Comparative Analysis of Preoperative and Postoperative Muscle Mass around Hip Joint by Computed Tomography in Patients with Hip Fracture

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Purpose: This study was conducted in order to assess changes in hip muscles by comparing results of preoperative and postoperative computed tomography (CT) in older patients who underwent surgery for treatment of hip fracture.

Materials and Methods: A total of 50 patients (aged ≥65 years) who underwent surgery for treatment of intertrochanteric fractures (25 patients) and femoral neck fractures (25 patients) between February 2013 and February 2019 and underwent preoperative and postoperative pelvic CT were enrolled in the study. The cross-sectional area, attenuation and estimates of muscle mass of the gluteus medius, gluteus minimus, iliopsoas, and rectus femoris on the uninjured side were measured. Basic patient data (sex, age, height, weight, body mass index [BMI], bone mineral density [BMD], Harris hip score [HHS], and length of follow-up) were collected from medical records.

Results: No significant differences in sex, age, height, weight, BMI, BMD, HHS, and length of follow-up were observed between the two groups. No significant difference in the cross-sectional areas and attenuations of gluteus medius and gluteus minimus was observed after surgery; however, a statistically significant decrease was observed in those of iliopsoas and rectus femoris after surgery. Lower estimates with statistical significance of muscle mass of the iliopsoas and rectus femoris were observed on postoperative CT.

Conclusion: Muscle mass of the hip flexor (iliopsoas, rectus femoris) showed significant decreases on postoperative CT compared with preoperative CT. Based on these findings, selective strengthening exercise for hip flexor should be beneficial in rehabilitation of hip fractures.

Key Words: Hip fractures, Sarcopenia, Computed tomography, Rehabilitation, Exercise
elderly patients with sarcopenia\(^5\)\(^7\). In addition, these patients have aggravated health conditions that result in high mortality\(^8\)\(^9\).

In studies on sarcopenia, dual-energy x-ray absorptiometry (DEXA) has primarily been used in the analysis of this condition\(^10\)\(^11\). Of these, no study comparing intertrochanteric fractures and femoral neck fractures has been reported. In the comparison of these fractures, DEXA can provide approximations of muscle mass and muscle density based on the amount of radiation absorbed; however, the analysis of precise muscle mass and density in different muscles is impossible to determine\(^12\). It has been reported that measurement of cross-sectional area (CSA) and attenuation shown on axial computed tomography (CT) is a good indicator of sarcopenia\(^13\). Therefore, the aim of this study was to conduct a comparative analysis of preoperative and postoperative muscle mass around the hip joint using axial CT in patients with hip fracture.

**MATERIALS AND METHODS**

1. **Subjects**

This study was conducted with Institutional Review Board (IRB) approval from Dong-A University Hospital (No. DAUHIB-20-124), and the informed consent was waived by the IRB. Data on 97 patients who underwent postoperative pelvic CT of 700 patients who underwent surgery for treatment of intertrochanteric or femoral neck fractures between February 2013 and February 2019 at Dong-A University Hospital were reviewed. Of these, 40 patients who underwent bilateral hip surgery, ambulatory disability, neuromuscular disorder, or hemiparesis due to cerebrovascular disease were excluded from the analysis. Among 90 patients aged 65 and older whose intervals between operation and CT were between 1 year and 3 years, 50 patients were reviewed retrospectively. Participants included 25 patients with intertrochanteric fracture and 25 patients with femoral neck fracture (Fig. 1).

**Fig. 1. Flow chart showing how cases were selected and analyzed.**

CT: computed tomography, F/U: follow-up, CVA: cerebrovascular accident.

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2. Surgical Methods

All operations were performed by the same surgeon. In the 25 patients with intertrochanteric fracture, adequate closed reduction obtained on a fracture table was preoperatively confirmed using C-arm radiography, and intramedullary nail insertion was performed using the PFNA-II nail system (Proximal femoral nail anti-rotation-II, Asian version; DePuy Synthes, Oberdorf, Switzerland). In the 25 patients with femoral neck fracture, bipolar hip arthroplasty was performed using a Bencox® hip stem (Corentec, Seoul, Korea) in a lateral position using the modified Gibson approach.

3. Rehabilitation Protocols

After the hip operation, rehabilitation commences in the following order:
- While lying in the supine position, press knees down and apply strength to the quadriceps, stop for 4 seconds.
- Lift hip and hold 5 seconds, squeezing the gluteus muscles.
- Repeat dorsiflexion and plantarflexion of the ankle.
- Repeat the following exercises.
  ① Stand and bend the knee up.
  ② Extend the knee and return to standing position
  ③ Bend the hip and knee down
  ④ Extend the hip and knee and return to standing position
- Stop by extending the hip with knee extension in a prone position.
- Lying in a supine position, repeat abduct and adduct the leg placing a soft towel between the leg and the floor.
- Stand up and move the leg to the side and back.

4. Clinical and Radiological Analysis

Based on medical records, basic patient data (sex, age, height, weight at time of surgery and at final follow-up, body mass index [BMI], bone mineral density [BMD], Harris hip score [HHS] relating to function and length of follow-up) were reviewed retrospectively. Axial CT images of the pelvis just below the sacroiliac joint and at the level of the lesser trochanter were used for radiographic analysis of the gluteus minimus, rectus femoris, and iliopsoas muscles. For measurement of the CSA and attenuation to estimate muscle volume and density, a line was drawn connecting the outer margin of the muscles on axial CT of 0.625-mm sliced thickness using the PACS system (INFINITT PACS, ver. 3.0; INFINITT Healthcare, Seoul, Korea), expressed in square millimetres (mm²) and Hounsfield units (HU). The CSA and attenuation were measured for estimation of muscle volume and density. According to Goodpaster et al., HU represents attenuation which is a relative value to density and is related to muscle strength. Therefore, it was assumed that the multiply of CSA representing the volume and attenuation (HU) representing density could mean the estimate of muscle mass. The CSA and attenuation of the gluteus medius, gluteus minimus, and iliopsoas were measured just below the level of the sacroiliac joint, and those of the rectus femoris were measured at the level of the lesser trochanter. The largest area around those levels was measured (Fig. 2). Assuming that measurement

Fig. 2. The area of muscles is outlined by a white-dotted line in the axial scan of each level. (A) Cross-sectional area and attenuations of the gluteus medius [a], gluteus minimus [b], and iliopsoas [c] were measured at the sacroiliac joint just below level. (B) Cross-sectional area and attenuations of the rectus femoris [d] were measured at the lesser trochanter level.
errors could occur due to hematoma and swelling on the
injured side of the hip, CSA and attenuation were measured
preoperatively on the uninjured side of the hip. The CSA
and attenuation of muscles were measured twice at a 2-week
interval by the same experienced surgeon, and the mean
value was used.

5. Statistical Analysis

All statistical analyses were performed using IBM SPSS
software (ver. 23.0; IBM, Armonk, NY, USA). The CSA,
and attenuation of each muscle were measured preopera-
tively and postoperatively, and the measured values were
compared between patients in the intertrochanteric fracture
group and patients in the femoral neck fracture group. The
chi square test was used for comparison of patients in the
two groups, and the Mann–Whitney U-test was performed
to determine differences in age, BMI, BMD, HHS relating
to function, and length of follow-up that are not normally
distributed or small samples between the two groups. The
Mann–Whitney U-test was performed for comparison on
CSA and attenuation between the patients in the two groups.
In addition, the Wilcoxon signed-rank test was performed
to test the differences in CSA, attenuation, and estimate of
muscle mass in all patients between preoperative and post-
operative CTs. Correlations between the CSA and CSA per
weight (CSA/wt, mm²/kg) with HHS relating to function
were analyzed using Spearman correlation tests that are
not normally distributed or small samples. Fisher’s exact
test was performed to test the differences in the walking ability
between the two groups. P<0.05 was considered statistically
significant.

RESULTS

1. Subjects

Of the 25 patients in the intertrochanteric fracture group,
six patients (24.0%) were males, and of the 25 patients in
the femoral neck fracture group, eight patients (32.0%) were
males; no significant differences were observed between
the two groups (P>0.05). No significant differences in mean
age, mean height, mean weight at the time of surgery and
postoperative CT scan, BMI at the time of surgery and post-
operative CT scan, BMD, HHS, HHS relating to function at
the time of postoperative CT scan, and the interval between
operation and postoperative CT scan, and the interval between
operation and postoperative CT between two groups and
walking ability at the time of postoperative CT scan were
observed between the two groups (P>0.05) (Table 1).

| Table 1. Demographic Data for the Intertrochanter Fracture Group and Femoral Neck Fracture Groups |
|-------------------------------------------------|---------------------------------|------------------|-----------------------|
| Variable                                         | Intertrochanter fracture (n=25) | Femoral neck fracture (n=25) | P-value |
| Sex                                              | Female 19 (76.0)                | 17 (68.0)               | 0.184                |
|                                                  | Male 6 (24.0)                  | 8 (32.0)                |                       |
| Age (yr)                                         | 79.8±6.9                      | 79.5±6.8                | 0.561                |
| Height (cm)                                      | 156.6±6.1                     | 157.1±7.2               | 0.413                |
| Weight [kg] - preoperative                       | 54.2±12.2                     | 52.8±8.5                | 0.555                |
| Weight [kg] - F/U                               | 55.4±12.9                     | 54.2±8.5                | 0.721                |
| BMI [kg/m²] - preoperative                       | 22.3±4.90                     | 21.32±3.55              | 0.438                |
| BMI [kg/m²] - F/U                               | 22.85±5.50                    | 21.98±3.88              | 0.535                |
| BMD                                              | –2.94±0.77                    | –2.91±0.87              | 0.889                |
| HHS (total) - F/U                               | 82.65±11.54                   | 85.36±13.74             | 0.461                |
| HHS (functional) - F/U                          | 48.69±9.67                    | 50.18±8.81              | 0.583                |
| Interval between operation and CT (mo)           | 20.23±6.28                    | 21.51±7.19              | 0.861                |
| Walking ability                                  | None support 12               | 10                      | 0.722                |
|                                                  | Cane for long walk 5          | 6                       |                       |
|                                                  | Cane all the time 4           | 6                       |                       |
|                                                  | Walker ambulation 4           | 3                       |                       |

Values are presented as number (%), mean±standard deviation, or number only.
F/U: follow-up, BMI: body mass index, BMD: bone mineral density, HHS: Harris hip score, CT: computed tomography.
2. Cross-sectional Area of Muscles

- Values of CSA of each muscle between the intertrochanteric fractures group and femoral neck fractures group were greater than 0.05, showing no statistically significant change (Table 2).

- Values of CSAs of the gluteus medius and of the gluteus minimus between preoperative and postoperative states were greater than 0.05, showing no statistically significant change. However, values of CSAs of the iliopsoas and the rectus femoris between preoperative and postoperative states were 0.027 and 0.017, showing a significant decrease after surgery (Table 3). Results of the correlation analysis between postoperative CSA and HHS relating to function showed that Spearman correlation coefficient was 0.23, 0.25, 0.03, and 0.07 in the gluteus medius, gluteus minimus, iliopsoas, and rectus femoris, respectively. All P-values were >0.05, indicating no significant correlation (Table 4).

3. Attenuation (ATT) of Muscles

- Values of ATT of each muscle between the intertrochanteric fractures group and femoral neck fractures group were greater than 0.05, showing no statistically significant change (Table 5).

- Values of attenuation of the gluteus medius and of the gluteus minimus between preoperative and postoperative states were greater than 0.05, showing no statistically significant change. However, P-values of attenuation of the iliopsoas and of the rectus femoris between preoperative and postoperative states were <0.001 showing a significant decrease after surgery (Table 6).
4. Estimate of Muscle Mass

The $P$-values of the estimates of muscle mass in the gluteus medius and gluteus minimus in all patients between the preoperative and postoperative states were greater than 0.05, showing no statistically significant change. However, the $P$-values of the estimates of muscle mass in the iliopsoas and rectus femoris in all patients between the preoperative and postoperative states were <0.001 showing a significant decrease after surgery (Table 7).

**DISCUSSION**

Skeletal muscle mass and strength are inversely proportional to increasing age. The decline in skeletal muscle mass and strength with age accelerates after 65 years of age and results in various social problems such as physical impairment, reduced quality of life, and increase in mortality\(^{15}\). The socioeconomic burden is a serious concern, and as a result, sarcopenia has recently gained significant attention\(^{16}\). Sarcopenia can increase the risk of hip fracture and cause dysphagia or voiding dysfunction due to muscle weakness\(^{17,18}\). These conditions are considered indicators
of frailty and associated with loss of independence19. Tatara et al.20 and Ellman et al.21 suggested that muscle force is a critical factor for proper growth and preservation of the bony skeleton, and Ford et al.22 reported the impact of imbalance of muscles around the hip joint on the hip joint. However, few studies evaluating muscles around the hip joint by dividing patients into two groups, one with intertrochanteric and one with femoral neck fractures, have been conducted.

Conventional methods for measurement of body composition include DEXA, bioelectrical impedance, CT, magnetic resonance imaging, and others. DEXA and bioelectrical impedance analysis can be used for estimation of the overall condition of the skeleton; however, they are not suitable for use in muscle-specific analysis. Although magnetic resonance imaging provides a precise analysis of muscle condition and mass, attenuation and fatty infiltration around skeletal muscles, it cannot be used in patients with metallic prostheses. On the contrary, Mitsiopoulos et al.23 reported approximately the same measurements of skeletal muscle and adipose tissue in both humans and cadavers using CT. According to a report by Rasch et al.24, the use of CT allows for simple circumscribing of large muscle bellies and minimizes measurement errors with easy identification of the bony landmarks of the pelvis.

Intertrochanteric fracture is an extracapsular fracture, whereas a femoral neck fracture is an intracapsular fracture. Extracapsular fractures are more likely to occur in patients with hip osteoarthritis, because their hip joints are stiffer25. Based on that assumption, it was presumed that patients with intertrochanteric fracture will likely have weaker abductor (gluteus medius, gluteus minimus) but stronger flexor (iliopsoas, rectus femoris) than patients with femoral neck fracture; however, no statistically significant differences were observed in this study.

Of all muscles around the hip joint, the gluteus medius serves a key role in abduction at the hip joint, provides stability of the pelvis during a single-leg stance and exhibits Tredelenburg’s sign in case of insufficiency26,27. The gluteus minimus aids abduction in a similar manner as the gluteus medius, therefore this muscle was included in the analysis. The iliopsoas muscle, which serves as the primary muscle in hip flexion and has been considered an indicator of sarcopenia, was also included28,29. The iliopsoas muscle contributes to the stability of the lumbar spine, which may cause problems such as herniated nucleus pulposus in patients with tightness or spasm30. The rectus femoris was included in this study because it crosses over both the hip and knee joints and maintains stability of the femur during walking. In patients with weakness of the rectus femoris, excessive knee extension may occur due to limitation of active knee extension. Moreover, in gait analysis, gluteus medius and gluteus minimus mainly play a role in the stance phase in the walking gait, whereas iliopsoas and rectus femoris mainly play a role in the pre-swing phase, such as lift off, and the swing phase. Therefore we presume that sarcopenia at these muscles may affect stance phase and swing phase respectively. In this study lower estimates with statistical significance of muscle mass of the iliopsoas and rectus femoris were observed on postoperative CT. It is presumed that this result is due to a decrease in stride length and power in the swing phase after surgery because of pain and stiffness.

In a recent study, Paganini-Hill et al.31 and Chilibeck et al.32 suggested that the strengthening of skeletal muscles through exercise is effective in preventing hip fracture, increasing BMD, and reducing the risk of falling. Gschwind et al.33 reported that hip fracture in the older population can be prevented with exercise that improves muscle balance and strength. However, no studies to determine which specific muscles need to be strengthened in rehabilitation for patients with hip fractures have been conducted. This study was conducted in an effort to suggest which exercises would be helpful for patients with hip fracture.

This comparative study has some limitations, including small sample size. In addition, because assessment was based on muscle CSA and attenuation, instead of measurement of muscle power at the hip joint in each patient, there may be differences in actual muscle function and power. Finally, because preoperative ambulation ability and overall function of the musculoskeletal system were not fully controlled, there may have been bias in the comparison of preoperative and postoperative changes.

CONCLUSION

Significant decreases in muscle mass in the hip flexor (iliopsoas, rectus femoris) were observed on postoperative CT. Based on these findings, selective strengthening exercise for the hip flexor should be beneficial in rehabilitation of hip fractures.

CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.
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