# A longitudinal study on the relationship between BMD and bone marrow perfusion of proximal femur based on DCE-MRI

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**Introduction**: The proximal femur is one of the most common sites of osteoporotic fracture and is also an area prone to avascular necrosis and fracture nonunion. Previous dynamic contrast-enhanced MRI (DCE-MRI) study on proximal femur has shown how perfusion reduced in osteoporotic bone compared to that with normal bone mineral density (BMD) [1]. However, if the perfusion function has a long term effect on BMD is still unknown. Therefore, this study further investigated the relationship between perfusion function and BMD changes within four years to give a better understanding on the trend of BMD variation under the conditions of bone marrow with different perfusion characteristics.

**Methods**: Eighty-seven elderly female subjects (71±4.1 yrs) in total were involved in this study. In the first year, DCE-MRI data were acquired in an oblique coronal plane aligned along the midportion of the proximal femur. A bolus of gadoteric acid at a concentration of 0.15 mmol per kilogram body weight was injected, followed by a dynamic scanning with a short T1-weighted gradient-echo sequence (2.7/0/95; prepulse inversion time, 400 ms; flip angle, 15°). A total of 160 dynamic images were obtained with a temporal resolution of 540 ms. Then the area bone mineral density (BMD) of proximal femur was measured for every two years by the dual-energy X-ray absorptiometry (DXA). There were 47 subjects with decreased BMD and 40 subjects with stable or increased BMD after 4 years.

A pharmacokinetic model [2, 3] was employed to analyze DCE-MRI data pixel-by-pixel. Specifically, DCE curve for each pixel was extracted and fitted by the model. The fitted curves were then classified into 3 patterns, where a threshold was set for the slope of the curve end as the classification criteria (pattern 1: slope> threshold; pattern 3: slope < -threshold; others are pattern 2) (Fig 1). The pixel was colored into red, green and blue corresponding to pattern 1, 2 and 3 (Fig 2). Pattern percentage of ROI (color area / ROI area) and normalized pattern percentage (pattern percentage / all pattern percentage of ROI) were calculated for each pattern.

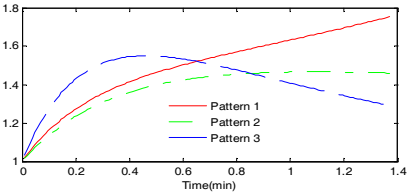


Fig 1. Classification of perfusion curve patterns. Pattern 1 (solid): fast enhancement, followed by a slow enhancement; Pattern 2 (dash-dot): fast enhancement, followed by a signal plateau; Pattern 3 (dash): fast enhancement followed by a quick washout.

**Results**: By the t-test, pattern 3 percentage and normalized pattern 3 percentage showed significant difference between BMD decreased group and BMD without decrease group (Table 1).

**Table 1 : Pattern percentage comparison by ANOVA**

| Group | Age | Color Percent(%) | Pattern 3 (%) | N_Pattern 3 (%) |
|---|---|---|---|---|
| BMD NoDecrease (N=40) | 70.85±4.12 | 52.70±17.88 | 7.02±7.64 | 11.49±10.56 |
| BMD Decrease (N=47) | 71.02±4.31 | 47.46±18.58 | 3.53±4.81 | 6.34±8.48 |
| P value (for trend) | 0.277 | 0.81 | 0.009 | 0.025 |

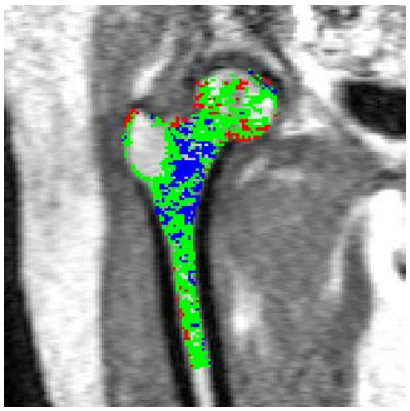

Fig 2. Pixel-by-pixel pattern mapping on the proximal femur

For the perfusion pattern, in most subjects with stable or increased BMD, we observed a blue band (pattern 3: fast enhancement followed by a quick washout) crossing the femur neck to the shaft (Fig 2). When the subjects were classified into two groups with pattern 3 above the average and below, we found that the BMD showed a consistent decreasing trend in the group with pattern 3 below the average, which was different from the other group (Fig 3).

**Discussion:** In our previous study, subjects with normal BMD showed an averaged perfusion feature as pattern 3, indicating that pattern 3 implies a better perfusion function for bone marrow health. We therefore supposed that the bone marrow would be healthy when it had high percentage of pattern 3 in bone marrow perfusion. In current study we found that subjects with decreased BMD over 4 years had a significant lower percentage of pattern 3 for bone marrow perfusion at the 0 year. Further, for a four-year period, the subjects' BMD indeed consistently decreased when they had less bone marrow with perfusion feature as pattern 3. These two findings suggested that subjects with bad bone marrow perfusion could consistently loss bone in successive years. This may imply that good bone marrow perfusion would help the bone modeling over years.

A link between vascular disease and osteoporosis has been reported by others [4]. This longitudinal study provided further evidence that BMD change is associated with bone marrow perfusion function. And a good bone marrow perfusion function would help to keep the bone health. However, this study was only carried out for 4 years. Longer time observation would provide more insightful information.

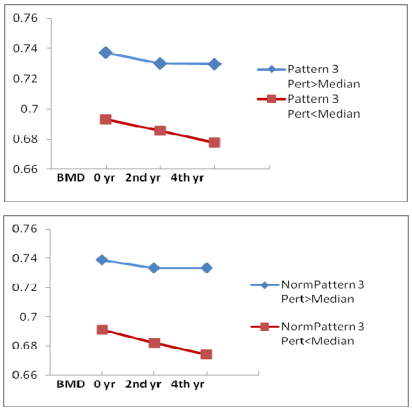


Fig 3. BMD change in 4 years in groups with different perfusin function

**Acknowledgement**: This work is supported by the National Natural Science Foundation of China (81000647) and Basic Research Foundation (Outstanding Young Investigator Track) from Shenzhen Science, Industry, Trade& Information Commission (JC201005260124A).

**References:** [1] Griffith JF, et al, J Bone Miner Res, 23:1068-1075(2008); [2] Hoffmann U, et al, Magn Reson Med, 33:506-514(1995); [3] Lee JH, et al, Orthop Clin North Am, 40:249-257(2009); [4] Mangiafico RA, et al, J Bone Miner Metab, 24:125-131(2006).