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Research Article

Evaluation of Effect of Acupoint Sticking Therapy on Idiopathic Edema by Ultrasound Imaging Based on Deep Learning Algorithm

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This study was aimed to evaluate the therapeutic effect of acupoint application therapy on specific edema by using denoising convolutional neural network (DnCNN) ultrasound images. 144 patients with idiopathic edema were selected as the research objects, and they were randomly divided into the conventional treatment group and the acupoint application group. Traditional Chinese medicine (TCM) symptom score, quality-of-life score, and adverse reactions were compared between the two groups before and after treatment. Ultrasound images based on the deep learning algorithm were used to evaluate the efficacy. The results showed that compared with conventional ultrasound, ultrasound based on DnCNN was more accurate in the diagnosis of idiopathic edema. The total effective rate of edema treatment in the acupoint application group was higher than that in the conventional treatment group (45% vs 93%, $P < 0.01$). After treatment, the scores of TCM symptoms in the acupoint application group were lower than those in the conventional treatment group, and the quality-of-life score in the acupoint application group was higher than that in the conventional treatment group ($P < 0.05$). There was no significant difference in the incidence of adverse reactions between the two groups ($P > 0.05$). In summary, ultrasound-assisted examination based on the algorithm is accurate in the diagnosis of idiopathic edema. Acupoint application therapy has a significant effect on idiopathic edema and does not increase the incidence of adverse reactions, which has a guiding role in clinical treatment.

1. Introduction

Idiopathic edema, a water-salt metabolic disorder syndrome, can be divided into cardiac, renal, hepatic, and malnutrition, which belongs to one of the edema diseases [1–3]. When edema is serious to a certain extent, the body will automatically discharge more water and salt out, so that edema recovery [4, 5]. Acupoint application is a commonly used disease treatment method, and the drug is made successfully specific dosage form, and then according to the dialectical analysis of its application to the specific treatment acupoint, so that the drug can stimulate the acupoint and stimulate the meridian qi to achieve the purpose of treatment of disease [6–8]. In recent years, through the continuous clinical trials of experts, acupoint application has also been tried to be applied to the treatment of edema diseases and has achieved a good therapeutic effect [9–11].

In terms of disease examination, the commonly used clinical examination method is imaging, in which ultrasonic imaging examination is widely used for clinical disease diagnosis with the characteristic pathological diagnosis information in the image [12]. Of course, ultrasonography can also be used in the diagnosis of edema. However, speckle noise and pseudotexture in ultrasonic images cause serious visual interference, especially speckle noise, which conceals the feature information of the image. Speckle noise is a deterministic interference phenomenon inherent in the coherent imaging system [13], which will reduce the signal-to-noise ratio of the image and make the image blurred and the image characteristics disappear when it is serious, causing difficulties for subsequent image processing. Therefore, the research on speckle noise removal technology has become a hot spot in clinical practice, so the deep learning algorithm has been widely applied to the processing of image. Among them, the denoising convolution neural network (DnCNN) algorithm is mostly used for the denoising processing of image [14, 15] and has also obtained a good denoising effect. However, because there are 128 feature maps in each layer of the network, the number of parameters that need to be trained is large, resulting in slow training [16].

Therefore, the DnCNN algorithm was improved to deal with the speckle noise of ultrasonic images and use the ultrasonic image technology based on the improved DnCNN algorithm to evaluate the therapeutic effect of acupoint application therapy on idiopathic edema, so as to provide more treatment methods for patients with idiopathic edema in the clinic.

2. Research Methods

2.1. Research Objects. 144 patients with idiopathic edema treated in Beijing Luhe Hospital Affiliated to Capital Medical University from January 2020 to May 2021 were selected as the research objects. The age range was 18–75 years, the average age was (39.35 ± 2.52) years, the course of the disease was 1 month ~ 2.5 years, and the average course of the disease was 10.24 ± 2.62 months. The edema sites of all patients were facial and limb edema, which increased periodically. According to the digital table method, 144 patients with idiopathic edema were randomly divided into the control group and the acupoint application group, with 72 cases in each group. The control group was treated with conventional western medicine, and the acupoint application group was treated with acupoint application of TCM. The effective rate, syndrome score, and adverse reactions of the two groups were compared before and after treatment, and the treatment effect was evaluated by ultrasound image based on improved DnCNN algorithm. This study was approved by the ethics committee of Beijing Luhe Hospital Affiliated to Capital Medical University (No. 2021-LHKY-001-02).

Inclusion criteria were as follows: (a) all patients met the following diagnostic criteria for idiopathic edema: (1) all patients were between 18 and 75 years old; (2) face edema was obvious in the morning, and lower limb edema was obvious in the afternoon, especially in the ankle and tibial front; (3) the difference in body weight between morning and evening was >1.4 kg; (4) water test in standing and lying position was positive. (b) All patients have signed informed consent.

Exclusion criteria were as follows: (a) edema caused by organic and nutritional deficiency lesions in organs such as heart, liver, and kidney; (b) edema caused by drugs and (c) accompanied by cardiovascular and cerebrovascular diseases, autoimmune diseases, and mental diseases.

2.2. Treatment Methods. Patients in the control group were treated with hydrochlorothiazide tablets (Cisen Pharmaceutical Co., Ltd., H37021905) and spironolactone (Zhejiang Yatai Pharma Co., Ltd., H33020111) daily. The method and dose of hydrochlorothiazide tablets were 25 mg, once a day, and spironolactone 20 mg, once a day.

In the treatment of the acupoint application group, it needs to determine the pathogenesis and syndrome type of edema according to the syndrome differentiation and treatment of patients and determine the Chinese medicine and acupoints needed for application according to the syndrome differentiation results. Therefore, it is highly targeted, such as renal edema-spleen-kidney deficiency syndrome. The prescription is composed of 30 g milkvetch root, 15 g cassia twig, 10 g radix aconiti carmichaeli, 15 g suberect spatholobus stem, 10 g prepared common monkshood mother root, 15 g Chinese angelica, 15 g safflower, 15 g hirsute shiny bugleweed herb, 15 g Chinese starjasmine stem, 10 g kadsura pepper stem, 10 g beautiful sweetgum fruit, 10 g earthworm, 15 g mulberry twig, 5 g borneol, and 30 g mirabilite. Acupoints find God jue hole, foot three mile, Fenglong point, Liangqiu, the sea of blood, Diji, 6–8 h/day, 10 days/a course of treatment, continuous 2 courses. There are many kinds of traditional Chinese medicine prescriptions and acupoint composition, which are not described here.

2.3. Improved DnCNN Algorithm

2.3.1. DnCNN Algorithm. The DnCNN algorithm is a more advanced denoising technology in current deep learning [17]. In terms of peak signal-to-noise ratio, the DnCNN algorithm has more advantages than traditional algorithms. The processing process of the DnCNN algorithm is shown in Figure 1, which can be divided into three parts: the first part—the first layer is convolution layer + Relu activation function. The second part—Layer 2 to Layer 16 consists of 15 Unit blocks. The third part consists of the convolution layer. DnCNN is a global jump from the input end to the output end, thus forming a residual learning strategy [18]. The algorithm process of DnCNN can be expressed as follows:

$$Q(x, y) = W(x, y) + e(x, y). \tag{1}$$

Among them, $Q(x, y)$ is two-dimensional noise image, $W(x, y)$ is noise-free original clean image, and $e(x, y)$ is additional noise.

Noise image is a degradation phenomenon of the original image caused by noise superposition. Image denoising is to obtain an estimated value $\overline{W}(x, y)$ of the original image. The smaller the differential value between $O(x, y)$ and $\overline{O}(x, y)$, the better the denoising effect of the DnCNN algorithm.

2.3.2. Improved Method

Step 1. Improvement for the second part.

There was no doubt about the denoising effect of the DnCNN algorithm. However, due to the large amount of network parameters, the training time was longer, and most of the network parameters were concentrated in layers 2–16. Therefore, to improve this problem, the 15 Unit blocks were optimized in the second part. Figure 2 shows the improved graphic diagram. 3 × 3 convolution (9 parameters to be trained in total) was divided into 1 × 3 and 3 × 1 convolution

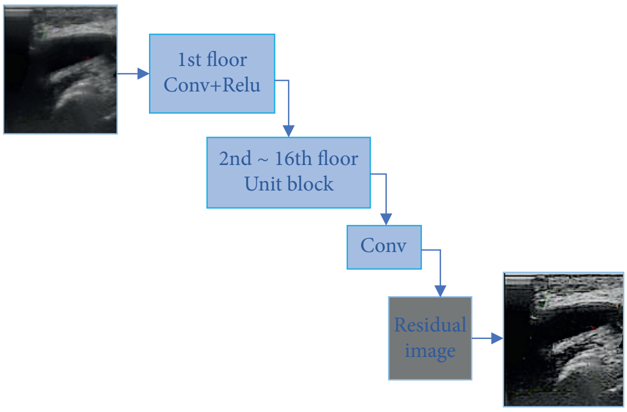

FIGURE 1: Denoising process of DnCNN algorithm.

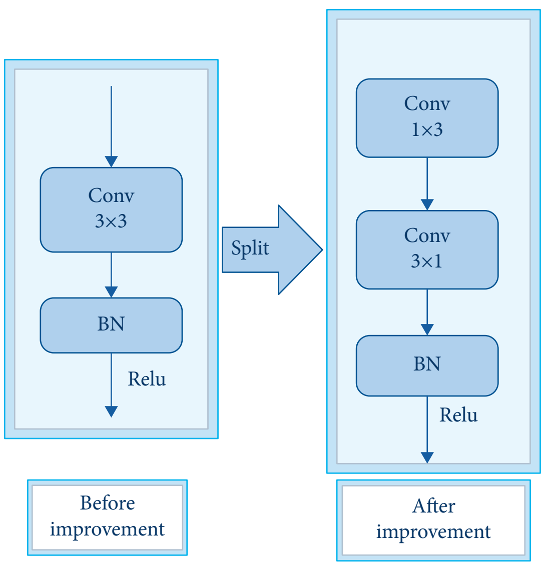

FIGURE 2: Unit block improvement diagram.

series (a total of 6 parameters to be trained), which could reduce the parameters of the whole network by about 1/3. The calculation method of the characteristic image size of the output of the improved convolution is as follows:

$$\text{output} = \frac{\text{input} - k + 2\text{padding}}{s} + 1, \tag{2}$$

where output is side length of output characteristic diagram, input is image input side length, k is convolution kernel side length, padding is input image side length complement of 0 number, and s is convolution step length.

Step 2. Improving feature fusion.

The DnCNN algorithm was prone to redetermine the second gradient direction during training, so the network training time was prolonged. Moreover, because it was a deep convolution neural network, there was only high-level semantic information and a lack of low-level semantic information. Therefore, in this step, the underlying semantic information was added and fused with high-level semantics.

Step 3. Time complexity and space complexity improvement.

The number of operations of the convolutional neural network model is determined by time complexity. The overall time complexity of the neural network is expressed as follows:

$$\text{Time} \sim O\left(\sum_{i=1}^{R} T_i^2 K_i^2 U_{i-1} U_i\right), \tag{3}$$

where R is the number of convolutional layers of neural network, i is neural network convolutional layer numbering, T is side length of output feature graph of convolution kernel, K is side length of convolution kernel, U_i is the number of output channels at the convolutional layer i of the neural network, and U_{i-1} is the number of input channels of the convolution layer i. Since DnCNN and improved DnCNN both adopt padding in the convolution process and the step length is 1, the side length of the target image and feature image will not change.

The side length of the convolution output feature graph is T, and then, the time complexity of DnCNN is as follows:

$$\begin{aligned}\sum_{i=1}^{R} T_i^2 K_i^2 U_{i-1} U_i &= T^2 \times 3^2 \times 1 \times 64 + T^2 \times 3^2 \times 64 \times 64 \\ &\quad \times 15 + T^2 \times 3^2 \times 64 \times 1 \\ &= T^2 \times 554\,112.\end{aligned} \tag{4}$$

Improved DnCNN is as follows:

$$\begin{aligned}\sum_{i=1}^{R} T_i^2 K_i^2 U_{i-1} U_i &= T^2 \times 3^2 \times 1 \times 64 + \left(T^2 \times 1 \times 3 \times 64 \times 64 + T^2 \times 3 \times 1 \times 64 \times 64\right) \times 15 \\ &\quad + T^2 \times 3^2 \times 64 \times 64 \times 2 + T^2 \times 3^2 \times (64 + 64 + 64) \times 1 \\ &= T^2 \times 444672.\end{aligned} \tag{5}$$

Spatial complexity is the number of parameters of the neural network model, and the overall time complexity of the convolutional neural network is as follows:

$$\text{Space} \sim O\sum_{i=1}^{R} K_i^2 U_{i-1} U_i. \tag{6}$$

By comparing with (3), it was found that the spatial complexity was only related to the edge length of convolution kernel K and the number of channels U.

Step 4. Loss function and training methods.

The denoising effect of DnCNN on images is usually evaluated by the peak signal-to-noise ratio, and the mean squared error (MSE) between the original image and denoising image directly affects the value of the peak signal-to-noise ratio. Therefore, the improved DnCNN algorithm adopted took MSE as a loss function.

$$\text{Loss}(\aleph) = \frac{1}{2N}\sum_{j=1}^{N}\left\| P\left(y_j;\aleph\right) - \left(y_j - x_j\right)\right\|^2. \tag{7}$$

Here, N is the number of samples per training batch; x is an initial image; y is the noised image; P is noise; loss function is calculated. Adam (adaptive moment estimation) method was used to optimize parameters, and the weights were updated.

$$\begin{aligned} D_{b+1}^i &= D_b^i + \Delta_{b+1}^i, \\ \Delta_{b+1}^i &= -\partial\frac{\wp I}{\wp D_b^i}, \end{aligned} \tag{8}$$

Here, D is convolution kernel; i is convolution layer n; b is the number of iterations; ∂ is the learning rate.

2.4. Ultrasonic Examination. All patients were examined by the same ultrasound operator and the same instrument, and the same doctor reviewed the film. The instruments used are Esaote MyLab Twice and Philips-iu22 color Doppler ultrasound, probe frequency (5–12) MHz, high-frequency frequency conversion probe; patients took supine position and prone position and fully expose the edematous parts; the edematous parts were repeatedly scanned, and the structural changes of the skin, subcutaneous tissue, deep fascia, and muscle tissue were carefully observed, and the thickness was measured.

2.5. Observation Indicators. The effect of edema improvement after treatment (Figure 3 was evaluation criteria) and accompanying symptoms, such as fatigue, dizziness, panic, frequent urination or urgent urination, dyspepsia, and other emotional and physical discomfort changes were observed. The symptoms were expressed in semiquantitative integral (Table 1). The quality of life assessment scale was used to evaluate the quality of life of patients before and after treatment.

2.6. Statistical Methods. SPSS22.0 statistical software was used for processing. T-test is used for measurement data, χ^2 test was used for counting data, and the difference was statistically significant ($P > 0.05$).

3. Results

3.1. Comparison of Denoising Performance of DnCNN Algorithm before and after Improvement. Figure 4 shows the comparison of the denoising performance between the improved Unit block DnCNN algorithm and the DnCNN algorithm. According to the comparison results in Figure 4, when the training parameters of the improved DnCNN algorithm were reduced by about 1/3 and the training was stable, the results of peak signal-to-noise ratio were basically consistent with those of DnCNN. Table 2 shows the comparison of the effects of feature fusion on denoising performance. Through the statistical results, when the amount of training parameters was reduced by about 1/5, the peak signal-to-noise ratio value of the improved DnCNN was higher than that of DnCNN every training. According to (4) and (5), it was found that the time complexity of DnCNN was $T^2 \times 554122$, and the space complexity was 554122. Under the same conditions, the time complexity of the improved DnCNN was $T^2 \times 444672$, and the space complexity was 444672. By comparison, the time and space complexity of improved DnCNN were lower than DnCNN. Figure 5 shows the training loss diagram after improving the loss function when the Gaussian noise level = 25. Through observation, the improved DnCNN loss decline was relatively stable, and there was no redefinition of the second gradient direction, while the gradient direction was redefinited during the loss decline of DnCNN. Figure 6 shows 12 standard images. When the noise level was 25, the processing effect of the overall improved DnCNN algorithm was compared with that of the DnCNN algorithm. The peak signal-to-noise ratio values of the images processed by the former were higher than those of the images processed by the latter ($P < 0.05$). The above results show that the improved DnCNN algorithm was better than DnCNN algorithm in image denoising performance.

3.2. Ultrasonic Image Based on Improved DnCNN Algorithm. Figure 7 shows the comparison of the processing effect of the improved DnCNN algorithm on the patient's ultrasonic image. The image quality of the original image before processing was blurred, and the resolution of the image was low. After processing, the image quality was significantly clearer than the former, and the image resolution was higher, and the edema part and the boundary between blood vessels and tissues were more clearly visible.

3.3. Comparison of General Data between the Two Groups. Figure 8(a) shows the comparison of the average age of the two groups. The average age of the acupoint application group was (38.95 ± 2.42) years, and that of the control group was (39.97 ± 2.55) years. The difference was not statistically

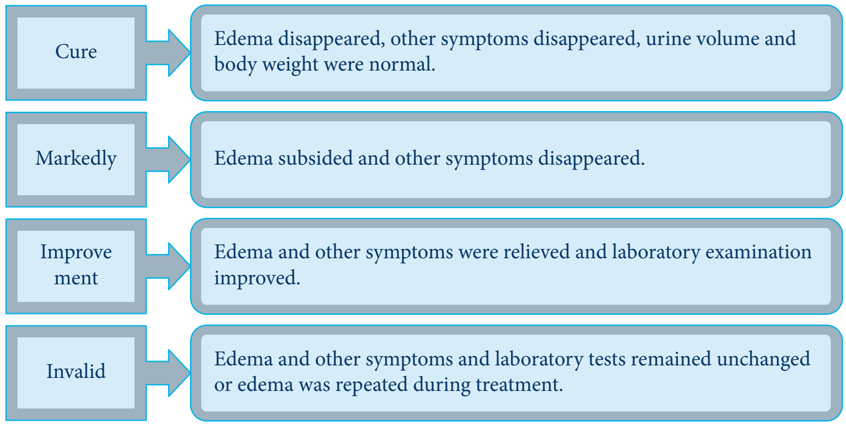

Figure 3: Evaluation indicators.

Table 1: Semiquantitative integral standard.

Score	Degree	Effect of accompanying symptom
0	Symptomless	No other accompanying symptom
1	Mild	No effect on the daily life of patients
2	Medium	Influence on the daily life of patients
3	Severe	Patients must rest

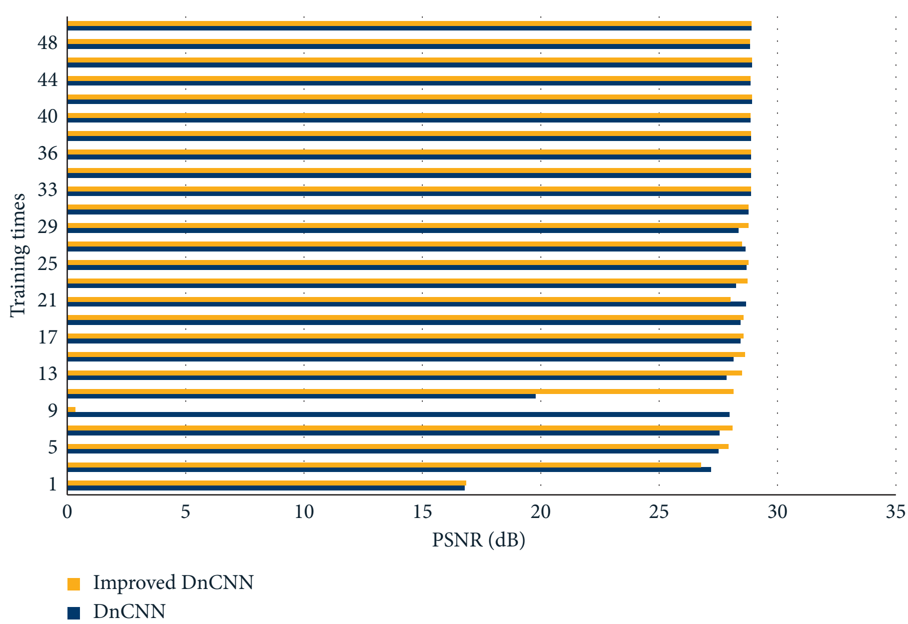

Figure 4: Influence of improved Unit block structure on image denoising performance.

Table 2: Effect of feature fusion on denoising performance.

Number of trainings		5	10	15	20	25	30	35	40	45
PSNR (dB)	Improved DnCNN	29.60	29.91	30.18	30.19	30.22	30.38	30.21	30.21	30.32
	DnCNN	29.50	29.50	29.86	30.00	30.12	30.18	30.17	30.18	30.21

significant ($P > 0.05$). Figure 8(b) shows the comparison of the average course of disease between the two groups. The average course of disease in the acupoint application group was (11.24 ± 2.92) months, and that in the control group was (10.14 ± 2.52) months. There was no significant difference ($P > 0.05$).

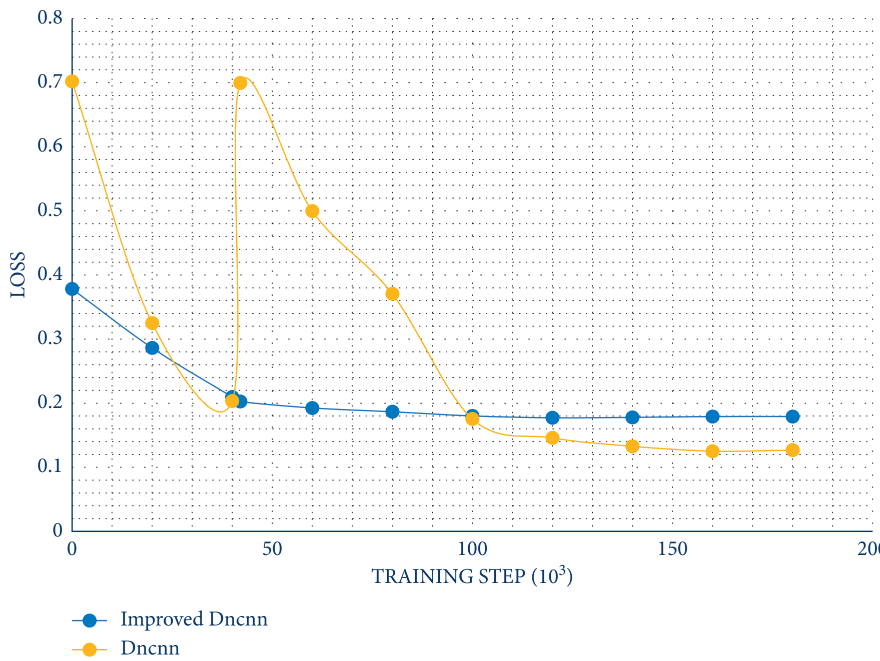

Figure 5: Comparison of training loss.

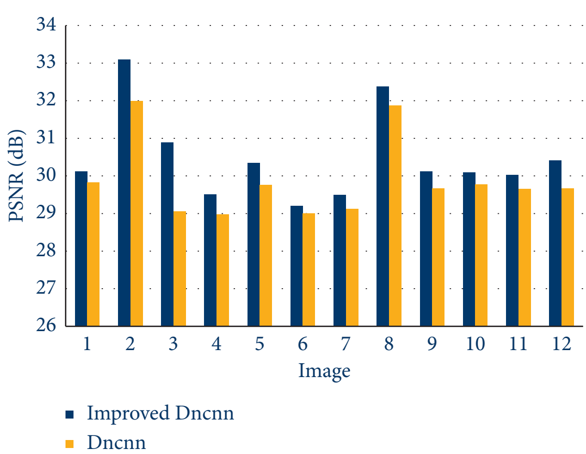

Figure 6: Comparison of PSNR results.

3.4. Comparison of Treatment Effects. Table 3 shows the comparison of edema treatment between the two groups of patients with idiopathic edema through clinical manifestations and ultrasound examination. In the acupoint application group, 35 were cured, 24 were markedly effective, 8 were improved, and 5 were ineffective. The total effective number was 67. As for the control group, there were 12 cured, 12 were markedly effective, 8 were improved, and 40 were ineffective, and the total effective number was 32. Through calculation and analysis, it can conclude that the total effective rate of the acupoint application group was 93%, and that of the control group was 45%, which was significantly higher than that of the control group ($P < 0.05$). Figure 9 shows the comparison of lower limb edema before and after treatment in the treatment acupoint application group. The blue dotted line in the figure shows the edema area in the tissue. After comparison, the dark echo in the tissue disappeared obviously.

3.5. Semiquantitative Integral Change. The changes of integral values of edema accompanying symptoms before and after treatment were compared between the two groups. The changes of integral values of accompanying symptoms in the acupoint application group were fatigue -1.21 ± 0.56, vertigo -1.89 ± 0.67, palpitation -1.23 ± 0.49, frequent micturition/urgency -1.16 ± 0.48, dyspepsia -1.01 ± 0.59. The change degree of integral value of each accompanying symptom in the control group was fatigue -0.21 ± 0.16, vertigo -1.12 ± 0.37, palpitation -0.46 ± 0.32, frequent micturition/urgency -0.25 ± 0.21, dyspepsia -0.10 ± 0.09. After comparison, it can conclude that the integral value after treatment and the change degree of integral value before and after treatment in the acupoint application group were better than those in the control group ($P < 0.05$) (Figure 10).

3.6. Adverse Reactions. Figure 11 shows the comparison of the incidence of adverse reactions between the two groups. According to statistical analysis, 9 patients in the acupoint application group had adverse reactions, while 7 patients had adverse reactions in the control group. After comparison, there was no significant statistical difference between the incidence of adverse reactions in the acupoint application group (12%) and the control group (10%) ($P > 0.05$).

3.7. Quality of Life Score. Figure 12 shows the comparison of quality-of-life scores between the two groups before and after treatment. The quality-of-life scores of patients in the pretreatment acupoint application group and the control

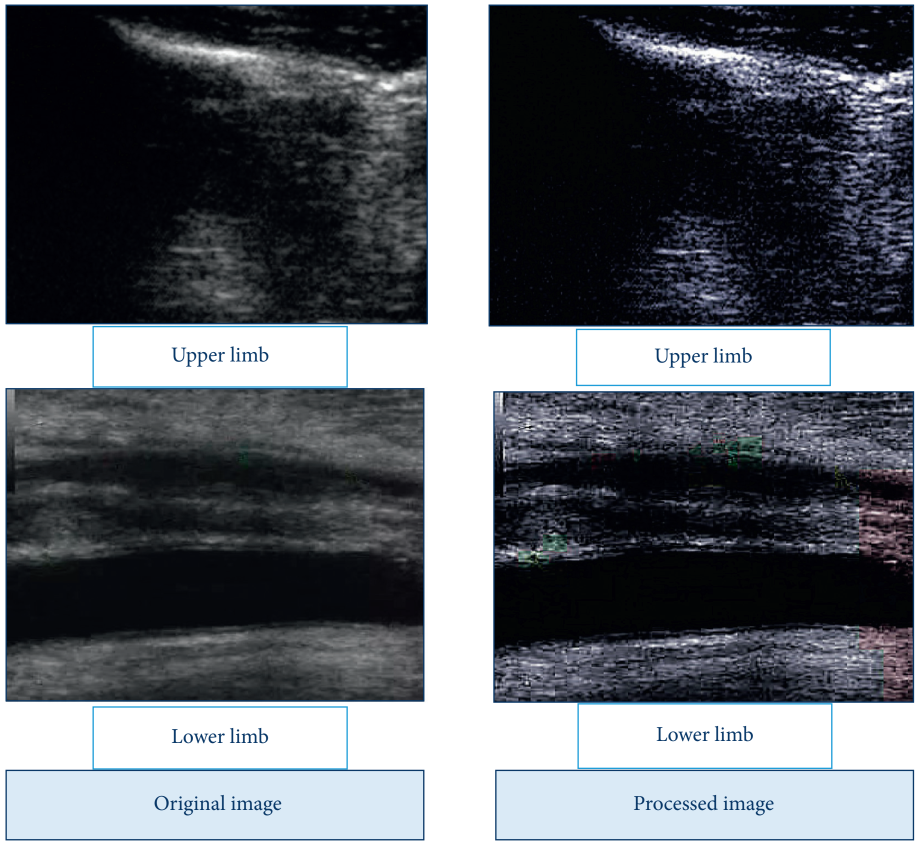

Figure 7: Comparison of ultrasound image processing of upper and lower limb edema.

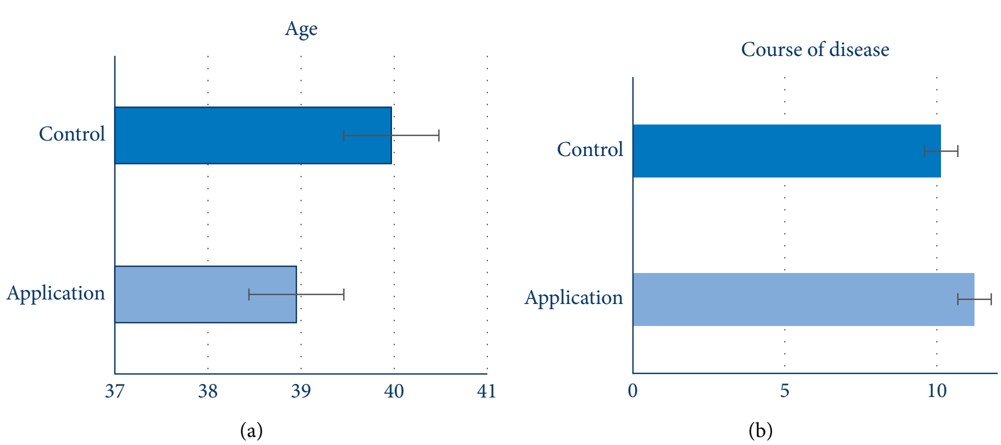

Figure 8: General data comparison.

Table 3: Treatment effect statistics.

Groups treatment	Cure	Effective	Improvement	Invalid
Application group ($n = 72$ cases)	35 (49%)	24 (33%)	8 (11%)	5 (7%)
Control group ($n = 72$ cases)	12 (17%)	12 (17%)	8 (11%)	40 (55%)

group were (62.43 ± 5.24) and (64.23 ± 4.01), with no significant comparison ($P > 0.05$). The quality-of-life scores of patients in the posttreatment acupoint application group were (90.26 ± 8.24) and (82.54 ± 5.44), respectively. The scores of quality of life in the two groups after treatment were higher than those before treatment, and the scores in

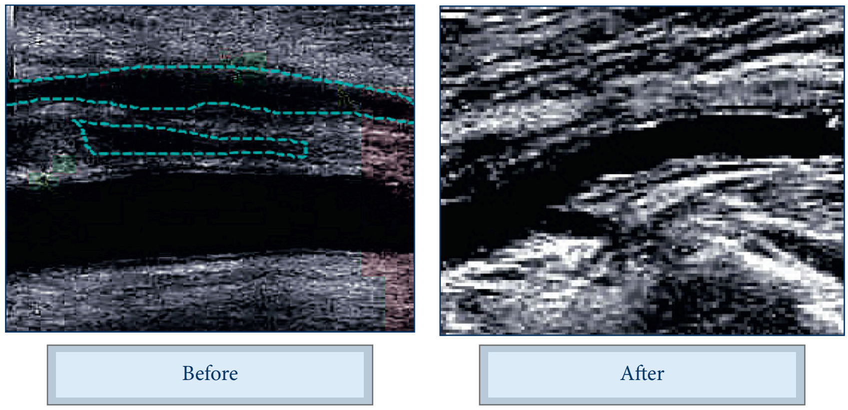

Figure 9: Comparison of ultrasound before and after treatment in the acupoint application group.

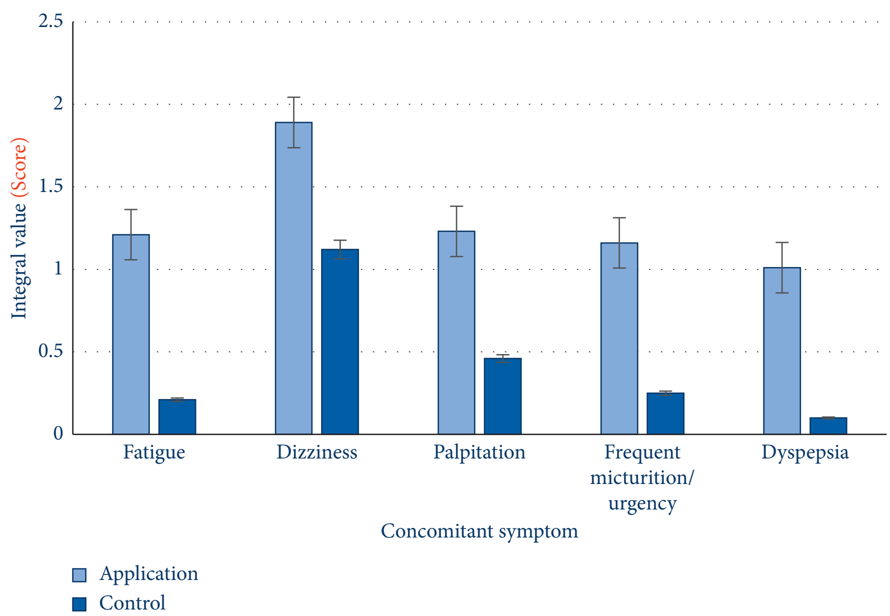

Figure 10: Comparison of variation of integral value.

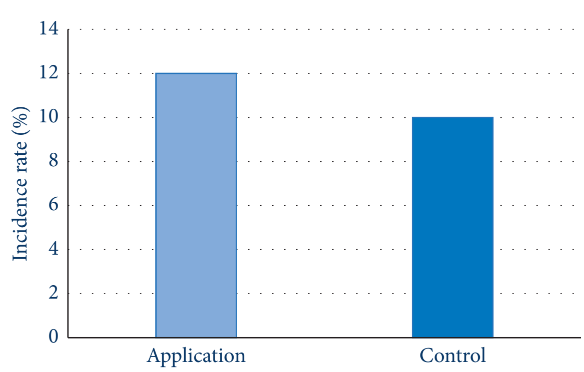

Figure 11: Comparison of adverse reaction rates.

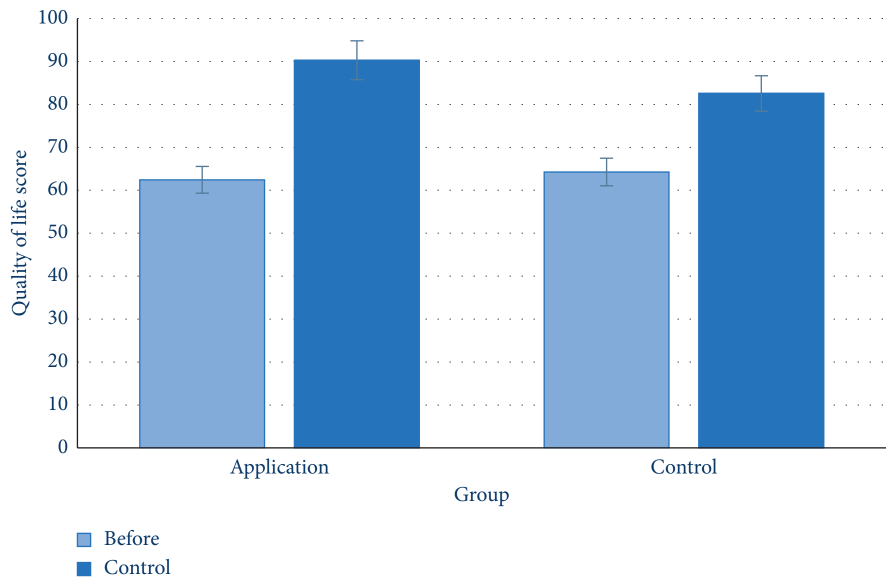

Figure 12: Comparison of quality-of-life scores.

the acupoint application group after treatment were significantly higher than those in the control group ($P < 0.05$).

4. Discussion

A large number of statistical studies have pointed out that the main incidence population of idiopathic edema is women, and the onset time is periodic. Most patients with idiopathic edema have mild-to-moderate symptoms, but a few patients have more serious concomitant symptoms. In order to better prevent the development of idiopathic edema patients, this study proposes to use the degree application therapy of TCM for treatment and compare the curative effect with the conventional western medicine therapy. The inspection method for comparison mainly adopts ultrasonic technology. In order to make the ultrasonic image clearer and further improve the accuracy of the research results, the improved DnCNN algorithm was used to denoise ultrasonic images.

After comparative analysis, the improved DnCNN algorithm reduced the training parameters and made the training process more stable under the premise of maintaining the denoising effect of the DnCNN algorithm. Under the same noise level, the PSNR value of the improved DnCNN algorithm was higher than that of the DnCNN algorithm, suggesting that the improved DnCNN algorithm improved the denoising performance. Many studies have shown that the DnCNN algorithm has a good application effect in image denoising processing [19–21]. However, Kidoh et al. (2019) [22] found that DnCNN algorithm also had a certain effect on MRI image denoising. Usui et al. (2021) [23] proposed that for CT images, DnCNN achieved significantly better denoising than other image denoising methods, especially at the ultralow dose level used to generate 10% and 5% dose equivalent images. Amin et al. (2021) [24] proposed DnCNN algorithm can also be used for idiopathic edema microscopic segmentation and classification of COVID-19 infection. The above shows that the DnCNN algorithm has good development prospects in the medical field.

Through the above ultrasonic examination technology combined with the clinical manifestations of patients, it was concluded that the therapeutic effect of acupoint application therapy for patients with idiopathic edema was better than conventional western medicine therapy. The total effective rate of the acupoint application group (93%) was significantly higher than that of the control group (45%) ($P < 0.05$), the quality-of-life scores of the two groups after treatment were higher than those of the two groups before treatment, and and after treatment, the point application group was significantly higher than the control group ($P < 0.05$), and the score of accompanying symptoms before and after treatment was lower than that of the control group. TCM treatment was based on syndrome differentiation and treatment. Therefore, as long as the syndrome type diagnosis of the disease was accurate, it was quite beneficial in the treatment effect of the disease. The results of many studies using TCM therapy show that the therapeutic effect of TCM therapy was better than that of simple western medicine therapy and had the characteristics of safety, effectiveness, and small side effects [25–27]. It also indicates that the incidence of adverse reactions in the acupoint application group (12%) had no significant statistical significance compared with the control group (10%) ($P > 0.05$), suggesting that there was no significant difference in the safety between acupoint application therapy and conventional western medicine. Moreover, this therapy not only shows its significant therapeutic effect but also shows its therapeutic advantages in the treatment of other diseases, such as hypertension [28] and bronchial asthma [29]. Of course, the role of Western medicine cannot be ignored. Some research experts have studied the effect of long-term use of metformin in the treatment of idiopathic circulatory edema. The results show that 77% of them have achieved complete remission, and no serious adverse events have been found [30].

5. Conclusion

The improved DnCNN algorithm was used to denoise the ultrasonic image to evaluate the therapeutic effect of acupoint application therapy on idiopathic edema. The results show that the improved DnCNN algorithm has a better denoising effect than the DnCNN algorithm. Acupoint application therapy is better than conventional western medicine in the treatment of idiopathic edema and has higher safety. However, there is a lack of related literature, so further research is needed. However, the application prospect of the deep learning algorithm in the field of medical imaging is very considerable, and the remarkable effect of TCM in the clinical treatment of diseases also suggests the development prospect of TCM.

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 that there are no conflicts of interest.

Acknowledgments

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