Brief Communication

Acute Ultrasonographic Changes in Lower Extremity Muscle Structure after Motor Complete Spinal Cord Injury

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Abstract

Background: There is a lack of studies examining ultrasonographic muscle changes in patients with acute spinal cord injury (SCI). **Methods:** We recruited adults with motor complete acute SCI and performed longitudinal ultrasound measurements. The primary outcome measures were rectus femoris and medial gastrocnemius thickness and echo intensity. **Results:** This study recruited 20 patients, with a mean time to the first ultrasound measurement of 17.2 ± 2.14 days, with the second measurement done 4 weeks after the first measurement. We found that there was a mean decrease in the rectus femoris muscle thickness of 18.7% ($P = 0.027$), as well as a mean increase in the rectus femoris echo intensity of 13.0 a.u. ($P = 0.009$), although no significant differences were found for the medial gastrocnemius. **Conclusion:** This study demonstrates decreased thickness and increased echo intensity in the rectus femoris but not in the medial gastrocnemius in patients with motor complete SCI.

Keywords: muscle disorders, neurologic disorders, spinal cord injury, ultrasonography

Introduction

The incidence of spinal cord injury (SCI) has been reported to be as high as 83 per million inhabitants per year, with 50% reporting complete lesions.[1] Individuals with SCI experience rapid muscle loss below the level of the lesion. Within the first few months postinjury, muscle morphological changes have been documented, including muscle atrophy, infiltration of intramuscular fat, and formation of fibrous tissue.[2] Based on magnetic resonance imaging (MRI) at 6 weeks postinjury, patients with SCI have been shown to have reduced lower extremity skeletal muscle cross-sectional area and increased relative intramuscular fat compared to healthy controls.[2]

During the process of rehabilitation, estimation of muscle thickness and fat infiltration is useful for understanding the adaptations in response to immobility and exercise.[2] Although MRI is often considered a gold standard in quantifying muscle cross-sectional area, ultrasound is a relatively inexpensive, quicker, and safer technique, which has shown comparative reliability in terms of measuring skeletal muscle mass.[3,4] However, the use of muscle ultrasound in SCI is limited to those with chronic injuries, and muscle ultrasonographic changes in acute injuries have not been studied. Changes in ultrasound-derived muscle echo intensity, a surrogate measure of intramuscular fat, have also not been reported in lower-limb extremities of patients with SCI.[3]

Our aim was therefore to study changes in muscle thickness and echo intensity over 4 weeks in the lower extremities of patients with motor complete SCI after acute injury.

Methods

Study participants

This was a prospective single-center cohort study recruiting a total of 20 consecutive patients with motor complete SCI admitted to the SCI unit in a tertiary rehabilitation center from January 1, 2020, to September 1, 2020.

The inclusion criteria for study participants were first-ever acute SCI, recent onset of injury <1 month, age of ≥21 years old, independent in ambulation before the onset of SCI, SCI above L2 as determined by neurological examination,

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and a motor complete injury determined by the American Spinal Injury Association Impairment Scale A or B of sudden onset (<24 h).

Participants were excluded if they had active malignancy; had premorbid lower-limb musculoskeletal conditions, for example, contractures, fractures, or previous operations; had other active neurological conditions; or were unable to understand study procedures.

All groups had standard inpatient rehabilitation treatment (2 h/day for 5 days/week), with daily physiotherapy and occupational therapy session for 1 h each session, which consisted of mobilization, gait therapy, and conventional rehabilitation. The time to mobilization was determined by the rehabilitation team based on patient assessment.

The Walking Index for Spinal Cord Injury II was used to assess the gait ability of study patients. This measures the physical assistance (i.e., number of people) and assistive devices (i.e., walking aids) a patient needs to ambulate 10 meters, with a scale from 0 to 20, with a higher number indicating less impairment.[5]

Ultrasound assessment

An initial ultrasound assessment was performed within 2 weeks of injury, and a follow-up assessment was performed at 4 weeks after the initial ultrasound assessment.

The thickness and echo intensity of the rectus femoris and medial gastrocnemius were measured using B-mode ultrasound scanning (Terason t3200, Terason Ultrasound, Burlington, Massachusetts, USA) with a 15-4 MHz transducer. Images were acquired using preset musculoskeletal imaging settings with a 4-cm scan depth, level 50 2D gain, level 64 dynamic range, and 21-Hz frame rate. For ultrasound assessment, participants were positioned supine on an examination bed with arms and legs in full extension and muscles completely relaxed. The probe was placed perpendicular to the skin without exerting compression, and all scans were obtained in the transverse plane [Figure 1].

The rectus femoris was measured at the midportion, calculated as half the distance between the anterior superior iliac spine and the lower edge of the patella was determined.[6] The medial gastrocnemius was measured at 30% proximal between the lateral malleolus of the fibula and the lateral condyle of the tibia.[7]

ImageJ software (National Institute of Health, Bethesda, MD, USA, version 1.46) was used for analysis. Muscle thickness was defined as the distance between the superior border of the subcutaneous fascia and the deep aponeurosis.[8] Echo intensity was assessed at the grayscale level, which was expressed in arbitrary units (a.u.), using ImageJ software. A rectangular region of interest as large as possible was established, excluding the visible fascia and bone [Figure 1].

All ultrasonography measurements were performed in triplicate, with the average of the scores used in the final analyses. All images were obtained by the same operator. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the hospital (NHG DSRB 2019/00923). Informed written consent was obtained from all patients before their enrollment in this study.

Statistical analysis

The distribution of sociodemographic and clinical data was presented with appropriate descriptive statistics. The paired *t*-test was used to compare differences in muscle thickness and echo intensity. All estimates were reported along with the 95% confidence interval (CI). Statistical analyses were performed using the SPSS version 26.0 (IBM Corp., Armonk,

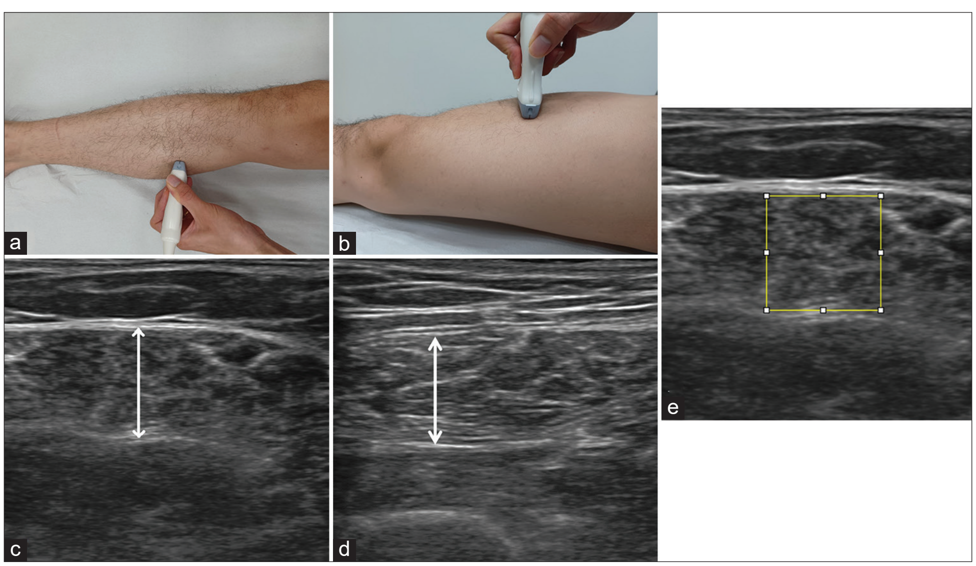

Figure 1: Ultrasound assessment of muscles. (a) Positioning of the probe over the rectus femoris and (b) medial gastrocnemius; (c) measurement of the muscle thickness of the rectus femoris and (d) medial gastrocnemius; (e) measurement of echo intensity

NY, USA). All statistical tests were performed at a two-sided 5% significance level.

Results

This study recruited 20 patients, with a mean age of 59.5 ± 17.0 years, of which 19 (95%) were male. The mean time to the first ultrasound measurement was 17.2 ± 2.14 days, with all patients receiving the second ultrasound measurement 4 weeks after the first ultrasound measurement [Table 1].

The rectus femoris muscle thickness and echo intensity on admission were 100 ± 42.8 mm and 71.3 ± 28.8 a.u., and 89.9 ± 47.7 mm and 79.7 ± 32.1 a.u. on discharge, respectively.

Table 1: Characteristics of participants (*n*=20)

Characteristics	*n* (%)/mean±SD/median (range)
Age (years)	59.5±17.0
Age range (years)	61.5 (30–85)
Gender	
Male	19 (95.0)
Female	1 (5.0)
Ethnicity	
Chinese	16 (80.0)
Malay	4 (20.0)
Etiology	
MVA	6 (30.0)
Fall	10 (50.0)
Infectious	1 (5.0)
Inflammatory	2 (10.0)
Vascular	1 (5.0)
ASIA classification	
A	4 (20.0)
B	16 (80.0)
Time to first measurement (days)	17.2±2.14
Time to second measurement (days)	28.0±0
Height (m)	1.68±0.0804
Weight (kg)	57.7±16.0
Body mass index	20.2±4.44
SCIM on admission	
0	19 (95.0)
1	1 (5.0)
WISCI II	
0	17 (85.0)
1	1 (5.0)
2	2 (10.0)
RF muscle thickness (on admission) (mm)	100±42.8
RF muscle thickness (on discharge) (mm)	89.9±47.7
RF echo intensity (on admission) (a.u.)	71.3±28.8
RF echo intensity (on discharge) (a.u.)	79.7±32.1
MG muscle thickness (on admission) (mm)	10.6±8.78
MG muscle thickness (on discharge) (mm)	10.1±7.49
MG echo intensity (on admission) (a.u.)	72.3±18.0
MG echo intensity (on discharge) (a.u.)	74.8±18.2

SD: Standard deviation, RF: Rectus femoris, a.u.: arbitrary units, MG: Medial gastrocnemius, MVA: Motor vehicle accident, WISCI: Walking index for spinal cord injury

The medial gastrocnemius muscle thickness and echo intensity on admission were 10.6 ± 8.78 mm and 72.3 ± 18.0 a.u., and 10.1 ± 7.49 mm and 74.8 ± 18.2 a.u. on discharge, respectively [Table 1].

There was a mean percentage difference in the rectus femoris muscle thickness of − 18.7% (95% CI = −35.2 to − 2.33; $P = 0.027$), as well as a mean increase in the rectus femoris echo intensity of 13.0 a.u. (3.63 to 22.4; $P = 0.009$) over 4 weeks after the first ultrasound measurement. No significant differences were found for the medial gastrocnemius in terms of change in muscle thickness (−2.41%; 95% CI = −13.3–8.50; $P = 0.649$) or echo intensity (4.58%; 95% CI = −3.92 to 13.1; $P = 0.273$).

Discussion

This study demonstrates that there are ultrasonographic changes in the rectus femoris during the acute postinjury period in patients with motor complete SCI.

Few studies have investigated ultrasonographic changes in muscle architecture in SCI. MRI findings have been reported in chronic SCI patients, with a study demonstrating that individuals 5–37 months postinjury had a 24% and 31% reduction in the cross-sectional area of the tibialis anterior and quadriceps femoris compared to controls.[9] However, studies investigating ultrasonographic muscle changes during the 1st few weeks after SCI remain sparse, with most studies performed in individuals with chronic SCI. The study findings of reduced rectus femoris muscle thickness on ultrasound were consistent with previous reports on thigh muscle thickness derived from MRI cross-sectional area.

Increased fatty infiltration in skeletal muscle, as a measure of muscle quality, is closely linked with decreased mobility in many clinical populations.[10] The accumulation of intramuscular fat is believed to be due to the failure of skeletal muscle to utilize glucose after paralysis, inhibiting the process of fatty acid oxidation, and this process has been speculated to contribute to insulin resistance.[9] Studies have documented a reduction in lower extremity fat-free mass after SCI, though these are mainly performed to patients with chronic injuries. For example, Moore *et al*. reported lower muscle density values of 43% in the calves of chronic motor complete SCI relative to controls,[10] and Shah *et al*. reported increased intramyocellular lipid content of the soleus muscle in patients with chronic incomplete SCI.[8] An increased intramuscular fat has also been reported in thigh muscle MRI from 6 weeks to 3 months postinjury in incomplete SCI patients.[2] However, further studies confirming the acute changes in muscle echo intensity in SCI patients during the acute phase are lacking. Our findings indicate an increase in muscle echo intensity of the rectus femoris over 1 month, which may have implications in the importance of early interventions after SCI to reduce muscle atrophy and prevent fat accumulation.

Some study limitations should be highlighted. These are preliminary findings due to the small sample size of the study. This study also only recruited motor complete SCI to obtain a homogenous participant pool. Further studies are required to determine if these findings are applicable to patients with incomplete SCI. In addition, potentially modifiable risk factors resulting in acute changes in muscle were not investigated, which may attenuate subsequent skeletal muscle adaptation after SCI. Selection of the region of interest for the measurement of muscle echo intensity may also be prone to bias due to a nonuniform distribution of echo intensity of muscle. We also did not investigate the relationship of spasticity with skeletal muscle mass.

Conclusion

This study reports decreased thickness and increased echo intensity in rectus femoris but not in medial gastrocnemius over the acute period in patients with motor complete spinal injuries.

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Conflicts of interest

There are no conflicts of interest.

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