Research Article

Application of Color Doppler Imaging of Portal Vein Based on Iterative Reconstruction Algorithm in the Diagnosis of Exercise-Induced Abdominal Pain

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This study was to explore the application of a 50% iterative reconstruction algorithm in the diagnosis of exercise-induced abdominal pain (AP) with color Doppler imaging, the changes of liver and gallbladder, and portal vein before and after the exercise. 108 students with exercise-induced AP caused by mid- and long-distance running from May 30, 2019, to April 15, 2020, were selected as the research objects in this study. They were performed with the color Doppler flow image (CDFI). An iterative reconstruction (IR) with a weight of 50% was adopted for image reconstruction, and the reconstructed images were evaluated subjectively and objectively. Then, the maximum liver diameter (MLD), gallbladder width (GW), and portal vein diameter (PVD) were recorded before and after the exercise. The results showed that the SNR and CNR after ultrasound image reconstruction (UIR) (1.07 ± 0.58 and 3.59 ± 0.61, resp.) were increased greatly in contrast to the values before the UIR (7.36 ± 1.15 and 1.07 ± 0.58, resp.) (p < 0.05); the score after the UIR (4.38 ± 0.59) was obviously higher than that before the UIR (3.52 ± 0.41) (p < 0.05); the MLD of the subject at the 12th minute during the exercise was observably smaller than that at the 0th minute (p < 0.05); the MLD of the subject at the 12th minute after the exercise was greatly larger than that at the 0th minute (p < 0.05); the GW of the subject during and after the exercise was not changed considerably; and the PVD of the subject at the 12th minute during the exercise was larger greatly than that at the 0th minute (p < 0.05). In short, the quality of the reconstructed image based on the IR and noise index was better than that of the original ultrasound image because the interference of artifacts and noise was reduced. After exercise, the liver volume decreased, while the PVD increased, resulting in exercise-induced AP.

1. Introduction

AP is a relatively common symptom during exercise, especially in middle- and long-distance running, race walking, cycling, and other events. The causes of AP during exercise are more complex. In addition to exercise-induced dysfunction and liver and spleen congestion, it may also be combined with various abdominal medical diseases, such as acute attacks of chronic diseases caused by intense exercise, or acute abdomen during exercise [1–3]. One of the more common views at present is the theory of liver and spleen congestion during exercise, which refers to that vigorous operation may lead to blood sugar deficiency and congestion in the liver, resulting in pain in the liver area [4]. However, some studies have shown that the cause of AP during exercise may be liver ischemia instead of blood congestion. This theory believes that the body will promote the adrenal medulla to secrete epinephrine and norepinephrine during exercise, which will cause the internal organs of the abdominal cavity to contract. When the blood is redistributed, the blood supply of the internal organs is significantly reduced, and more blood is supplied to the bones and the skin [5, 6]. Related statistic data shows that the blood flow of internal organs will be reduced by about 78% during strenuous exercise, resulting in extreme ischemia. Therefore, this article intends to discuss the mechanism of exercise-induced AP based on the above descriptions.

Ultrasound imaging is one of the commonly used diagnostic methods in clinical medicine. It is widely used in human skeletal system diseases, muscle injuries, organ
diseases, and other diseases. It is superior with high diagnostic accuracy, low price, easy operation, and non-invasiveness and can be compared with the computed tomography (CT) and magnetic resonance (MR) [7, 8], of which the blood flow in blood vessels can be observed by using the reflected sound waves through Doppler Ultrasound, which can help doctors evaluate the blood flow of major arteries and veins, such as arms, legs, neck arteries, and veins [9]. The current research literature on exercise-induced abdominal pain in recent years mainly focuses on analyzing the blood changes of the body before and after exercise. There are a few studies on the specific regulation mechanism, so there is no unified conclusion. Therefore, the CDFI was adopted in this article to detect the portal vein, liver, and gallbladder [10]. IR technology is a long-developed image reconstruction algorithm, which is mainly to iteratively optimize the target equation for image reconstruction based on preset convergence criteria. Moreover, iterative algorithms with different weights have obvious differences in the quality of image reconstruction. The 50% weight is currently known to be a better setting [11]. Sunaguchi et al. [12] adopted an iterative method based on the advanced optical interference for CDFI reconstruction while ensuring the image quality and greatly reducing the phase artifacts in the initial phase map. Puchner et al. [13] applied the IR algorithm to coronary vascular ultrasound images and found that IR could effectively improve the accuracy of semiautomatic plaque assessment. Therefore, reducing the radiation dose while maintaining image quality is the focus of many scholars [14]. An IR with a weight of 50% was adopted in this article to reconstruct and analyze the CDFI of the patient’s liver.

In summary, CDFI has been widely used in the field of medical imaging, and the iterative method can further improve the quality of the original image. Based on this, 108 students who caused exercise-induced AP in the long-distance running were selected as the research objects. They all performed the CDFI scan of the liver, and the 50% IR was adopted to reconstruct the original ultrasound image. The changes in MLD, GW, and PVD levels of subjects during and after the exercise were compared, so as to comprehensively evaluate the application value of portal vein CDFI based on a 50% iterative reconstruction algorithm in the diagnosis of the exercise-induced AP.

2. Materials and Methods

2.1. Selection of Samples. 108 students who suffered exercise-induced AP in the middle- and long-distance running from May 30, 2019, to April 15, 2020, were selected as the research objects, and they were all scanned by CDFI. The study had been approved by the Medical Ethics Committee and the patients and their families had understood the study and signed the informed consent and inspection failure consents.

Inclusion criteria were defined as follows: patients older than 18 years, patients with complete clinical data, patients who had not received treatment, and patients with clear consciousness and who are able to cooperate with the examination.

Exclusion criteria were determined as follows: patients with a history of iodine allergy, patients with mental illness, patients with incomplete clinical data, patients with metal implants, patients who were not cooperative during the scanning, and patients who had a history of liver disease.

2.2. Experimental Methods. The subjects were instructed to fast before the test to reduce the interference of intestinal gas. The specific steps were given as follows: the subject was allowed to run for 6 minutes at a speed of 150 times/min on the treadmill, and then they were scanned with CDFI to acquire images; after the heart rhythm was restored, the subject was required to run again at a speed of 150 times/min for 12 minutes, then they were scanned with CDFI to acquire the images again; after the heart rhythm was restored to the calm condition, the subject had to run again at a speed of 150 times/min for 18 minutes, and then the images were obtained again; after the heart rhythm was restored to the calm state, the running was repeated at the same speed for another 24 minutes, and then the images were obtained. Three times of data were recorded for each scan and the average value was calculated.

During CDFI scanning, the subject was placed in a supine position, and the images were frozen during inhalation before and after the exercise. In addition, the ultrasound probe was placed on the lower edge of the costal arch for scanning. After the scan was completed, the ultrasound images were sent to the workstation and optimized with the 50% IR method. Then, the length of the subject’s liver (the distance from the top of the right clavicle to the lower edge of the liver), the maximum width and height of the gallbladder, and the inner diameter of the portal vein were measured and recorded.

2.3. Evaluation Indicators of Reconstructed Image. Objective evaluation: an area of interest with appropriate size in the cross section of the subject’s liver ultrasound image was selected to measure the signal value (SV) and noise value (NV) of the liver in the ultrasound image, and the SV of the right erector spinae muscle and the standard deviation (SD) between the value and the subcutaneous fat SV of the anterior abdominal wall were measured accurately. During the measurement, it had to ensure staying away from blood vessels, bile ducts, lesions, and calcifications to reduce the influencing factors of the measurement. Then, the SNR and CNR of the image were calculated based on the SV and NV:

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\text{SNR} = \frac{\text{SV}_{\text{liver}}}{\text{SD}_{\text{liver}}} \]
\[
\text{CNR} = \frac{(\text{SV}_{\text{liver}} - \text{SV}_{\text{erector spinae}})}{\text{SD}_{\text{abdominal wall fat}}}.
\] (1)

Subjective evaluation: two senior imaging physicians were asked to evaluate the quality of ultrasound images by using the double-blind method, with a score of 1–5. If the score was 1, it indicated that the quality of ultrasound images
was poor with too high noise and lots of artifacts so that it could not be applied for image diagnosis completely. 2 indicated that the image quality was relatively poor with some artifacts and noises so that it could not satisfy the needs of image diagnosis. A score of 3 suggested that the image quality was good with a small amount of artifacts and noises, which basically satisfied the requirements of imaging diagnosis. A score of 4 indicated that the image quality was excellent with almost no artifact and noise, which fully met the requirements of imaging diagnosis.

2.4. Statistical Methods. The data processing was analyzed by SPSS19.0 statistical software, the measurement data was expressed as mean ± standard deviation (X ± s), and the count data was indicated as percentage (%). The SNR, CNR, and subjective scores before and after the UIR were compared by independent t-test. The MLD, GW, and PVD levels of subjects before and after the exercise were compared by one-way analysis of variance. The difference was statistically significant at p < 0.05.

3. Results

3.1. Objective Evaluation Results before and after Ultrasound Image Reconstruction. Figure 1 shows the objective evaluation results before and after the UIR. The SNR and CNR before the UIR were 7.36 ± 1.15 and 1.07 ± 0.58, respectively; the SNR and CNR after the UIR were 1.07 ± 0.58 and 3.59 ± 0.61, respectively. The SNR and CNR after UIR were much higher than those before the UIR (p < 0.05).

3.2. Subjective Evaluation Results before and after Ultrasound Image Reconstruction. Figure 2 illustrates the comparison of subjective evaluation scores before and after UIR. The score before and after the reconstruction was 3.52 ± 0.41 and 4.38 ± 0.59, respectively. The score after the UIR was obviously higher than that before the UIR, and the difference was statistically meaningful (p < 0.05).

The original ultrasound image was compared with the reconstructed image, and the results are given in Figure 3. Figure 3(a) shows that the overall clarity of the original image was so poor with many artifacts and noises that it could not meet the requirements of clinical diagnosis, so its score was determined as 2. Figure 3(b) is a reconstructed 3-score ultrasound image; the overall clarity had been improved accordingly, and noises and artifacts had been reduced in contrast to the original image, which could basically meet the needs of a physician for visual diagnosis. Figure 3(c) shows a reconstructed 5-score ultrasound image, the overall image definition of which was good enough without noise and artifact and with relatively clear contrast, so it could satisfy the requirements of imaging diagnosis.

3.3. Changes in Maximal Liver Diameter of the Subject during and after the Exercise. Figure 4 shows the changes in MLD during the exercise. It revealed that MLD of the subject at the 0th, 6th, 12th, 18th, and 24th minutes during the exercise was 136.66 ± 0.25 mm, 132.09 ± 0.18 mm, 124.57 ± 0.17 mm, 123.05 ± 0.28 mm, and 122.96 ± 0.31 mm, respectively, of which the MLD of the subjects decreased obviously after the 12th minute during the exercise comparing to the value at the 0th minute (p < 0.05).

Figure 5 illustrates the changes in MLD after the exercise. It disclosed that the MLD of the subjects at the 0th, 6th, 12th, 18th, and 24th minutes after exercise was 122.96 ± 0.31 mm, 126.11 ± 0.22 mm, 132.21 ± 0.35 mm, 134.11 ± 0.16 mm, and 136.82 ± 0.39 mm, respectively, of which the MLD of at the 12th minute after exercise increased greatly comparing with that at the 0th minute after exercise (p < 0.05).

3.4. Changes in Gallbladder Width of Subjects during and after the Exercise. Figure 6 discloses the change of GW during and after the exercise. GW of the subject at the 0th, 6th, 12th, 18th, and 24th minutes during exercise was 64.31 ± 0.27 mm, 64.64 ± 0.39 mm, 64.77 ± 0.41 mm, 65.08 ± 0.35 mm, and 65.26 ± 0.33 mm, respectively. GW of the subject at the 0th, 6th, 12th, 18th, and 24th minutes after the exercise was 64.31 ± 0.27 mm, 64.64 ± 0.39 mm, 64.77 ± 0.41 mm, 65.08 ± 0.35 mm, and 65.26 ± 0.33 mm. Thus, the GW was not changed obviously during and after the exercise with only slight increase and decrease.

3.5. Changes of Portal Vein Diameter of the Subject during and after the Exercise. Figure 7 illustrates the PVD changes of subjects during exercise. The PVD of the subject at the 0th, 6th, 12th, 18th, and 24th minutes during the exercise was 9.87 ± 0.41 mm, 10.35 ± 0.38 mm, 12.73 ± 0.43 mm, 12.85 ± 0.27 mm, and 12.69 ± 0.28 mm. Thus, the PVD increased observably at the 12th minute during the exercise in contrast to the level at the 0th minute (p < 0.05).

Figure 8 illustrates the changes of PVD after the exercise. It revealed that the PVD at the 0th, 6th, 12th, 18th, and 24th minutes after the exercise was 9.87 ± 0.41 mm, 10.35 ± 0.38 mm, 12.73 ± 0.43 mm, 12.85 ± 0.27 mm, and 12.69 ± 0.28 mm, respectively. In addition, the PVD at the 12th minute after exercise was obviously lower than that at the 0th minute (p < 0.05).

4. Discussion

Exercise-induced AP refers to the abdominal pain caused or induced by sports. The main reasons are insufficient preparation before exercise, rapid increase in activity intensity, and poor physical condition, such as the strenuous stomach cramps caused by exercise soon after a meal or eating too much or eating the raw and cold stimulating foods or intestinal cramps caused by constipation or constipation. Therefore, it is clinically recommended to avoid eating or drinking too much before exercise and to rest for one and a half to two hours after meals [15, 16]. At present, it is not clear about exercise-induced AP and liver blood flow changes. Therefore, 108 students who suffered from the exercise-induced AP in the
middle- and long-distance running were selected and performed the CDFI scans of the liver. The 50% IR was adopted to reconstruct the original ultrasound image. Firstly, it was found that the SNR and CNR after UIR were higher observably than those before the image reconstruction ($p < 0.05$), which was different from the research results of Ehsani et al. [8]. It may be related to the performance of algorithm reconstruction. Thus, it indicated that the quality and noise index of the UIR based on the IR were better than those of the original ultrasound image because the interference of artifacts and noises were reduced greatly. The subjective score after UIR was much

Figure 1: The objective evaluation results before and after the UIR. (a, b) Results of SNR and CNR, respectively. *Difference followed to $p < 0.05$ in contrast to the reconstructed image.

Figure 2: The comparison of subjective evaluation scores before and after UIR. *$p < 0.05$ in contrast to the reconstructed image.

Figure 3: Comparison of the original ultrasound image and the reconstructed image. (a) Original image of a patient. (b, c) Reconstructed 3-score image and a 5-score image, respectively.
higher than in contrast to that before the UIR ($p < 0.05$), indicating that the quality of reconstructed images based on the 50% IR had been greatly improved.

The MLD of the subjects decreased obviously at the 12th minute during the exercise and was much smaller than the MLD at the 0th minute ($p < 0.05$), which was different from the results of Taulaniemi et al. [17]. It may be related to the duration of sport exercise of the subjects. In addition, it was found that a decrease in liver volume indicated the liver blood was redistributed to the circulatory system after exercise and it had been proved that the probability of AP at about the 10th minute during exercise was the highest clinically. Thus, the exercise-induced AP may be accompanied by a decrease in liver volume and blood distribution.
The MLD of the subject at the 12th minute after exercise increased remarkably, which was higher considerably than that at the 0th minute ($p < 0.05$). It was because the blood volume required by the exercise organs after the body stopped exercising decreased, the blood storage function of the liver returned to normal, and the volume of the liver recovered to its original shape.

The GW changed slightly during and after the exercise, which was different from the result of Cuellar et al. [18]. It may be because the decrease in liver volume would cause the intrahepatic bile duct to squeeze out some bile so that the gallbladder became bigger. The PVD of the subjects increased notably at the 12th minute during the exercise, which was higher hugely than the level at the 0th minute ($p < 0.05$). The portal vein was obviously thickened during the exercise, which would increase the blood flow in the organ, indicating that exercise-induced AP may be accompanied by the enlargement of the portal vein and the enhancement of blood circulation [19]. The PVD of the subjects at the 12th minute after exercise decreased considerably, which was much lower than the level at the 0th minute ($p < 0.05$), indicating that the blood volume required by the exercise system decreased after the body stopped exercising, so the portal vein returned to its normal shape.

5. Conclusion

108 students who suffered from exercise-induced AP in the long-distance running were selected as the research objects, and they all performed the CDFI scan of the liver. The original ultrasound image was reconstructed with 50% IR. It was found that the quality and noise index of the ultrasound reconstruction image based on the IR were much better than those of the original ultrasound image, with greatly reduced interference of artifacts and noises. After exercise, the liver volume decreased, while the portal vein volume increased due to redistribution of the blood, resulting in exercise-induced AP. However, it was proved that the changes in the gallbladder volume before and after exercise were not obvious, which may be related to the data accuracy of the experimental equipment and the small sample size. In the future, it will consider increasing the sample size of the subjects to improve the precision of the experimental equipment and to further explore the related factors of exercise-induced AP. In conclusion, the regulatory mechanism of human organs before and after exercise was explored innovatively, which could provide a good practical significance for the clinical diagnosis of exercise-induced AP.

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 they have no conflicts of interest.

References


