Research Article

Scale-Invariant Feature Transform (SIFT) Algorithm-Based Detection of Cardiac Insufficiency in Sepsis Patients with Echocardiography

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1. Introduction

Sepsis has attracted more and more attention because of its high mortality and morbidity [1–3]. There are often multiple organs affected by sepsis, among which the heart is one of the most seriously affected organs. When sepsis patients suffered from septic shock, 30%–80% of them die because of severe damage to the cardiovascular system [4]. Most patients with sepsis have varying degrees of cardiac insufficiency, which will lead to reduced perfusion of the whole body tissues to promote the development of sepsis; thus, the rest organs were further in failure [5, 6]. At present, cardiac insufficiency is usually examined by CUI, and there are two-dimensional speckle tracking imaging (2D-STI) and three-dimensional STI (3D-STI) in ultrasonic examination [7]. 3D-STI is a new technology developed in recent years, which overcomes the defects of angle dependence in Doppler, and 2D-STI is limited to defects in the plane, which makes the evaluation of left ventricular function more realistic and comprehensive. However, 3D-STI still has some dense, irregular, and speckle noise, which makes the overall image relatively fuzzy. Therefore, the algorithm is further introduced to further improve the image quality, so as to make the image clear [8].
Cardiac ultrasound is the best imaging detection method for the clinical assessment of cardiac structure and function of severe patients, but most patients with sepsis have already developed severe organ dysfunction when changes in cardiac structure and function are observed by CUI. In addition, echocardiographic examination is limited to the influences of equipment and the operator’s clinical experience and subjective judgment, so its sensitivity is relatively poor. Thus, it is necessary to supplement the corresponding indexes for the evaluation of cardiac function [9, 10]. In the case of cardiac insufficiency, the myocardial cells are damaged and the heart structure and function are changed so that the concentration of various cardiac markers in the blood is correspondingly increased, which can appear in the serum at the early stage of cardiac function impairment. Thus, their concentrations can be used as good early warnings and supplementary indicators for echocardiography evaluation of cardiac function [11, 12]. What is more, SIFT has been widely applied in the processing of clinical imaging. For example, Shiji et al. [13] applied SIFT and Canny edge detection algorithm to automatically detect accurate segmentation of breast ultrasound images and found that the true-positive rate was as high as 90.1% compared to the real situation. Besides, it is of great significance to employ the intelligent algorithm in the preprocessing of clinical medical images to effectively segment the useful information in the images and promote the clinical diagnosis rate of diseases.

Therefore, CUI on the basis of STA was adopted in this study for diagnosis, so as to further study the diagnostic effects of cardiac ultrasonic images in sepsis patients with cardiac insufficiency.

2. Materials and Methods

2.1. Feature Point Location and Matching of SIFT. SIFT operator was a kind of image local feature description operator based on scale space and invariant image scaling, rotation, and even radiation transformation. SIFT could correspondingly combine the steps of feature point detection, feature vector generation, and feature matching search, which were optimized based on the actual situation. Besides, two images with a very large difference could also achieve feature matching. The specific process of SIFT matching is shown in Figure 1.

Accurate positioning of SIFT was often achieved by difference of Gaussian (DOG) pyramids, and the DOG value of the DOG pyramid was sensitive to noise and edge. The location and scale of feature points were adjusted accurately through further three-dimensional quadratic function fitting for local extremum points. In addition, the Taylor expansion equation of scale-space function $D(a, b, \alpha)$ in local extreme point $D(a_0, b_0, \alpha_0)$ is shown as follows:

$$D(a, b, \alpha) = D(a_0, b_0, \alpha_0) + \frac{\partial D}{\partial E} E + \frac{1}{2} E^2 \frac{\partial^2 D}{\partial E^2} E.$$  \hspace{1cm} (1)

In equation (1), $E = (a, b, \alpha)^T$ is the deviation of a key point and $D(a_0, b_0, \alpha_0)$ is the value of $D(a, b, \alpha)$ at the local extremum of the image. What is more, it is necessary to further take the derivative of equation (1) to obtain $\partial D(E)/\partial E = 0$, so as to get the accurate extremum location $\hat{E}$, as shown in the following equation:

$$\hat{E} = -\frac{\partial^2 D^{-1} \partial D}{\partial E \partial E}.$$  \hspace{1cm} (2)

When the deviation of $\hat{E}$ from the interpolation center in any direction was greater than 0.5, it meant that the key point motivated another monitoring point to be very close, and this point should be deleted.

The reference direction of local image features was obtained through the above processes. Besides, the Gaussian image closest to the scale value was gained from the obtained feature point scale value $a$. The calculation method could be expressed as follows:

$$L(a, b, \alpha) = G(a, b, \alpha) \cdot I(a, b).$$  \hspace{1cm} (3)

The finite difference was employed to calculate the gradient direction and gradient modulus of the image gradient in the region with the radius of $3 \times 1.5$ and the feature point as its center. Equations (4)–(6) represent the gradient $\text{grad} I(a, b)$ of feature point, gradient modulus $n$, and gradient direction $\theta$, respectively.

$$\text{grad} I(a, b) = \left( \frac{\partial I}{\partial a}, \frac{\partial I}{\partial b} \right).$$  \hspace{1cm} (4)

$$n(a, b) = \sqrt{\left(L(a + 1, b) - L(a - 1, b) \right)^2 + \left(L(a, b + 1) - L(a, b - 1) \right)^2},$$  \hspace{1cm} (5)

$$\theta(a, b) = \tan^{-1} \left[ \frac{L(a, b + 1) - L(a, b - 1)}{L(a + 1, b) - L(a - 1, b)} \right].$$  \hspace{1cm} (6)

After the gradient feature points of the Gaussian image were calculated completely, the gradient mode value and gradient direction of pixels in the neighborhood were further collected through histogram, as shown in Figure 2.

2.2. Subjects Investigated and Grouping. A total of 90 patients with sepsis were selected, who were admitted to the hospital from January 2018 to May 2020. All the selected patients did not die or were hospitalized for less than 3 days during their
hospitalization. There were 54 males and 36 females in the experiment with an average age of 72.58 ± 10.27 years. The sources of sepsis infection included pulmonary infection, abdominal infection, urinary system infection, central nervous system infection, and blood infection. Moreover, 20 healthy people were selected as the control group for the study, who underwent a normal physical examination in the hospital. The patients with sepsis were divided into two groups (groups A and B) under whether they had cardiac insufficiency or not. All patients participating in the experiment had signed informed consent forms, and this study had been approved by the ethics committee of the hospital.

2.3. Inclusion and Exclusion Criteria. All the enrolled patients were diagnosed based on the diagnostic criteria of sequential organ failure assessment (SOFA), and sepsis could be confirmed when the SOFA score was greater than or equal to 2. All the SOFA scores are shown in Table 1.

The exclusion criteria were defined as follows: patients who suffered from myocardial diseases such as myocardial infarction, old myocardial infarction, and ischemic cardiomyopathy; had primary cardiomyopathy including hypertrophic cardiomyopathy, dilated cardiomyopathy, and restrictive cardiomyopathy; suffered from metabolic cardiomyopathies such as anaemic cardiomyopathy, hyperthyroidism cardiomyopathy, and uremia cardiomyopathy; had congenital heart disease; had received other treatments including traditional Chinese medicine; and refused to accept rehabilitation training with poor compliance.

2.4. Relevant Experimental Data Collection. The experienced doctors examined cardiac ultrasound images of all the patients to record their cardiac function indicators. The subjects in the control group were tested on the day of physical examination, while patients with sepsis were tested on the 7th day of admission.

5 mL of venous blood was extracted on an empty stomach from all the subjects investigated, and it was centrifuged at 35,000 rpm for 10 minutes. The products obtained from the centrifugation were detected by cardiac
troponin I (cTnI), N-terminal pro-B-type natriuretic peptide (NT-proBNP), H-FABP, and GPBB.

2.5. Statistical Analysis. SPSS 19.0 software was employed to analyze the data statistically. The enumeration results were expressed as mean ± standard deviation, and the t-test was used for comparison between two groups. P < 0.05 meant the difference was statistically significant.

3. Results

3.1. Scale-Invariant Feature Transform Algorithm Matching Results and Comparison. The first frame and the second frame of the image were taken as an example, and the following were the matching images obtained by sequential matching, reverse matching, and template matching, respectively (Figures 3–5). In the template matching, the one with more feature points in the two frames was used as a template for matching.

Figure 6 reveals that the results obtained by SIFT matching were further summarized. It suggested that there was little difference between the logarithm of matching points corresponding to the sequential matching and reverse matching methods, while the logarithm corresponding to the template matching method was greatly higher with better matching results.

3.2. Comparison of General Data of Subjects in Each Group. The comparison of general data among the subjects in the three groups is shown in Figure 7. It showed that there were no statistically remarkable differences in gender and age among all subjects in the three groups (P > 0.05). However, there were statistically substantial differences in SOFA scores among all subjects in the three groups (P < 0.05) and all subjects of the three groups had different hospital admission times with statistical meanings (P < 0.05).

3.3. Comparison of Experimental Results of Subjects in Each Group. Sepsis patients were given the same laboratory tests on the seventh day of admission, and the results of subjects in the three groups were compared as shown in Figure 8. Compared with the control group, the number of white blood cells (WBC), procalcitonin (PCT), NT-proBNP, cTnI, CK-MB, H-FABP, and GPBB were dramatically higher in groups A and B, showing statistically substantial differences (P < 0.05). In addition, those values were the highest in sepsis patients of group B (P < 0.05).

3.4. Typical Cardiac Ultrasonic Images of Patients in Each Group. The typical cardiac ultrasonic images of subjects in the three groups were taken as shown in Figure 9. Figure 9(a) shows the cardiac ultrasonic image of one healthy person, the whole heart and left ventricle were normal, movement and morphological structure of the ventricular wall were not hugely changed, and the mitral valve was normal. Figure 9(b) shows the cardiac ultrasonic image of one septic patient with sound cardiac function; there was a normal diameter of the ventricular and a normal thickness of his or her heart wall; asymmetric cardiac hypertrophy did not emerge; and the ventricular wall motion amplitude was also basically regular. Besides, the cardiac ultrasonic image of one septic patient with cardiac insufficiency is shown in Figure 9(c), and the ventricular wall was extremely thickened and the aortic valve was obviously narrowed, so the left ventricle was considerably thickened.

3.5. Comparison of Cardiac Ultrasonic Data of Patients in Each Group. On the seventh day after admission, patients with sepsis underwent the same cardiac ultrasound examination as the subjects in the control group, and Figures 10 and 11 indicate the comparison of the results of subjects in the three groups. The values of left ventricular systolic function indicators (EDV, end-systolic volume (ESV), SV, CO, and E-point of septal separation (EPSS)) in groups A and B were extremely higher than the values of the control group with the statistically obvious differences (P < 0.05), and those values of subjects in group B were the highest (P < 0.05). There were statistically substantial differences in the values of left ventricular diastolic function indicators (early transmitral flow velocity (E), late diastolic blood flow peak velocity (A), IVRT, E-peak deceleration time (EDT), systole (S), and diastole (D)) of subjects from the three groups (P < 0.05), among which those values of patients in the control group were the highest (P < 0.05).
Figure 3: The result of sequential matching.

Figure 4: The result of reverse matching.

Figure 5: The result of template matching.
Figure 6: Comparison of the matching results of different methods.

Figure 7: Comparison of general data among all subjects in the three groups. (a–d) Comparisons of gender, age, SOFA scores, and hospital admission time among subjects in each group, respectively; * indicates that there was a statistically great difference compared with the control group ($P < 0.05$); and # indicates the differences were statistically obvious compared to group A ($P < 0.05$).
Figure 8: Comparison of experimental data among all subjects in the three groups. (a) Comparison on PCT, cTnI, and H-FABP among subjects in each group; (b) comparison on NT-proBNP and GPBP among subjects in the three groups; (c) comparison on WBC and CK-MB among subjects in each group; * means that there was a statistically huge difference in contrast to the control group ($P < 0.05$), and # indicates that the differences were statistically remarkable compared to group A ($P < 0.05$).

Figure 9: The typical cardiac ultrasonic images of subjects in each group. (a) The image of a healthy person, (b) the image of one septic patient with sound cardiac function, and (c) the image of one septic patient with cardiac insufficiency.
4. Discussion

Sepsis refers to a series of uncontrolled conditions caused by inflammation in the body due to infection. When these conditions are serious, they often endanger the functions of living organs, so that the functions of related organs in the body could be reduced or even fail. On this basis, the definition of sepsis puts more emphasis on its role in organ function. Among these organ function changes, the cardiovascular system has been most affected with the most serious problems. Meanwhile, more personalized treatment is often required for sepsis accompanied by cardiovascular system damage. However, accurate judgment is often the premise and basis of personalized treatment. At present, the methods of studying myocardial changes have been developed from traditional tissue Doppler to angle-free speckle tracking with the improvement of various technologies [14–17]. In this study, SIFT was applied to match cardiac ultrasonic images with three methods (sequential matching method, reverse matching method, and template matching method) to obtain the corresponding results, showing that the template matching method was better for image processing. Martin et al. [18] also confirmed in their study of cardiac ultrasound that there was little difference between sequential matching and reverse matching in cardiac ultrasonic processing, but there was room for improvement. Cardiac ultrasound is now the most important evaluation method for patients’ cardiac function. Chen et al. [19] revealed in the study that patients with sepsis could be defined as having sepsis cardiac insufficiency when their EF values were less than 50%. This study suggested that there were statistically obvious differences in cardiac ultrasonic indicators among subjects in the control group, group A, and group B. Kawaguchi et al. [20] found in a study of 262...
patients with severe sepsis that nearly half of the patients had left ventricular diastolic function impairment, 8.7% of the patients had simple systolic dysfunction, and 15.1% had both systolic and diastolic dysfunction. To a large extent, it disclosed that there were certain universalities of heart function problems in patients with sepsis.

The results of this study showed that the SOFA score of patients in group B was generally higher at admission, suggesting that sepsis patients with more severe single organ dysfunction or multiple organ dysfunction were more likely to have cardiac insufficiency at admission. However, this research result was not consistent with the results of domestic and foreign research data summarized by Strand et al. [21]. It was speculated that more complex standards were applied in this experiment while EF < 50% was often used for diagnosis in current studies. This study also indicated that NT-proBNP was associated with whether patients suffered from cardiac insufficiency or not. NT-proBNP is a common cardiac function evaluation marker with high sensitivity and specificity at present. However, if patients with sepsis at admission received a large amount of fluid resuscitation, it would often lead to an increase in NT-proBNP due to iatrogenic cardiac volume load, which has been confirmed in the study of Gao et al. [22].

5. Conclusion

In this study, the SIFT operator of STA was studied to get the corresponding verification. The ultrasonic images and physiological characteristics of sepsis patients with cardiac insufficiency were further studied, and the results revealed that there were changes in cardiac imaging of patients in group B on the 7th day after the onset, and the values of H-FABP, NT-proBNP, and A’ were all changed in contrast to the control group and group B, which could be regarded as predictors of sepsis cardiac insufficiency. The algorithm in the study was only limited to cardiac ultrasonic images, and it should be further explored whether STA could also play a role in other ultrasonic images. Moreover, there were few samples in this study, and the sources of sepsis patients were not subdivided, which needed further in-depth study. The results of this study could provide a reference for improving the efficiency of the clinical diagnosis of sepsis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

References


