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ORIGINAL ARTICLE

Comparison of hip subregion bone mineral density to the type of proximal femur fracture

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Abstract

Summary Beta values of the intertrochanteric fracture group were about twice as high as those of the femoral neck fracture group. These results can be used to increase the awareness of proximal hip fracture among physicians and improve treatments and outcomes.

Purpose To compare the BMD of the femoral neck region and the intertrochanteric region between the femoral neck fracture group and the intertrochanteric fracture group.

Methods We did a retrospective review of radiographs of the proximal femoral fractures in patients registered from 2010 to 2017. A total of 329 patients were classified into the femoral neck fracture group (group A, $n = 162$) and the femur intertrochanteric fracture group (group B, $n = 167$). We did intergroup comparisons of age, sex, BMI (body mass index), and bone mineral density (BMD) of the neck and intertrochanteric region, adjusting for age. We did multiple logistic regression analysis among these parameters.

Results The BMD of the femoral neck and intertrochanteric was statistically significantly different between the two groups ($p < 0.001$), and the BMD of the femur intertrochanteric was also significantly different between the two groups ($p < 0.001$). BMD of both regions in the intertrochanteric fracture group was lower than that of the femoral neck fracture group. In linear regression analysis, the beta values of the intertrochanteric fracture group were about twice as high as those of the femoral neck fracture group.

Conclusion In linear regression analysis, the beta values of the intertrochanteric fracture group were about twice as high as those of the femoral neck fracture group.

Keywords Proximal femoral fractures · Femur · Bone mineral density · Osteoporosis

Introduction

Proximal femur fracture is a worldwide problem related to the aging of the population [1–5]. The incidence of proximal femur fractures is increasing each year because of the increase in the number of the elderly [6]. Furthermore, Melton et al. expected that 63 million hip fractures will occur globally in 2050 [3, 4]. Because proximal femur fracture is a leading cause of morbidity and mortality in the elderly [7–9], it is the most serious complication of osteoporosis and the most disabling type of fracture in the elderly population [7, 10]. The 1-year mortality in elderly patients ranges from 14 to 36% [6]. One-year mortality in patients who underwent surgery was 23.6% [11].

Proximal femur fracture is classified into two types depending on the anatomic region: femoral neck fracture and intertrochanteric fracture [12]. The composition of bone in the two regions differs, so the etiology of each fracture type may also differ [13]. Some studies suggest that lower bone-mineral density (BMD) in the trochanter and whole neck is associated with the intertrochanteric fracture and that BMD in the superior femoral neck lower than in the inferior is associated with femoral neck fracture [14, 15].

Dual-energy X-ray absorptiometry (DXA) of the hip is the most widely applied technique in quantitative assessment of BMD in vivo and is currently used as an indicator of osteoporosis by the World Health Organization (WHO) [16]. In this

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study, we analyzed BMD of the femoral neck and intertrochanteric regions between the femoral neck fracture group and the intertrochanteric fracture group.

Materials and methods

Subjects

We assessed a total of 500 patients who were treated for proximal femur fracture between January 2010 and February 2017 by an experienced single surgeon (the corresponding author) for eligibility. Femoral neck fracture was defined as an intracapsular fracture that occurred in the anatomical neck of the femur [12]. Intertrochanteric fracture was defined as an extracapsular fracture that occurred between the greater trochanter and lesser trochanter [12]. The inclusion criteria for this study were (1) age older than 65 years, (2) agreement to the BMD measurement, and (3) diagnosed as osteoporosis on a WHO basis. The exclusion criteria were as follows:

1. endocrinology disorders, such as primary or secondary hyperparathyroidism and hyperthyroidism;
2. fracture due to high-energy injury, defined as any of the following mechanisms: ① motor vehicle, motorcycle accidents, or bicycle accidents; ②crushing injuries; and ③ falls from a height of ≥ 10 ft. [17]
3. pathologic fractures related to an underlying metastatic disease;
4. rheumatoid arthritis and multiple myeloma; and
5. history of taking corticosteroid, methotrexate, or heparin.

All proximal femur fracture patients were ambulatory before trauma and had suffered a first unilateral proximal femur fracture.

The remaining 329 patients (233 females, 96 males), with a group mean age of 75.92 years (95% confidence interval equals 73.82–80.23 years; range: 65 to 97 years), were classified into the femoral neck fracture group (group A, $n = 162$; mean age 78.53 years) and the femur intertrochanteric fracture group (group B, $n = 167$; mean age 80.49 years) (Fig. 1.). The protocol of this retrospective comparative study was approved by our Institutional Review Board of Kangbuk Samsung Hospital (KBSMC 2014-01-127).

Measurements

BMI (body mass index) was calculated by measuring height and weight in the ward when patients were hospitalized for fracture. DXA scans of the contralateral

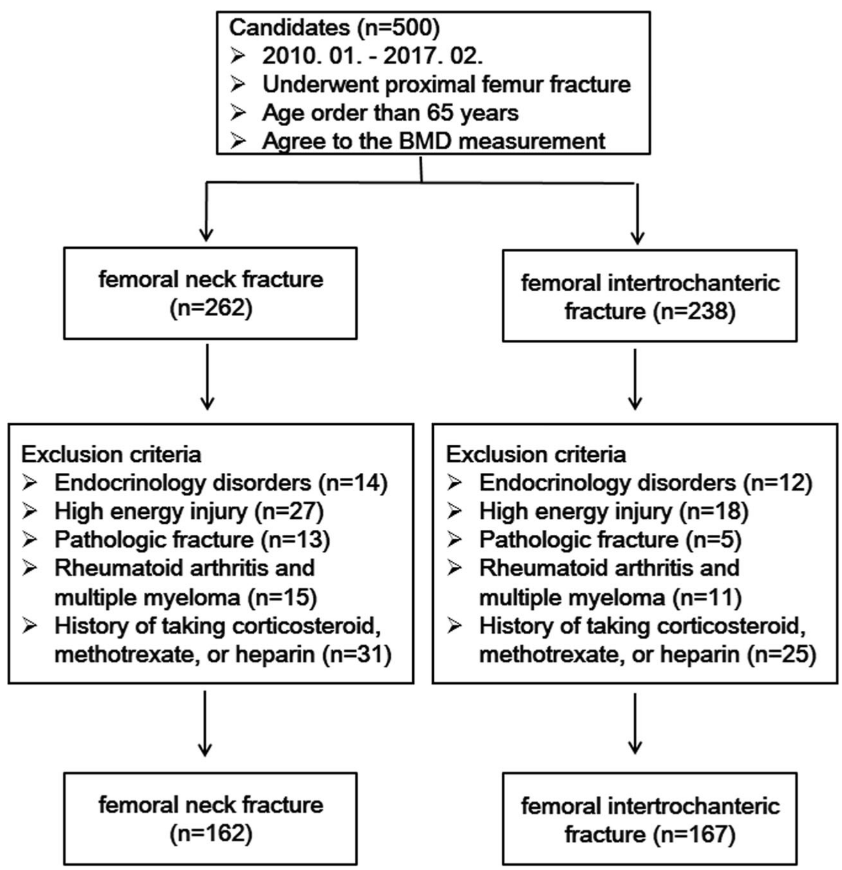

Fig. 1 Flowchart showing the selection of subjects in the current study

proximal femur were obtained using a QDR X-ray bone densitometer (Horizon W, Hologic, MA, USA), and BMD (g/cm^2) was obtained using APEX software (version 5.6.0.5, USA). The boundaries of femoral neck box, greater trochanter area, and intertrochanteric area were defined automatically using one-time auto analysis of APEX software (Fig. 2).

Statistical analysis

All the values are expressed in terms of mean ± standard deviation (SD), depending on the characteristics of the parameters. We used SPSS Statistics for Windows, Version 24.0. (IBM, NY, USA), for all statistical analyses. Comparisons between groups were made using an independent *t* test. Comparison with adjustment of some parameters (age, BMI) were made using ANCOVA (analysis of covariance). For comparison of gender difference, a chi-square test was performed. The relationship between variables was analyzed using Pearson correlation analysis in overall cases and in each group. We used linear regression analysis to obtain regression coefficient between age and BMD of intertrochanteric, femoral neck. All values with a $p < 0.05$ were considered statistically significant.

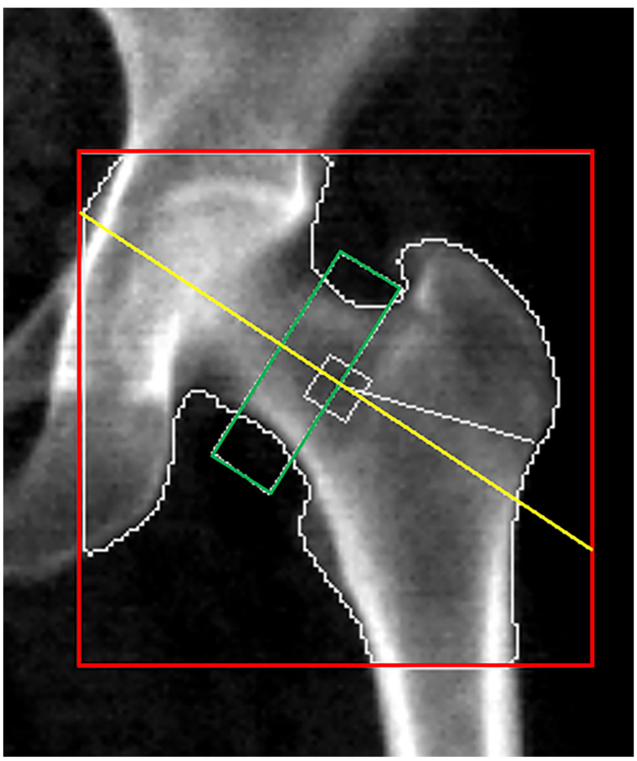

Fig. 2 The boundaries of femoral neck box, greater trochanteric area, and intertrochanteric area obtained from APEX software. The red box is Global ROI (region of interest) that extends 1 cm distal the base of the lesser trochanter, and the femur shaft is parallel to the vertical axis of the image. The dotted line is femur neck midline, which is connecting the middle part of the femur head and femur neck middle portion. The femoral neck box (green box) should not include the ischium and greater trochanter. The greater trochanter area boundaries are femoral neck box (green line) medially and the line from the point where femoral neck box inferior margin meets femur neck midline to the point where greater trochanter starts to protrude inferiorly (yellow line). The intertrochanter area boundaries are femur box inferior margin (green line) medially, the yellow line superiorly and global ROI inferior margin inferiorly

Results

The intertrochanteric fracture group was statistically significantly older than was the femoral neck fracture group ($p = 0.006$; 78.53 vs. 80.49). There was a significant difference between femoral neck fracture group and intertrochanteric fracture group only in the female subgroup ($p = 0.001$). There was no statistically significant difference in BMI and gender ratio ($p = 0.880$, 0.892) (Table 1). The BMD of the femoral neck was statistically significant different between the two groups ($p < 0.001$), and the BMD of the femur intertrochanteric was also significantly different between the two groups ($p < 0.001$). The BMD of both regions in the intertrochanteric fracture group was lower than that of the femoral neck fracture group (Table 2). After adjusting for age and BMI, which correlated with BMD, the BMD between the two groups showed a significant difference (Table 3). Age, BMI, and BMD of intertrochanteric, femoral neck were correlated (Table 4). BMD of intertrochanteric and femoral neck decreased with age in both groups (Fig. 3). In both groups, the BMD of the intertrochanteric and femoral neck regions of females decreased more steeply than did that of males (Fig. 4). In linear regression analysis, the beta values of the intertrochanteric fracture group were about twice as high as those of the femoral neck fracture group (Table 5), but there was no statistically significant difference between two groups.

Table 1 Demographic data

	Femoral neck fractures	Intertrochanteric fractures	*p* value
Age (years)	78.53 ± 6.52	80.49 ± 6.37	0.006
Male	77.89 ± 6.43	78.73 ± 6.24	0.286
Female	78.79 ± 6.35	81.23 ± 6.11	0.001
BMI (kg/m^2)	22.34 ± 3.44	22.27 ± 3.89	0.880
Male	47	49	
Female	115	118	0.892

Data are shown as mean ± standard deviation or number

BMI body mass index

Table 2 Bone mineral density of femur neck and intertrochanteric region (g/cm^2)

	Femoral neck fractures	Intertrochanteric fractures	*p* value
BMD neck	0.542 ± 0.106	0.489 ± 0.123	< 0.001
Male	0.587 ± 0.106	0.560 ± 0.122	0.133
Female	0.523 ± 0.102	0.459 ± 0.122	< 0.001
BMD intertrochanteric	0.808 ± 0.147	0.735 ± 0.164	< 0.001
Male	0.894 ± 0.147	0.799 ± 0.164	0.003
Female	0.773 ± 0.145	0.709 ± 0.161	< 0.001

Data are shown as mean ± standard deviation

BMD bone mineral density

Discussion

Many studies have tried to find the predictors of proximal femur fracture types. Various parameters have been suggested, such as mechanism of fall, functional mobility, bone mineral density (BMD), and morphological features of the femur [18–21].

BMD of the proximal femur has been usually measured in people with proximal femur fracture, and DXA is the most commonly used tool to evaluate BMD [22, 23]. Li et al. [24] reported that there were no significant differences of BMD in the femoral neck fracture group and intertrochanteric fracture group. But Hey et al. [25] reported that BMD of greater trochanter and intertrochanteric region was significantly lower in the intertrochanteric fracture group than in the femoral neck fracture group, the same result as in this study. They suggested that proximal femur fracture patterns following low-energy trauma may be influenced by the pattern of reduced bone density in different areas of the hip. Although there was no statistical difference in age between groups in their study, the number of patients was only 106, about one third of this study. In the study by Wu et al. [26] of 87 patients, they also found BMD of the greater trochanter was significantly lower in the intertrochanteric fracture group than that in the femoral neck fracture group. They insisted the risk of intertrochanteric fractures may be determined by BMD, but the risk of femoral neck fractures may be determined by multiple factors. They also insisted that intertrochanteric fractures may start at the greater trochanter because of its lower BMD.

Table 3 Age- and BMI-adjusted bone mineral density (g/cm^2) of femur neck and intertrochanteric region using ANCOVA

	Femoral neck fractures	Intertrochanteric fractures	*p* value
BMD neck	0.538 (0.009)	0.492 (0.008)	< 0.001
BMD intertrochanteric	0.803 (0.011)	0.740 (0.011)	< 0.001

Data are shown as adjusted mean (standard error of mean)

Table 4 Pearson correlation analysis between variables

Characteristics	Age (years)	BMI (kg/m^2)	BMD of femur neck	BMD of femur intertrochanteric
Age (years)				
Correlation		− 0.170	− 0.254	− 0.265
p value		0.002	< 0.001	< 0.001
BMI (kg/m^2)				
Correlation	− 0.170		0.295	0.284
p value	0.002		< 0.001	< 0.001
BMD of femur neck				
Correlation	− 0.254	0.295		0.767
p value	< 0.001	< 0.001		< 0.001
BMD of femur intertrochanteric				
z	− 0.265	0.284	0.767	
p value	< 0.001	< 0.001	< 0.001	

BMI body mass index. *BMD* bone mineral density

The trochanteric region has a greater proportion of trabecular bone than does the femoral neck [27]. Most studies have found significantly lower BMD with intertrochanteric fractures than with the femoral neck fractures [18, 28]. Uitewaal et al. [28] found significantly lower trabecular bone volume and surface density in patients with intertrochanteric fractures than in patients with femoral neck fractures.

This study has found significant differences in BMD by region depending on the type of proximal hip fractures; these were due to aging. In a study of spatial distribution differences in volumetric BMD between femoral neck fractures and trochanteric fractures using voxel-based morphometry, Yu et al. [29] reported that spatial distribution of trabecular volumetric BMD might play a significant role in proximal femur fracture. The BMD of intertrochanteric regions is higher than the BMD of femoral neck regions. We hypothesized that if the BMD of the intertrochanteric region is maintained, impact energy is transferred to the neck, causing a femoral neck fracture. But the BMD of the intertrochanteric region decreases with age, which leads to intertrochanteric fracture before the impact energy is transferred to the femoral neck. Fox et al. [13] insisted that low BMD might protect against femoral neck fractures if fractures of the intertrochanteric region dissipated the energy of a direct impact on the hip. The intertrochanteric region must be strong enough to stay intact while transmitting sufficient energy to fracture the neck. Regression analysis in this study also revealed that the BMD reduction slope of intertrochanteric regions in the femur intertrochanteric fracture group was twice as steep as that in the femur neck fracture group. Therefore, intertrochanteric fracture patients need more attention than femoral neck fracture patients.

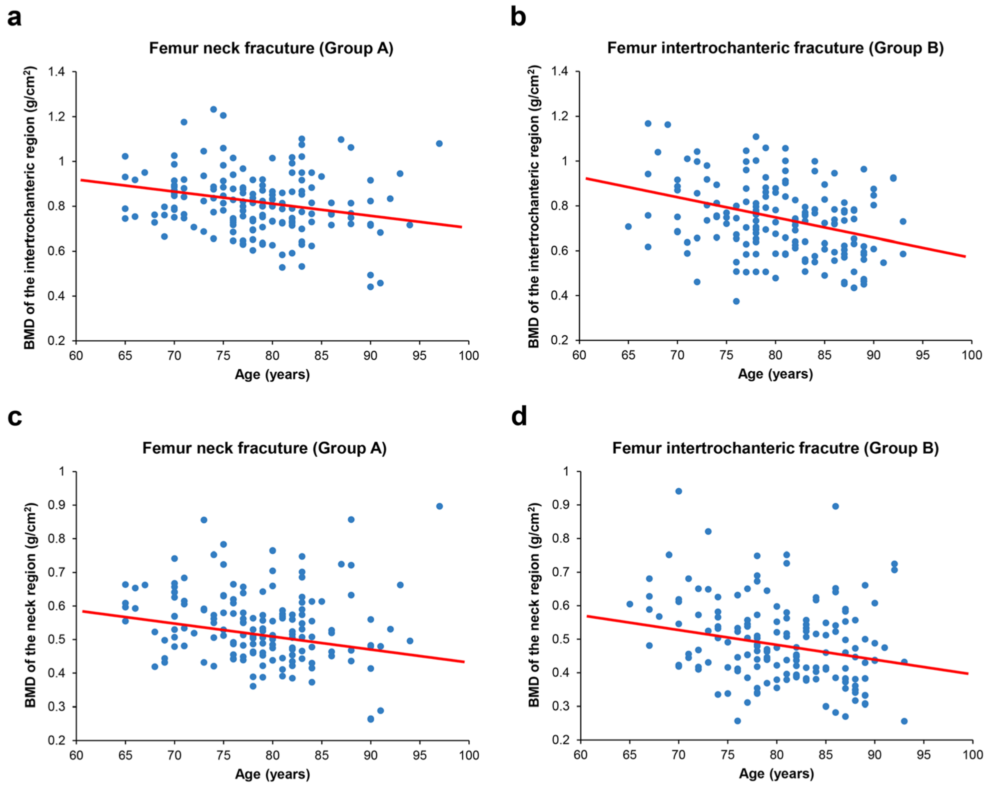

Fig. 3 **a** The change of BMD of the intertrochanter region depending on age(Group A). b The change of BMD of the intertrochanter region depending on age(Group B). **c** The change of BMD of the neck region depending on age(Group A). d The change of BMD of the neck region depending on age(Group B)

This study has several limitations as follows; there is a selection bias because of its study design conducted on patients who have already had fractures. We also do not know the natural history of decreasing bone density with age. This study is based on bone density without other influences, such as mechanism of fall, functional mobility, and morphological

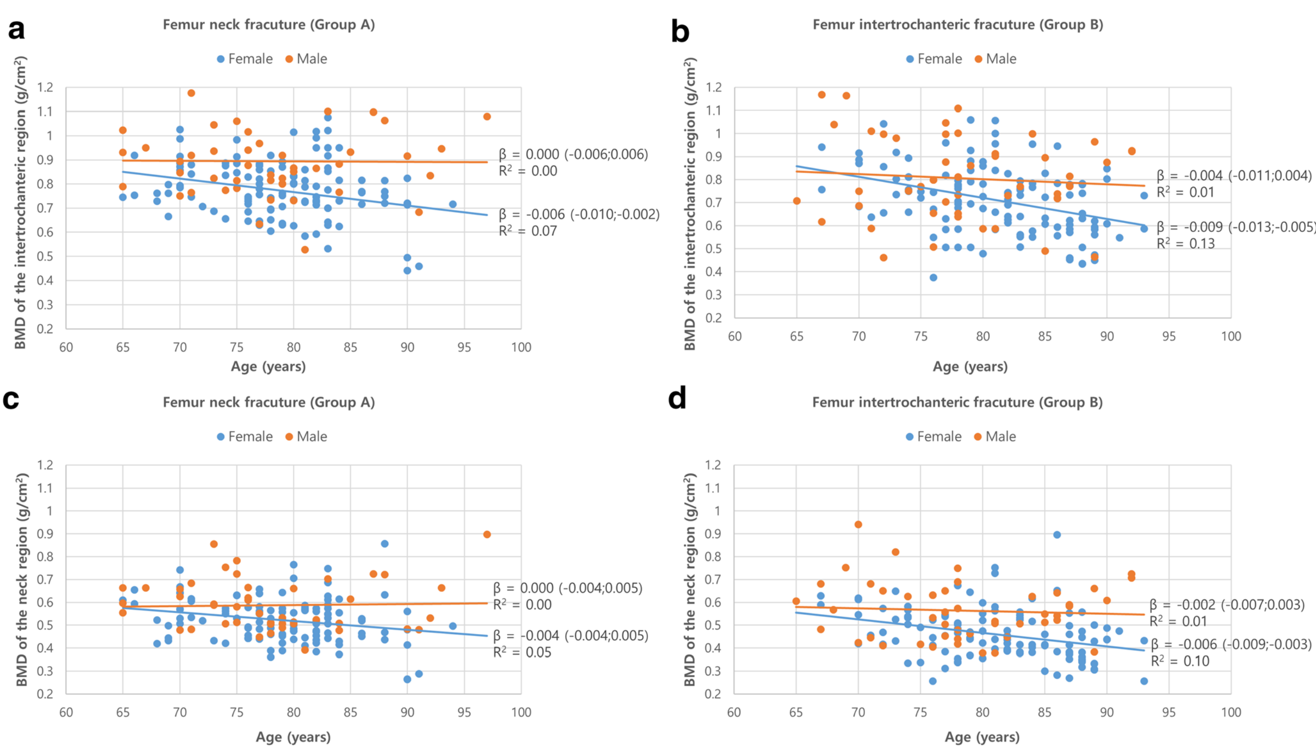

Fig. 4 **a** The change of BMD of the intertrochanter region depending on age(divided by sex)(Group A). **b** The change of BMD of the intertrochanter region depending on age(divided by sex)(Group B). **c** The change of BMD of the neck region depending on age(divided by sex)(Group A). **d** The change of BMD of the neck region depending on age(divided by sex)(Group B)

Table 5 Regression coefficient between age and BMD of intertrochanteric, femoral neck

	BMD of femur neck		BMD of femur intertrochanteric	
	Coefficients	*p* value	Coefficients	*p* value
Femoral neck fractures	− 0.004	0.020	− 0.003	0.045
Intertrochanteric fractures	− 0.008	< 0.001	− 0.006	< 0.001
Interaction *p* value	0.104		0.130	

Dependent variable: BMD inter (g/cm^2)

BMD bone mineral density

features [19–21]. Yang et al. [30] analyzed femoral neck BMD and geometric parameters (including neck length, neck diameter, head diameter, and neck-shaft angle). They reported that multiple linear regression analyses indicated that the best predictor of hip fracture was the combination of femoral neck BMD, head diameter, and neck diameter ($r^2 = 0.844$, $p < 0.001$). They confirmed that compared with BMD alone, the combination of BMD and geometric parameters of proximal femur is a better estimation of hip fracture. Lastly, the fracture region of clinically defined femoral neck fracture is consistent with the femoral neck region of interest (ROI) of the QDR X-ray bone densitometer, but the fracture region of intertrochanteric fracture is not consistent with the intertrochanteric ROI. But authors think that intertrochanteric ROI can represent the region of clinically defined intertrochanteric fracture because that ROI also has a greater proportion of trabecular bone [27].

Conclusions

Intertrochanteric fractures occur at an older age than do femoral neck fractures, and a decrease in BMD in the intertrochanteric region is related to proximal femur fracture type.

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Compliance with ethical standards

Conflict of interest None.

Ethical approval The study protocol was approved by the Institutional Review Board of Kangbuk Samsung hospital (protocol number: KBSMC-2014-01-127).

Consent to participate Not applicable.

Consent for publication Not applicable.

Code availability Not applicable.

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