients after chemotherapy were higher than that of PCT and CRP, which was consistent with the research results of Qin et al. (2017).

Conclusion

In this research, the digital filter mathematical model-based ZigBee wireless sensor network system was used to monitor patients with hematological tumors after chemotherapy. The results showed that, the filter suppressed the baseline shift, leaving the waveform of the electrical signal clearer, and heightened the detection accuracy. Based on this mathematical model, the average intensity of nCD64 fluorescence in the peripheral blood of patients was measured by the flow cytometer, with its diagnostic value for bacterial infections explored. However, there are still some deficiencies in this study. The number of subjects is effective, and it is impossible to distinguish gram-positive or negative-positive bacteria. Whether the bacteria species affect the expression of nCD64 needs to be further studied and determined. In summary, using the ZigBee wireless sensors raised the detection accuracy. The results of this study provide a theoretical basis for the diagnosis of physiological indicators of bacterial infections.

CRediT authorship contribution statement

Maocheng Cao: Conceptualization, Software, Writing - original draft. **Junjing Wang:** Data curation, Formal analysis. **Chunfeng Wu:** Methodology, Writing - review & editing. **Aseel Takshe:** . **Bishr Muhamed Muwafak:** .

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This work was supported by Shenzhen Science and technology innovation basic research project in 2106 (JCYJ20160427192622779).

References

[1] Dong B, Yang J, Ma Y, Zhang X. Medical monitoring model of internet of things based on the adaptive threshold difference algorithm. International Journal of Multimedia and Ubiquitous Engineering 2016;11(5):75–82.
[2] Wu YJ, Liu WJ, Yuan CH. A mobile-based barrier-free service transportation platform for people with disabilities. Comput Hum Behav 2018;08:253–7.
[3] Pashootanizadeh M, Rafie Z. Social Media Marketing: Determining and Comparing View of Public Library Directors and Users. Ind Mark Manage 2019;1:1–17.
[4] Wadhwa LK, Deshpande RS, Priye V. Extended shortcut tree routing for ZigBee based wireless sensor network. Ad Hoc Netw 2016;37:295–300.
[5] Rajendran VG, Jayalalitha S, Anushaa R, Karpagalakshmi S, Karthikeyan S. GSM based Physiological Monitoring of Patient by using Zigbee. Far East J Electron Commun 2016:33–41. https://doi.org/10.17654/EC03010033.
[6] Martínez M E I, Antonino-Daviu J A, Córdoba P F D, et al. Higher-Order Spectral Analysis of Stray Flux Signals for Faults Detection in Induction Motors[J]. Applied Mathematics and Nonlinear Sciences, 2020, 5(2):1-14.
[7] Lv ZH, Xiu WQ. Interaction of Edge-Cloud Computing Based on SDN and NFV for Next Generation IoT. IEEE Internet Things J 2019;45:2942719.
[8] Galloway-Peña JR, Smith DP, Sahasrabhojane P, Ajami NJ, Wadsworth WD, Daver NG, et al. The role of the gastrointestinal microbiome in infectious complications during induction chemotherapy for acute myeloid leukemia. Cancer 2016;122(14):2186–96.
[10] Groselj-Grenc M, Derganc M, Kopitar AN, Pavcnik M. Neutrophil CD64 index in cerebrospinal fluid as a marker of bacterial ventriculitis in children with external ventricular drainage. BMC pediatrics 2019;19(1). https://doi.org/10.1186/s12887-019-1497-4.
[11] Sulaiman T, Bulut H, Baskonus H. On the exact solutions to some system of complex nonlinear models. Applied Mathematics and Nonlinear Sciences 2020;6(1):29–42.
[12] Gençoğlu M, Agarwal P. Use of Quantum Differential Equations in Sonic Processes. Applied Mathematics and Nonlinear Sciences 2020;6(1):21–8.
[13] Cheng R, Cheng P, Zhou H. Analysis of the clinical significance of CD64 and SAA detection in early bacterial infections of children with respiratory tract. International Journal of Laboratory Medicine 2018; 39(8):956-958;962.
[14] Guo XY, Kang YK, Guo SX. Comparison of Diagnosis Values of CD64 Infection Index, CRP, PCT and NEU% in the Leukemia Complicated with Bacterial Infection. Journal of Experimental Hematology 2018;26(1):132–5.
[15] Dai X, Li JP, Li WQ, et al. Changes of Neutrophil CD64 in Patients with Hematological Mali-gnancies Combined with Bacterial Infections. Journal of Experimental Hematology 2017;25(2):577–81.
[16] Chen Y, Hu S, Mao He, Deng W, Gao X. Application of the best evacuation model of deep learning in the design of public structures. Image Vis Comput 2020;102:103975. https://doi.org/10.1016/j.imavis.2020.103975.
[17] Muzlovic I, Ihan A, Stubljar D. CD64 index on neutrophils can diagnose sepsis and predict 30-day survival in subjects after ventilator-associated pneumonia. The Journal of Infection in Developing Countries 2016;10(03):260–8.
[18] Qin DJ, Tang ZS, Chen SL, et al. Value of combined determination of neutrophil CD64 and procalcitonin in early diagnosis of neonatal bacterial infection. Chinese journal of contemporary pediatrics 2017;19(8):872–6.