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Research paper

Evaluation of the site specificity of acute disuse muscle atrophy developed during a relatively short period in critically ill patients according to the activities of daily living level: A prospective observational study

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ABSTRACT

Introduction: In critically ill patients, excessive bed rest and immobilisation have been shown to cause disuse muscle atrophy, which contributes to prolonged hospitalisation and decreased activity of daily living (ADL) levels. However, the degree and site specificity of acute disuse muscle atrophy in critically ill patients during a relatively short intensive care unit (ICU) stay have not been fully elucidated.
Methods: Critically ill patients, who required bed rest on ICU admission, were eligible for this study. The degree of skeletal muscle atrophy was evaluated on the day of, and 72 and 144 h after ICU admission by measuring the limb circumference in ADL-dependent or -independent patients separately at five different sites: the midpoint of the upper limb between the acromion and the olecranon, the maximum diameter of the triceps surae in the lower leg, and three different sites in the thigh at 5, 10, and 15 cm above the superior pole of the patella. Value of the limb circumference was presented as a percentage relative to the baseline (median).
Results: In ADL-dependent patients, limb circumferences at all five sites were decreased significantly at 144 h compared with the baseline (98.9–100% in the upper limbs, 97.1–97.2% in the lower legs, and 96.5–99.1% in the thighs), but not at 72 h. In contrast, the limb circumferences at almost all sites decreased significantly at both 72 and 144 h (100% in the upper limbs, 94.5–94.7% in the lower legs, and 89.7–94.7% in the thighs), compared with the baseline in ADL-independent patients. Muscle atrophy was greater at the four different lower-limb sites compared to the upper limb during 144 h in the ICU in the ADL-independent, but not in the ADL-dependent patients.
Conclusions: Compared to ADL-dependent patients, ADL-independent patients are prone to develop muscle weakness, especially in the lower limbs.

1. Introduction

Many critically ill patients in the intensive care unit (ICU) have been placed on long-term bed rest during treatment because of the severity of their disease or their postoperative condition after a major surgery. Excessive bed rest and immobilisation have been shown to cause disuse muscle atrophy,[1–4] which contributes to

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prolonged hospitalisation and decreased activity of daily living (ADL) levels after discharge.[5–7] Moreover, ICU-acquired weakness and an elevated inflammatory status, which often complicate critically ill patients, cause deterioration of functional abilities following ICU admission.[8,9] Many patients who have developed disuse muscle atrophy, ICU-acquired weakness, and an elevated inflammatory status during their ICU stay do not fully recover their preadmission physical function levels, and residual limitations persist in 69% after ICU discharge.[10]

It has been reported that skeletal muscle volume may decline by 1–1.5% per day of strict bed rest,[11] and by 4–5% for each week of bed rest,[12] which leads to a 10% reduction in skeletal muscle strength after one week.[13] Patients aged above 60 who are admitted to the ICU are expected to have a 20% skeletal muscle loss because of sarcopenia, which is greater than that seen in younger patients.[14] Even when ADL levels before ICU admission are normal, even moderate muscle atrophy can affect the ability to perform ADLs after discharge.[15] Furthermore, the decline of skeletal muscle strength due to immobilisation can be associated with not only a delay of ADL recovery to former levels but also with substantial morbidity.[6,16] In patients with an elevated inflammatory status, muscle atrophy following bed rest progressed three-fold faster than in patients without an elevated inflammatory status.[17] Although previous studies examined the degree and importance of disuse muscle atrophy after long-term bed rest, few studies have evaluated the effect of short-term bed rest on the degree of disuse muscle atrophy in critically ill patients, who often present with an elevated inflammatory status, as well as haemodynamic and respiratory instability.

The aim of this study was to evaluate the degree of skeletal muscle atrophy during a relatively short ICU stay and to identify the region of skeletal muscle that is susceptible to disuse muscle atrophy in critically ill patients who were on bed rest due to disease severity or postoperative conditions. Whether the degree of muscle atrophy was different according to the ADL level before ICU admission was also examined.

2. Methods

2.1. Setting

This observational study was conducted in the ICU of Keio University Hospital, which is a 1044-bed teaching hospital, from October 2012 to October 2013. This study was approved by the hospital ethics committee before any participants were enrolled (approval number 20130181), and was performed according to the STROBE guidelines for cohort studies.[18] Informed consent was obtained from participants or their authorised representatives according to the code of ethics when needed.

2.2. Patients

Patients over 20 years old, who were expected to stay in the ICU for more than six days and required bed rest at the initial rest level on ICU admission, were eligible for this study. The exclusion criteria were as follows: patients who had received either upper or lower limb amputation, patients with refractory shock who received large volume transfusions and high-dose catecholamine therapy, patients with deep vein thrombosis, upper or lower limb burns, or limb bone fractures. Obese patients with a body mass index (BMI) of over 35 (morbid obesity), who had more adipose tissue at the peripheral sites, such as the upper and lower limbs,[19] were also excluded to eliminate the effects of the fat layer. Subjects were divided into two groups depending on the ADL level before ICU admission: an ADL-independent group and an ADL-dependent group. The ADL level prior to ICU admission was determined on admission by nursing staff not involved in care of the patient, using the Barthel Index (ranging from 0 to 100 points, with a higher score indicating greater independence),[20] and based on information obtained from immediate family or relatives; 100 points was defined as independent in this study. Briefly, while the ADL-independent group included patients who did not require daily assistance for eating, transferring to a chair, cosmetic cleaning, bathing, toileting, ambulation, or changing clothes, the ADL-dependent group required partial or total assistance in their daily lives. The demographic information and baseline characteristics of the subjects, such as age, sex, BMI, primary admission diagnosis, sequential organ failure assessment (SOFA) score,[21] blood chemical analysis data, and past medical history, and need for mechanical ventilation, continuous hemodiafiltration, an intra-aortic balloon pump, or extracorporeal membrane oxygenation, were recorded.

In this study, sedation levels were assessed by the attending nurse once an hour using the Richmond Agitation Sedation Scale (RASS).[22] The dose of reagents used for sedation was adjusted by intensivists to maintain RASS sedation levels between −2 and 0 as much as possible during the daytime. For usual care, patients were kept in a semirecumbent position with at least 30° head elevation during the daytime if haemodynamic status was stable. Passive range of motion (ROM) exercise was provided by the attending nurse three times per day for about 10 min as a standard practice in all patients. The physical therapists in our ICU provided both passive ROM exercise and active or active-assist ROM exercise once a day for about 15 min to patients who were not on mechanical ventilator support, but only passive ROM exercise once a day for about 10 min to patients on mechanical ventilation. Resistance exercises and aggressive rehabilitation, such as in a sitting or standing position, were never provided during the study period.

2.3. Outcome

The primary outcome of this study was the degree of skeletal muscle atrophy in the upper and lower limbs as measured by the chronological change of muscle thickness. For the evaluation of muscle thickness, the limb circumference was measured by using the same flexible tape. Five measurement sites were selected on the basis of previous studies of anthropometric measurements: the midpoint of the upper limb between the acromion and the olecranon for the evaluation of the maximum diameter of the biceps brachii,[23,24] the maximum diameter of the triceps surae for the evaluation of the maximum size of the lower leg,[25–27] and three different sites at 5 cm, 10 cm, and 15 cm above the superior pole of the patella for quadriceps femoris evaluation.[28–35] The measurement sites for limb circumference are shown in Fig. 1. The measurements were performed on the day of ICU admission, and at 72 and 144 hours (h) after ICU admission. Subjects were maintained in the supine position with each limb in extension during the measurement of the circumference, and respective measurement points were marked in red at the initial measurement to avoid inter-measurement errors. Interclass and intraclass correlation coefficients (ICC) were calculated to evaluate the anthropometric artificial error [ICC (1, 1) = 0.997, ICC (2, 1) = 0.996]. To exclude the effect of fluid therapy on limb circumference,[36] the daily fluid balance was recorded.

2.4. Statistics

Demographic data were compared between the ADL-independent group and the ADL-dependent group using Student's *t*-test and were presented as mean ± standard deviation (SD) for normally distributed continuous data. The normality of