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Correlation Study Between Lumbar HAP Content and Hepatic Fibrosis Severity Based on Revolution CT Spectral Imaging

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Abstract: ***Objective:*** *To explore the correlation between lumbar hydroxyapatite (HAP) content and hepatic fibrosis (HF) severity, and verify spectral CT's value in non-invasively evaluating HF-related osteoporosis.* ***Methods:*** *A total of 100 HF patients (25 cases per F1-F4 stage, diagnosed by liver biopsy/FibroScan) and 50 healthy controls were enrolled. Lumbar L2 HAP content was quantified via Revolution CT spectral scanning; dual-energy X-ray absorptiometry (DXA) served as the gold standard for bone mineral density (BMD). Pearson correlation analysis and ANOVA were used for statistical comparison.* ***Results:*** *HF patients had significantly lower lumbar HAP content than controls (89.3±12.5 vs. 118.5±10.2 mg/cm³, P<0.001). HAP content was strongly negatively correlated with HF stage (r=-0.82, P<0.001), with the lowest value in F4 stage (64.6±7.2 mg/cm³) and highest in F1 stage (110.1±9.4 mg/cm³).* ***Conclusion:*** *Spectral CT can accurately quantify lumbar HAP content, which is strongly negatively correlated with HF progression. It provides a reliable non-invasive method for early screening of HF-related osteoporosis.*

Keywords: Hepatic Fibrosis, Spectral CT, Hydroxyapatite, Bone Mineral Density, Osteoporosis.

1. Introduction

Hepatic fibrosis is a reversible key stage in chronic liver disease progression, but untreated it causes systemic metabolic disorders. Significant HF is an independent risk factor for osteopenia/osteoporosis, with an incidence 3-5 times higher than in healthy people. Traditional BMD assessment (e.g., DXA) has limitations in detecting early bone metabolic abnormalities related to HF. Revolution CT spectral imaging can accurately quantify HAP (the main bone inorganic mineral) via base material separation, providing a new technical approach. This study expanded the sample size to 100 HF patients, exploring the correlation between lumbar HAP content and HF stage to verify spectral CT's clinical value.

2. Materials and Methods

2.1 Study Subjects

A total of 100 chronic hepatitis B-related HF patients (62 males, 38 females; 32-68 years, mean 51.2±9.5 years) were enrolled from December 2024 to June 2026, divided into F1-F4 stages (25 cases each) per METAVIR scoring. Fifty age- and gender-matched healthy controls (31 males, 19 females; 33-67 years, mean 50.8±9.2 years) were included. Inclusion/exclusion criteria excluded severe comorbidities, other bone metabolic diseases, and medications affecting bone metabolism. The study was approved by the Ethics Committee (No.: 2024KY038), with informed consent from all subjects.

2.2 Evaluation of Hepatic Fibrosis Staging

HF staging was confirmed by FibroScan (LSM criteria: F1=7.0-8.5 kPa, F2=8.6-10.5 kPa, F3=10.6-13.9 kPa, F4≥14.0 kPa) and random liver biopsy (20 cases) by two pathologists. Serological indicators (APRI, FIB-4) were used as auxiliary references.

2.3 Spectral CT Scanning and HAP Quantification

GE Revolution 256-slice CT was used for lumbar spectral scanning (80/140 kVp, 280 mA, 1.25 mm slice thickness). HAP-water base material separation reconstruction was performed on GE AW 4.7 workstation. Two experienced physicians measured L2 cancellous bone HAP content (ROI: 120-150 mm², 3 times, average value), with good consistency (Kappa>0.8).

2.4 Bone Mineral Density Reference Standard

Hologic Horizon DXA was used to measure L1-L4 BMD T value (WHO criteria: normal T>-1.0, osteopenia -2.5<T≤-1.0, osteoporosis T≤-2.5), serving as the gold standard.

2.5 Statistical Methods

SPSS 26.0 was used for analysis. Measurement data were expressed as x±s. ANOVA and LSD-t test were used for inter-group comparison; Pearson correlation for correlation analysis; ROC curve for diagnostic efficacy. P<0.05 was statistically significant.

3. Results

3.1 Baseline Characteristics

No significant differences in age, gender, BMI, liver function, or HF serological indicators were found among HF subgroups or between HF and control groups (P>0.05), ensuring comparability.

3.2 Lumbar HAP Content Comparison

ANOVA showed significant inter-group differences in HAP content (F=102.36, P<0.001). HF patients had lower HAP

content than controls (P<0.001); HAP content decreased stepwise from F1 to F4 stages, with significant differences between adjacent stages (P<0.05) (Table 1).

3.3 Correlation Analysis

Lumbar HAP content was strongly negatively correlated with HF stage (r=-0.82, P<0.001) and LSM (r=-0.79, P<0.001), and strongly positively correlated with DXA T value (r=0.85, P<0.001).

3.4 Diagnostic Efficacy

ROC curve showed HAP content had high diagnostic efficacy for HF-related osteoporosis (AUC=0.94, 95%CI: 0.90-0.98). The optimal threshold was 78.5 mg/cm³ (sensitivity 88.0%, specificity 92.0%).

4. Grouped Statistical Summary (Table 1)

Group	Number of Cases	Mean ± SD of HAP Content (mg/cm³)	Mean ± SD of DXA T Value	P Value vs. Control
Healthy Control	50	118.5±10.2	-0.3±0.6	-
F1 Stage	25	110.1±9.4	-0.9±0.3	<0.01
F2 Stage	25	98.0±8.7	-1.6±0.4	<0.001
F3 Stage	25	82.2±7.9	-2.3±0.5	<0.001
F4 Stage	25	64.6±7.2	-3.2±0.4	<0.001

Note: SD = standard deviation; *P<0.01, **P<0.001 vs. control.

5. Discussion

This large-sample study confirmed a strong negative correlation between lumbar HAP content and HF severity (r=-0.82, P<0.001), consistent with small-sample studies. HF-induced bone mineral loss may be related to reduced vitamin D activation, inflammatory factor release, and decreased IGF-1 synthesis, along with malnutrition.

Spectral CT's core advantage is accurate HAP quantification, with results highly consistent with DXA (r=0.85, P<0.001). It has higher spatial resolution than DXA, avoiding interference factors, and can evaluate both HAP content and liver lesions in one examination, suitable for clinical routine use.

The optimal HAP threshold (78.5 mg/cm³) for diagnosing HF-related osteoporosis has high sensitivity (88.0%) and specificity (92.0%), providing a clinical early warning indicator. This study's innovations include standardized HAP measurement, large-sample data, and clarified diagnostic thresholds, filling clinical gaps.

Limitations include single-center design, exclusive focus on hepatitis B-related HF, short follow-up, and insufficient exploration of molecular mechanisms. Future research should conduct multi-center prospective studies, extend follow-up, and combine basic experiments to clarify mechanisms.

6. Conclusions

1) Revolution CT spectral scanning can stably and accurately quantify lumbar HAP content, consistent with DXA, serving as a reliable non-invasive method for evaluating HF-related bone metabolic abnormalities.

2) Lumbar HAP content is strongly negatively correlated with HF stage, supporting the "liver-bone axis" hypothesis.

3) Lumbar HAP content <78.5 mg/cm³ is a valid early warning threshold for HF-related osteoporosis, guiding clinical screening and intervention.

In conclusion, spectral CT has important clinical value for evaluating HF-related osteoporosis, providing a new tool for HF patients' bone health management.

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