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Low-complexity ultrasonic backscattering measurement in cancellous bone evaluation

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1. Introduction

Ultrasonic backscattering measurement has been proved its effectiveness in cancellous bone evaluation[1]. Due to asymmetrical stress distribution, the microstructure of cancellous bone is inhomogeneous. Ultrasonic backscattering measurement fluctuated with different measuring regions[2]. Spatial scanning and averaging method could effectively improve the stability of ultrasonic measurement[3]. However, how ultrasonic backscattering signal changed with different regions of cancellous bone is still unclear. Besides, spatial scanning required a large number of ultrasonic measurements, which increased the complexity of ultrasonic measurement in clinical application. Therefore, how to simplify ultrasonic backscattering measurement is quite necessary and need futher study. In this paper, ultrasonic backscattering experiment was carried out and backscatter parameters were processed. We studied the distribution of ultrasonic backscattering parameters and analyzed how the stability and effectiveness of backscattering parameters changed with the number of measured regions, to raise a low-complexity ultrasonic backscattering measurement suitable for bone evaluation.

2. Material and methods

Twenty cancellous bone specimens were taken from the end of bovine femur and cut into flat cubes (approximately 20 mm × 20 mm × 15 mm) along the anatomic orientations. The specimens was immersed in trichloroethylene to remove the marrow and grease. Then washed by high-pressure water gun and dried in the shade. The bone mineral density (BMD) and bone volume over total volume (BV/TV) of specimens were measured by Micro-CT (Sky-scan 1076, Skyscan, Antwerp, Belgium).

The ultrasonic transducer operated in pulse-echo mode with a center frequency of 2.25 MHz, a focal length of 1 inch, and a focal area diameter of 0.96 mm. The bone specimens were placed in distilled water and degassed by a vacuum pump before the experiment. During the experiment, bone specimens and the transducer were water-coupled. A three-dimensional scanning system (Ultrapac scanning, PK268-03B, NJ, USA) was used to measure different regions of interest (ROI) of bone specimens. The scanning area of each bone specimen was 15 mm×15 mm. And the adjacent regions were spaced 0.5 mm apart. Thus, 900 backscattering signals were obtained for each specimen. The reference signal is obtained by a flat steel plate.

Due to the considerable acoustic impedance difference between water and the surface of bone specimen, an ultrasonic reflected wave appeared at the start of the signal[4]. To avoid the disturbance of the reflected wave, we usually exclude the reflected part and choose the following part as the signal of interest (SOI)[5]. Then, apparent integral backscattering coefficient (AIB) and spectral central shift (SCS) were calculated with the same SOI selection criteria[6].

The distribution of backscattering parameters from different ROIs was analyzed. Then, the number of involved ROIs was gradually reduced by two different methods (method one: random selection, the number decreasing from 900 to 10 with an interval of 10; method two: array selection, the array of spatial scanning ROIs gradually decreasing from 30×30 to 3×3, 2×2). Backscattering parameters were averaged, and the correlations with BMD were analyzed. Finally, the stability and effectiveness of backscattering parameters with defferent ROIs were studied.

3. Results and discussion

Fig.1 shows the histograms of AIB values for four bone specimens with different BV/TV. Chi-square test (with a confidence level of 0.01) accepted the hypothesis that AIB and SCS followed the normal distribution.

Fig.2 shows the standard deviation of SCS measurement and the correlation coefficient between SCS and BMD with respect to the number of measured ROIs. As the number of measured ROIs gradually increased to 100 ROIs, the standard deviation of SCS decreased rapidly and the correlation coefficient increased dramatically from 0.1 to 0.7. After the number exceeded 200, the result tended to be stable. The experimental results of two different ROI selections were similar.

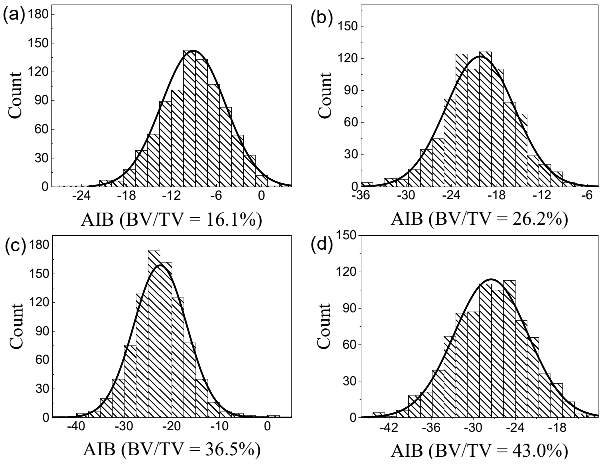

Fig.1 The histograms of AIB values for four bone specimens with different BV/TV

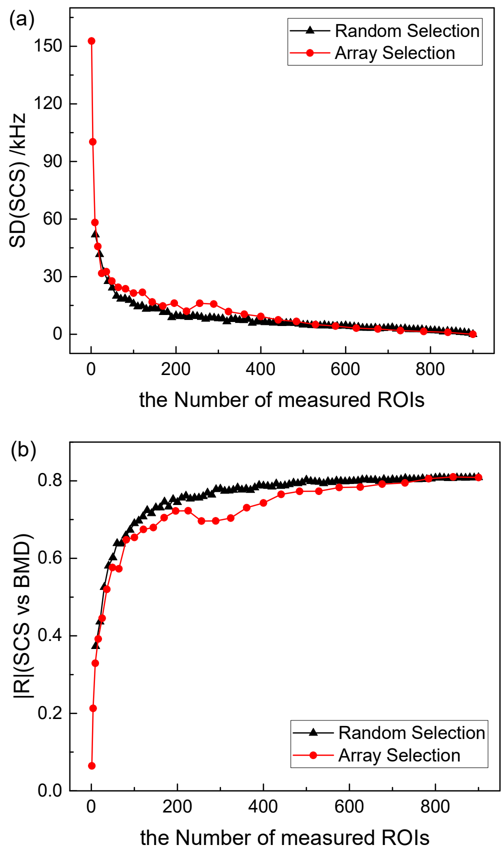

Fig.2 The standard deviation of SCS measurement and the correlation coefficient between SCS and BMD with respect to the number of measured ROIs.

Many factors such as porosity, the number and density of trabeculae could lead to the fluctuation of ultrasonic backscatter measurements. The complex and irregular bone microstructure and the various disturbances in the backscattering experiment brought deviation to the backscattering parameters, which made the parameters getting closer to a normal distribution. Therefore, each ultrasonic backscattering measurement could be regarded as an observation of backscattering parameters. When the times of observation is large enough, the parameters are approaching their real value.

The standard deviation of backscattering parameters decreased rapidly with increasing the number of measured ROIs. The results of two different ROIs selection methods were similar, which means that the stability improvement of ultrasonic measurement is mainly depends on the number of ROIs measured. In addition, the threshold of ROIs number (200 ROIs in this experiment) is much less than the requirement of spatial scanning method, which reduce the complexity of ultrasonic measurement and would be helpful for clinical bone evaluation. Ultrasonic array transducer could enhance the stability of ultrasonic backscattering measurement *in vivo*.

4. Conclusion

This paper indicated that the stability of ultrasonic backscattering measurement could be promoted with fewer number of ROIs measured. It could simplify the requirement of spatial scanning and averaging method, which is meaningful for ultrasonic backscattering measurement in clinical application.

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