Original Article

An initial study of core muscles using ultrasound in postmenopausal women with osteoporosis

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Background: Osteoporosis is a systemic bone disease, resulting in bone pain and fragility fractures. This study sought to explore the ultrasonic characteristics of core muscles in postmenopausal women with osteoporosis.

Methods: A total of 91 participants underwent ultrasound examinations of the lumbar and abdominal core muscles. The participants were divided into the following two groups: group 1 (the normal control group, comprising 20 participants, aged 25–35 years); and the osteoporosis group (comprising 71 participants). The participants in the osteoporosis group were further divided into the following three groups: group II (comprising 20 participants, aged 50–59 years); group III (comprising 30 participants, aged 60–69 years); and group IV (comprising 21 participants, aged 70–87 years). The 2-dimensional (2D) sonographic manifestations, thickness and gray values of the core muscles of the lumbar and abdomen were observed, and a further analysis was conducted that included the bone density of the lumbar vertebrae results.

Results: Compared to the control group, the total thickness of the core muscles in the osteoporosis group was significantly decreased ($P<0.05$), and the gray values were significantly increased ($P<0.05$). The comparison of the osteoporosis groups showed that in relation to the total thickness of the core muscle, group II > group III > group IV ($P<0.05$). The 2D ultrasonography showed that the muscles of the participants in group I were full and had an equally low echo. Conversely, in the osteoporosis group, the muscles of the participants were less full, the echo was enhanced, the boundary between the muscle and the fascia was unclear, and the long axis of the rectus abdominis and transverse abdominis tracts were wavy and linear, with reduced tension.

Conclusions: In postmenopausal women with osteoporosis, the core muscles of the waist and abdomen are degenerative, which can be evaluated with ultrasonography via the echo, thickness, and gray value of the muscles.

Keywords: Ultrasonography; osteoporosis; core muscles; dual-energy X-ray absorption method (DXA method)

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Introduction

Osteoporosis is a systemic bone disease characterized by decreased bone mass and the destruction or degeneration of the bone microstructure, resulting in the increase of bone fragility and fractures. The typical clinical manifestations of osteoporosis are bone pain, spinal deformation (bone deformation), and fragility fractures (1-3), which seriously affect patients' motor function, and place a heavy burden on families and society. Osteoporosis leads to decreased or even loss of motor function in patients. At present, most imaging studies on osteoporosis focus on bones, including the evaluation of bone mineral density, changes in bone marrow fat composition, fractures and other complications (4-6). However, skeletal muscle, which is closely related to motor function, is rarely studied. This study focuses on the changes of skeletal muscle of osteoporosis. The core muscle group includes the skeletal muscle that connects the lumbar vertebrae-pelvis-hip joints, which controls the stability of the spine, pelvis and hip joints, and maintains the neutral state of the human body. The most important core muscle groups are thought to include the rectus abdominis, external oblique abdomen, transverse abdominis, iliopsoas, erector spine, gluteus medius, and gluteus maximus (7-9). This study sought to evaluate the internal echo, thickness, and echo intensity of the waist and abdomen core muscles with ultrasound technology, to explore the ultrasound performance of the lumbar and abdominal core muscles in patients with osteoporosis, and to provide new ideas for the study of osteoporosis and treatment reference. We present the following article in accordance with the MDAR reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-22-314/rc).

Methods

Information of research objects

From January 2020 to May 2021, 91 adult females underwent examinations using the dual-energy X-ray absorption method (DXA method). The participants were aged 21–87 years old, with a height of 1.50±0.11 m, and a weight of 48±11.32 kg. Among them, there were 20 healthy participants (aged 25–35 years old), and 71 participants with osteoporosis (aged 50–87 years old). And patients in the osteoporosis group were divided into three groups according to the age: 20 patients in the group II, aged 50–59 years; 30 patients in the group III, aged 60–69; 21 patients in the group IV, aged 70–87 years. Any individuals with bone metabolic diseases, such as diabetes, hyperthyroidism, hyperparathyroidism, or chronic kidney disease, were excluded from the study. DXA was used to measure the bone mineral density of the lumbar spine, and the recommended T value of the diagnostic criteria for osteoporosis by the World Health Organization (WHO) was ≤−2.5 SD (10). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Affiliated Hospital of North Sichuan Medical College (No. 2021ER187-2), and informed consent was taken from all the patients.

Instruments and methods

The ultrasonic diagnostic instrument AixPlorer (SuperSonic Imagine, French) was used, with gray measurement software, and a SL10-2 probe (musculoskeletal MSK default setting, and guide number: Gn48%). The depth and focus position were fine-tuned as necessary. After a pre-experiment, the same senior sonographer conducted the examinations and stored the data. During the examination, it was necessary to keep the probe perpendicular to the muscle bundle as much as possible to collect the routine 2-dimensional (2D) sonogram of the lateral abdominal muscles (including the external oblique, internal oblique, and transverse abdominis), rectus abdominis and erector spinae, measure and record the gray value and thickness of each muscle group and calculate the total gray scale and thickness of the core muscle group. The average values of the total gray scale and the total thickness from both sides were taken for the statistical analysis.

The collection positions of the parameters of each muscle group were as follows: in the supine position, the cross section of the external oblique, internal oblique, and transverse abdominis was the horizontal cross section of the umbilicus from the midclavicular line to the anterior axillary line; in the supine position, the rectus abdominis collection section was the horizontal cross section of the umbilicus; in the prone position, the erector spinae was horizontally transected at the line of the spinous process to the inferior facet joint of the third lumbar vertebra. Data collection in all positions was stopped, stored, and measured at the end of inhalation. During the routine 2D ultrasound examination, it was necessary to observe the long axis and broken axis section of the muscle group. The gray scale of the same part was measured 3 times, and the median was taken. When collecting the gray values, the sonographer tried to avoid areas with obvious anisotropy, as in such areas, the sound beam and the muscle beam are not perpendicular and the echo is reduced, which might result in too low a gray value or affect the repeatability of the measured value.

Statistical analysis

The data were analyzed using SPSS 20.0 statistical software

Table 1 Comparison of the total gray and total thickness of the core muscles among the groups

Skeletal muscle mass parameters	Control group	Osteoporosis group		
	I	II	III	IV
Total gray value of the core muscles ($\bar{x}$±s)	221.85±9.52[a]	268.50±18.41[a]	264.80±23.30[a]	272.33±24.63[a]
Total thickness of the core muscles ($\bar{x}$±s, cm)	4.14±0.24[a]	3.91±0.19[a,b]	3.44±0.27[a,b]	3.30±0.18[a,b]

[a], comparison between groups, P<0.05; [b], intra-group comparison, P<0.05.

Table 2 2D sonogram results of the lumbar and abdominal core muscles for each group

2D sonogram of muscle group	Control group	Osteoporosis group		
	I	II	III	IV
Plumpness	Full	Not very full	Not full	Not full, obviously thinning
Internal echo	Iso-hypoechoic, the long axial section of the muscle bundle was flat hypoechoic, and the fascicle was linear hyperechoic	Enhancement of the echo of the musculature, and an unclear boundary between the musculature and the fascicle	Enhancement of the echo of the musculature, and an unclear boundary between some of the musculature and the fascicle	Enhancement of the echo of the musculature, and an unclear boundary between the musculature and the fascicle, part of the long axis of the rectus abdominis and transversalis abdominis showed wavy linear echo and decreased tension. Muscle groups with severe infiltration of fat can be full in shape, such as the erector spine
Comparison with fat echo intensity	Muscle group ≤ fat	Muscle group ≥ fat	Muscle group ≥ fat	Muscle group ≥ fat

2D, 2-dimensional.

(IBM, New York, USA). The measurement data are described as the mean ± standard deviation ($\bar{x}$±s), and a 1-way analysis of variance was used to compare the gray values and thicknesses among the 4 groups. If the variances were homogeneous, multiple pairwise comparisons were performed using the least significant difference method; if the variances were not uniform, Tamhane's T2(M) method was used. Results with a P value <0.05 were considered statistically significant.

Results

Comparison of the total gray value of core muscles between the control group and the osteoporosis group

The total gray value of the core muscles of the control group was significantly lower than that of the osteoporosis group (P<0.05). A comparison of the osteoporosis groups showed that there was no significant difference in the total gray value of the core muscles between groups I, II, and IV (P>0.05; see *Table 1*).

Comparison of the total thickness of core muscles between the control group and the osteoporosis group

The total thickness of the core muscle of the control group was significantly greater than that of the osteoporosis group (P<0.05). A comparison of the osteoporosis groups showed that in relation to the total thickness of the core muscle, group II > group III > group IV, and the differences were significant (P<0.05; see *Table 1*).

Routine ultrasound images of the core muscles

Routine ultrasound images of the core muscles in the control group and the osteoporosis group are shown in *Table 2* and *Figures 1-6*.

Discussion

With China's aging population, the incidence of osteoporosis is increasing year by year. According to the World Health Organization, the number of osteoporotic fractures will

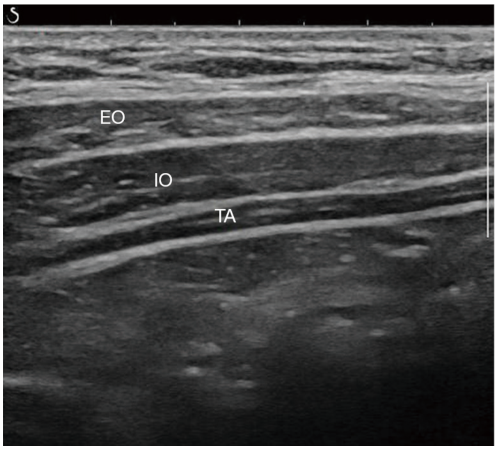

Figure 1 Lateral abdominal muscles in the normal control group. EO, external oblique; IO, internal oblique; TA, transversus abdominis.

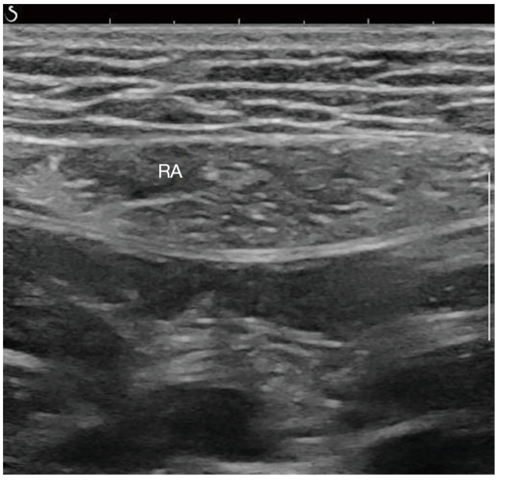

Figure 3 Rectus abdominis muscles in the normal control group. RA, rectus abdominis.

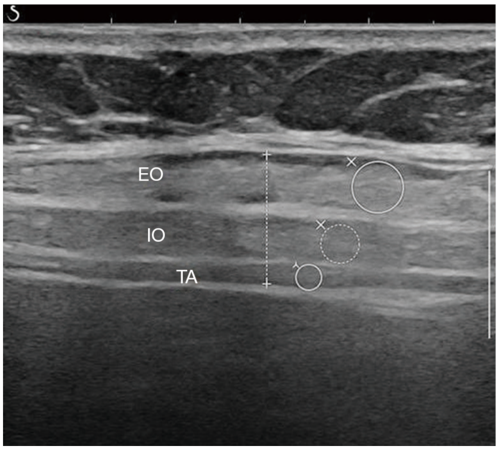

Figure 2 Lateral abdominal muscles in the osteoporosis group. Dashed line: thickness measurement; Circle: grayscale measurement sampling box. EO, external oblique; IO, internal oblique; TA, transversus abdominis.

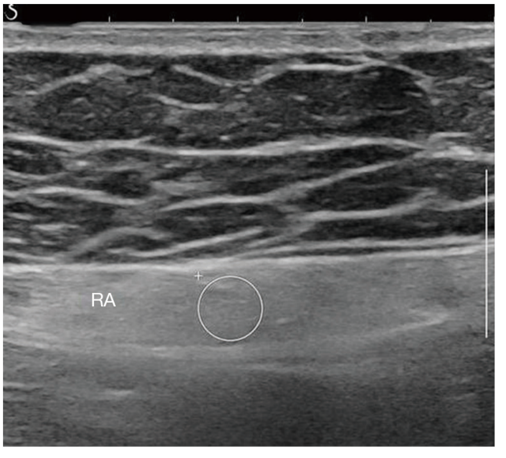

Figure 4 Rectus abdominis muscles in the osteoporosis group. Circle: grayscale measurement sampling box. RA, rectus abdominis.

reach 6 million by 2050 (11). Thus, the health of the elderly is seriously under threat. Compared with men, women are more prone to osteoporosis, and the prevalence rate of women in my country (32.1% over the age of 50) is significantly higher than that of European and American countries, and is similar to that of Asian countries such as Japan and South Korea. The prevalence of osteoporosis is 16.5% in women over the age of 50 in the United States, 15.8% in Canada, and 38.0% in South Korea (2). And the incidence of postmenopausal osteoporosis was 34.25% (12). In postmenopausal women, DXA was used to measure the bone mineral density of the lumbar spine, and the recommended T value of the diagnostic criteria for osteoporosis by the World Health Organization (WHO) was ≤–2.5 SD (10). Early intervention and treatment are of great significance if the prognosis and quality of life of patients is to be improved. Currently, a comprehensive treatment regimen of drugs and non-drugs is usually used for postmenopausal osteoporosis. Drug therapy includes basic supplements, such as calcium, vitamin D; anti-bone

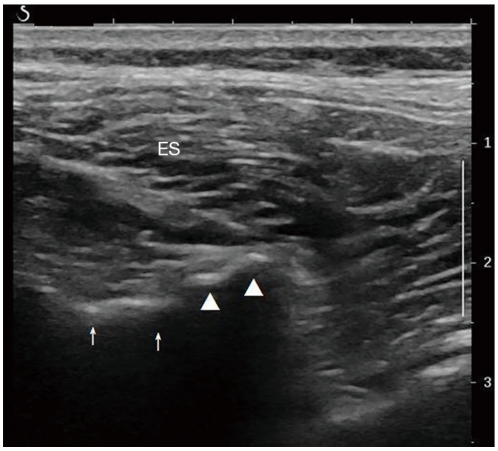

Figure 5 Erector spinae muscles in the normal control group. ↑: L3 inferior articular process; ▲: L4 superior articular process. ES, erector spinae.

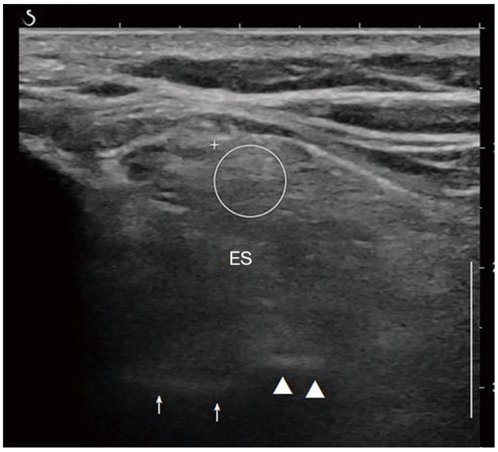

Figure 6 Erector spinae muscles in the osteoporosis group. Circle: grayscale measurement sampling box. ↑: L3 inferior articular process; ▲: L4 superior articular process. ES, erector spinae.

resorption drugs, such as bisphosphonates, calcitonin, estrogen; bone-promoting drugs, such as parathyroid hormone, fluoride; bidirectional regulators such as strontium ranelate, which can both inhibit bone resorption and promote bone formation, are expensive, and have risks such as adverse reactions and potential carcinogenicity, which limit the wide clinical application of many drugs (13). Non-drug treatment includes diet, exercise and lifestyle adjustment, especially long-term and moderate-intensity exercise is as important as drug treatment (14).

In recent years, the theory of the core muscle groups has been applied in the field of sports competition and medical rehabilitation (15-17). Progressive resistance training increases the cross-sectional area of muscles and the number of muscle fibers, thereby improving muscle strength, and muscle traction. The force of gravity transmitted to the bones through the device can stimulate the bones to a certain extent, thereby promoting bone formation (18). Osteoporosis rehabilitation guidelines in many countries and regions state that resistance training of the abdomen, waist, and hip muscles increases lumbar bone density, reduces patient pain, strengthens muscles, and improves physical function (18-20). However, the specific exercise prescription (including the exercise type, frequency, intensity, and time) is thought to differ from person to person, and thus personalized plans need to be developed.

At present, imaging evaluations of changes in the quality of the core muscles of the lumbar and abdomen in osteoporosis are still rare. Based on the theory of the core muscle groups, this study first performed ultrasound examinations of the important muscle groups of the lumbar and abdomen to examine changes in the ultrasound images of the quality of the related muscle groups. Ultrasound can evaluate the quality of skeletal muscle, reflect changes in skeletal muscle mass based on thickness, and changes in skeletal muscle mass based on echo intensity. Skeletal muscle degeneration causes a decrease in muscle mass. The pathological manifestations are muscle fiber atrophy, an increase in the content of intermuscular and intramuscular fat tissue, and an increase in fibrous tissue and extracellular water (21). The echo intensity of skeletal muscle is related to the tissue composition, such that the higher the proportion of muscle fibers, the lower the echo, and the higher the proportion of fat and fibrous tissue, the higher the echo (22,23).

Skeletal muscle degeneration causes decreased muscle contractility and flexibility, and decreased physical function (24,25), which is also related to the occurrence of degenerative arthritis. The decrease of thigh muscle mass increases the risk of radiographic knee osteoarthritis (ROA) (26). Conroy *et al.* used computed tomography to study muscle mass and found that the skeletal muscle content and the quadriceps cross-sectional area of the ROA patients were higher than those of the normal control patients, but the contractile force of the quadriceps muscles was reduced (27).

Other studies have shown that in addition to skeletal muscle mass, skeletal muscle changes (such as fat infiltration) also have an important effect on contractility and joint function. Maly *et al.* (28-30) used magnetic resonance imaging (MRI) to study the quadriceps femoris of female ROA patients and found that there was an increase in intermuscular fat in ROA patients, which was slightly related to the decrease in quadriceps muscle strength and motor function (28). Using MRI, Kumar *et al.* studied the quadriceps cross-sectional area and the degree of muscle fat infiltration in patients with knee osteoarthritis (KOA) and found that compared to the normal control group, there was no significant difference in the cross-sectional area the quadriceps transverse area of the KOA patient group, but the intramuscular fat content of the quadriceps muscles of the patients in the KOA group was higher than that of patients in the normal group and was related to clinical manifestations and the degree of joint structural damage (29). The difference between fat infiltration in the groups was about 1.5%, which was clinically significant and explains the clinical manifestations of knee dysfunction in patients with ROA. Further, there was an independent correlation between the fat infiltration and contractility of the quadriceps. Muscle degeneration was also observed in the rotator cuff lesions. Patients with symptomatic rotator cuff tears had higher rotator cuff muscle fat content than normal control patients, and intramuscular fat content was significantly correlated with the degree of pain and the range of motion of the shoulder joint (30).

Ultrasound has a good resolution for skeletal muscles, and not only displays the muscle anatomical hierarchy, but also reflects the fat infiltration of skeletal muscle via the echo strength. However, the number of operators who can recognize the echo strength of the image with the naked eye using a routine ultrasound is limited, and the ability to do this is experience dependent. Unlike previous computer-aided grayscale analyses, the ultrasonic diagnostic instrument (AixPlorer) in this study was equipped with the 2D grayscale measurement technology to directly measure the grayscale value. After freezing the frame on the 2D grayscale image, the gray value was measured when placed in the target area by adjusting the size of the measurement circle. The larger the gray value, the higher the echo, and the smaller the gray value, the lower the echo. Comparing the echoes of the rectus abdominis and the subcutaneous fat layer, the similarity of the echoes of the muscle group and the subcutaneous fat layer as determined by the naked eye was regarded as "isoechoic". The gray-value analysis showed that even under the "isoechoic" condition, the gray value of the rectus abdominis muscle differed significantly to that obtained by a routine ultrasound and that obtained by the instrument in this study, and the echo intensity was more objectively quantified by the gray measurement in this study.

In recent years, computer-aided skeletal muscle sound image grayscale analysis has been applied to the quality evaluation of lower limb muscles. Taniguchi *et al.* used ultrasound to evaluate the quality of the muscles around the hip, knee, and ankle joints in female KOA patients and found that the lower extremity muscles of the KOA patients had quality degeneration. The echo intensity of the mild KOA medial femoris muscle was significantly higher than that of the normal control group, and the thickness was less than that of the normal control group, while the echo intensity of the severe KOA medial femoris muscle was significantly higher than that of the normal control group, and the thickness of the medial femoris and vastus intermedius muscle was less than that of the control group (31). In this study, similar findings were found in the quality of the lumbar and abdomen core muscles. Compared to the normal control group, the gray value of the core muscles in the osteoporosis group was significantly higher ($P<0.05$), and the thickness was significantly thinner ($P<0.05$), indicating that the core muscle group of the osteoporosis patients displayed degenerative changes in quality and quantity compared to the normal control group. Additionally, the thickness was significantly different among the osteoporosis groups ($P<0.05$; group II > group III > group IV), but there was no significant difference in the gray values ($P>0.05$), suggesting that the core muscle mass changes of osteoporosis patients tend to be stable among groups, while the quantitative changes continue to progress.

With aging and disuse, muscle loss (sarcopenia) and skeletal muscle fat infiltration increase (32). In this study, osteoporosis was accompanied by the degeneration of the core muscle mass. A biomechanical analysis showed that the core muscle mass of patients with osteoporosis was atrophied, and fat infiltration was obvious. This quality degeneration reduced muscle contractility and reduced the transmission of the strength stimulation to the bones. A long-term lack of strength stimulation leads to bone loss. Thus, targeted resistance training can improve muscle mass, increase muscle strength, and increase lumbar bone density. Notably, with an increase in age, the amount of core muscles in the osteoporosis group continues to decrease. Thus, the early detection and early treatment of osteoporosis are extremely important. Long-term, comprehensive treatment options, including exercise prescriptions, may be essential to maintain muscle mass, reduce bone loss, maintain motor function, and prevent complications, such as falls and fragility fractures.

In addition to the objective quantification of muscle quality through echo intensity and thickness, the conventional 2D sound image also directly reflects the internal structure of the skeletal muscle. In this study, the routine 2D ultrasound in the normal control group showed that the muscles were full, and the muscle bundles were isohypoechoic. In the osteoporosis group, the core muscles were not full, and were even thin, and the muscle bundle echoes were enhanced; in the long axis view, the rectus abdominis and transversus abdominis in some elderly patients were wavy, the tension disappeared, the erector spinae was sometimes accompanied by obvious fat infiltration, and the muscle layer became relatively "full". The relaxed wavy linear muscle bundle did not appear in the relatively younger aged patients in group II and III. This finding suggests that it might be necessary to assess the patient's skeletal muscle mass when performing exercise rehabilitation, and to formulate a personalized exercise program accordingly to avoid iatrogenic injuries caused by improper exercise methods or intensity. At the same time, whether higher-quality muscle mass means better therapeutic and rehabilitation effects is also worthy of our attention. The results showed that the core muscle mass of patients with osteoporosis was different between groups, and the thickness of muscle group was significantly different among groups, suggesting that the muscle mass of core muscle group may become an auxiliary screening indicator for osteoporosis, but it needs to be confirmed by a wider research group with larger sample size in the further study.

Conclusions

Ultrasound has the advantages of high soft tissue resolution, safety, and non-radiation. It provides a non-invasive and convenient imaging method for studying the quality of the core muscle groups. The core muscle group of the lumbar and abdomen of patients with osteoporosis showed degenerative changes, and the changes in relation to the internal echo, gray value, and thickness differed to those of the normal group.

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Footnote

Reporting Checklist: The authors have completed the MDAR reporting checklist. Available at https://apm.amegroups.com/article/view/10.21037/apm-22-314/rc

Data Sharing Statement: Available at https://apm.amegroups.com/article/view/10.21037/apm-22-314/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://apm.amegroups.com/article/view/10.21037/apm-22-314/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work, including ensuring that any questions related to the accuracy or integrity of any part of the work have been appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Affiliated Hospital of North Sichuan Medical College (No. 2021ER187-2), and informed consent was taken from all the patients.

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