Comparison of lower limb muscle characteristics and bone mineral density between femoral neck and intertrochanteric fractures using AI-based CT analysis

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INTRODUCTION:

Proximal femoral fractures, often classified as femoral neck or intertrochanteric fractures, are common fractures in the elderly that are associated with increased mortality and decline in activities of daily living. Although both fractures usually occur in osteoporotic patients following minor trauma, their treatment strategies and prognoses are different. Previous studies have pointed out that femoral morphology, including proximal femoral geometry and bone mineral density (BMD), and fall direction are factors related to fracture type [1-2]. However, only a few studies have focused on the role of muscles, which contribute to fall occurrence [3]. Thus, detecting specific muscle groups that exhibit atrophy and require strengthening may help reduce fall risk and promote earlier recovery. This study aimed to compare muscle volume, muscle quality, and BMD between femoral neck and intertrochanteric fractures using AI-based preoperative computed tomography (CT) analysis.

METHODS:

Among 367 consecutive patients who underwent surgery for proximal femoral fractures between July 2023 and June 2025, those who had preoperative whole-leg CT scans, no contralateral hip implants, were female, and aged ≥75 years were included. Then, 1:1 propensity score matching was performed for height, weight, and age, leaving 64 patients each for femoral neck fractures and intertrochanteric fractures. The overall mean age, height, weight, and BMI were 87.2 years, 149.0 cm, 44.4 kg, and 20.0 kg/m^2, respectively. Using an AI model (Bayesian U-net [4]) that we previously developed and validated, the gluteus maximus, gluteus medius, gluteus minimus, rectus femoris, vastus lateralis plus vastus intermedius, and vastus medialis in the healthy limb were segmented from preoperative CT images (Fig. 1). The volume and CT attenuation (HU) of the muscles, and proximal femur BMD (total region) were then quantified from CT images and compared between the groups using the Mann-Whitney U test. Statistical analyses were conducted with R software (ver. 4.5.0).

RESULTS:

No significant differences in muscle volumes were observed between the femoral neck fracture group and the intertrochanteric fracture group (Table 1). In contrast, CT attenuation of the gluteus medius and vastus medialis was significantly lower in the intertrochanteric fracture group than the femoral neck fracture group ($p = 0.01$ and $p = 0.03$, respectively), while no significant differences were observed in the other muscles (Table 2). Further, the proximal femur BMD did not differ significantly between the femoral neck fracture group (0.52 g/cm²) and the intertrochanteric fracture group (0.48 g/cm², $p = 0.09$).

DISCUSSION:

This study quantitatively evaluated muscle volume, CT attenuation, and also assessed BMD, in patients with proximal femoral fractures and compared the results between the intertrochanteric fracture group and the femoral neck fracture group. While no differences were observed in muscle volume and BMD, the lower CT attenuation of the gluteus medius and vastus medialis in the intertrochanteric fracture group suggested greater fatty degeneration in these muscles.

Previous studies reported inconsistent findings regarding hip muscle size between fracture types, with some showing significantly smaller values for intertrochanteric fractures than those with femoral neck fractures, while others found no difference [3,5]. Further, previous studies on hip muscle CT attenuation reported significantly lower values in the gluteal muscles of patients with intertrochanteric fractures compared with those with femoral neck fractures [6]. Some of these previous results align with our findings; however, our analysis is novel in that it adjusted for patient characteristics such as height and weight. Importantly, muscle volume and CT attenuation were assessed in 3D in this study, rather than relying on cross-sectional area (i.e., 2D) that has been commonly used. As a previous study has shown the effect of measurement level on muscle cross-sectional area [7], it is likely that our analysis clarified the differences between fracture types in greater detail.

Both the gluteal medius and the vastus medialis are known to play an important role in postural stability [8]. Thus, fatty degeneration in these muscles may contribute to fall mechanisms that likely lead to intertrochanteric fractures.

SIGNIFICANCE/CLINICAL RELEVANCE:

This study demonstrated differences in muscle quality between femoral neck and intertrochanteric fractures. The observed differences in CT attenuation of the gluteus medius and vastus medialis may reflect variations in hip stability and fall patterns. Identifying which muscles should be prioritized for strengthening may contribute to reducing fall risk and promoting earlier recovery.

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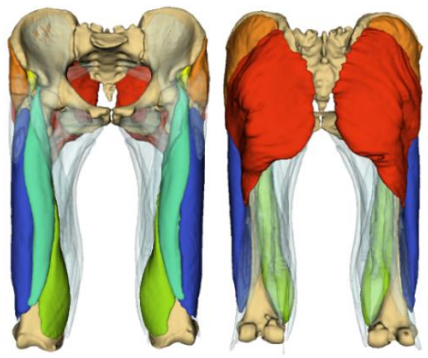

Fig. 1. Three-dimensional models segmented using a Bayesian U-net (Red: gluteus maximus; Orange: gluteus medius; Yellow: gluteus minimus; Light blue: rectus femoris; Blue: vastus lateralis + vastus intermedius; Light green: vastus medialis)

Table 1. Muscle volume

Volume (cm³)	Neck fractures	intertrochanteric fractures	p- value
Gluteus maximus	430 [240 – 693]	425 [236 – 597]	0.43
Gluteus medius	195 [125 – 295]	193 [105 – 297]	0.44
Gluteus minimus	41.0 [28.9 – 59.0]	41.6 [23.7 – 66.2]	0.70
Rectus femoris	87.3 [45.9 – 123]	90.3 [51.9 – 154]	0.99
Vastus lateralis + intermedius	395 [193 – 566]	381 [166 – 552]	0.53
Vastus medialis	182 [86.8 – 265]	172 [75.0 – 242]	0.32

Table 2. CT attenuation

CT attenuation (HU)	Neck fractures	intertrochanteric fractures	p- value
Gluteus maximus	19.6 [-16.8 – 35.0]	14.8 [-32.0 – 35.2]	0.06
Gluteus medius	31.2 [-9.4 – 41.7]	26.8 [-35.1 – 39.5]	0.01*
Gluteus minimus	26.1 [-21.9 – 45.8]	23.6 [-29.6 – 44.3]	0.13
Rectus femoris	44.9 [22.3 – 52.8]	43.7 [19.6 – 50.3]	0.20
Vastus lateralis + intermedius	44.4 [-11.5 – 52.4]	42.4 [-6.3 – 52.7]	0.06
Vastus medialis	46.5 [-7.4 – 54.2]	42.9 [-1.5 – 57.5]	0.03*

* $p < 0.05$