Study on perfusion distribution of proximal femur based on DCE-MRI

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Introduction: A link between vascular disease and osteoporosis has been reported [1]. Dynamic contrast-enhanced MRI (DCE-MRI) provides a more direct measure of bone perfusion and has been employed in study of bone marrow perfusion. 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 DCE-MRI study on proximal femur has shown how perfusion parameters are consistently reduced in osteopenic and osteoporotic bone compared to that with normal bone mineral density (BMD) [2]. However, those parameters derived from region of interest (ROI) are limited in the information regarding the perfusion distribution, which may correspond to BMD distribution and fracture location. This study, therefore, was to investigate perfusion distribution characteristics of bone marrow at proximal femur in subjects of varying BMD to increase our knowledge of the blood perfusion anomalies occurring at osteoporotic proximal femur.

Methods: The cohort included 45 elderly female subjects (71±4.4 yrs), including 15 subjects with normal BMD (69.6±2.8 yrs), 15 subjects with osteopenia (7.4±5.3 yrs), and 15 subjects with osteoporosis (73.1±4.1 yrs). 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.

A pharmacokinetic model [3,4] 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.2). The pixel was colored into red, green and blue corresponding to pattern 1, 2 and 3. Pattern percentage of ROI (color area / ROI area) was calculated for pattern 1, pattern 2 and pattern 3, respectively. Analysis of variance method (ANOVA) was used to evaluate differences in parameters among groups.

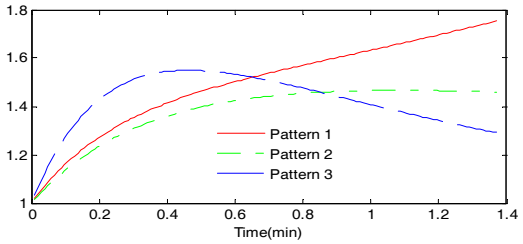

Fig 1. Classification of perfusion curve patterns. Pattern 1 (solid): fast enhancement, followed by a slow enhancement; Pattern 2 (dash-dot): fast enhancement, followed by a signal plateau; Pattern 3 (dash): fast enhancement followed by a quick washout.

Results: The pattern coloring rate showed difference among groups, as summarized in Table 1. Those uncolored pixel was due to too weak DCE signal. Normal subjects had a significant higher pattern coloring rate than other two groups, indicating a better perfusion in normal subjects. Relatively, normal subjects had an obviously higher rate in pattern 3 than osteoporotic patients.

Table 1: Pattern percentage comparison by ANOVA

Group	All pattern (%)	Pattern 1 (%)	Pattern 2 (%)	Pattern 3 (%)
Normal (n=15)	64.8±13	11.2±9.3	44.4±15.4	9.3±8.7
Osteopenia (n=15)	47.1±24.2	10.0±5.6	30.8±17.1	6.3±8.5
Osteoporosis (n=15)	42.2±21	6.9±4.6	32.7±17.7	2.7±4.3
P value (for trend)	<0.01	=0.221	=0.066	=0.062

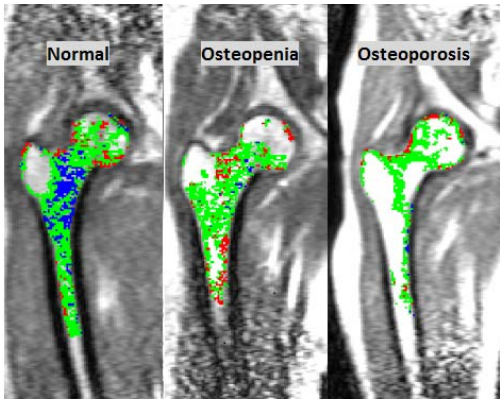

Fig 2. Representative pixel-by-pixel pattern mapping on the proximal femur for the 3 groups with different BMD

Figure 2 gives the typical color mapping results for the 3 groups. For the color distribution, in most normal subjects we observed a blue band (pattern 3: fast enhancement followed by a quick washout) crossing the femur neck to the shaft. However, such distribution pattern was rarely observed in osteoporotic patients, while it was sometime observed in osteopenia subjects, as the typical illustration shown in Fig.2.

Discussion: First, a notable reduction in pattern coloring rate in subjects with reduced BMD was observed compared to normal subjects, indicating that the blood perfusion decreased as a whole in the development of osteoporosis. Secondly, it appears that perfusion distribution changes as BMD decreases, especially at femoral head and the area crossing the femoral neck to the shaft. Thirdly and interestingly, it is obvious for all 3 groups that alone the intertrochanteric line, the perfusion decreases significantly from the lesser trochanter to the greater trochanter. As intertrochanteric fracture is one of the most common fractures at hip, such blood perfusion distribution manner may be one of its underlying mechanism.

The current findings are very intriguing to discover mechanisms of osteoporotic fracture at proximal femur in respect to bone marrow histology and vascular characteristics. This study shows a great potential of perfusion distribution investigation to contribute in the study of bone metabolism and osteoporotic fracture at proximal femur.

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