‖原 著‖

Changes in the thickness of leg muscles before and after laparotomy

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In order to establish an objective and convenient technique to assess postoperative recovery following laparotomy, in particular activities of daily living, we measured the thickness of muscle tissues by ultrasound sonography. In the present study, the following four muscular compartments were selected: rectus femoris, biceps femoris, extensor digitorum longus, and soleus. These account for a large portion of the systemic skeletal musculature and are important for locomotion. Subjects were 28 patients who underwent moderately invasive surgery for stomach or colon cancer. The results showed that muscle thickness decreased significantly in all four compartments. Rectus femoris exhibited the greatest reduction in thickness and was most affected by short-term or long-term recumbency. Furthermore, for soleus, the tendency was that the longer the recumbency, the greater the wasting. These findings suggest that, of the four areas of the lower limb, rectus femoris is most affected by short-term recumbency and is most suited for objectively assessing postoperative recovery. The results of the present study suggest that it would be effective to design a recovery program focused on maintaining the femoral extensor muscles, which are most affected by short-term recumbency following laparotomy.

Introduction

Following surgery, patients are likely to experience muscle fatigue [1-3] and reduced muscle strength because surgical invasion facilitates the destruction of proteins in skeletal muscles[4]. Currently, various measures are taken to shorten the length of hospital stay, resulting in greater numbers of patients being discharged who still require nursing care to facilitate postoperative recovery. Moreover, while it is generally desirable for postoperative patients to mobilize early, long-term bed rest is required in some cases to prevent the onset of postoperative complications or to treat such complications. Therefore, from the standpoint of nursing, it is necessary to minimize the negative impact of postoperative recumbency and to achieve independence in activities of daily living as quickly as possible. The lower limb muscles account for a large portion of the systemic skeletal musculature and play the most important role in walking. While maintaining lower limb muscle strength is important for achieving early independence in walking, few nursing studies in Japan have focused on these muscles[5,6].

Several bedside techniques for assessing muscle tissue and strength have been reported: 1) measuring maximum voluntary muscle strength using a dynamometer[7-9]; 2) estimating the cross-sectional area of muscles based on subcutaneous fat thickness and circumference of the extremity[5,10]. However, when these methods are applied postoperatively, accuracy is low[11] because patients cannot exert maximum effort due to wound pain[10].

In order to gather the basic data for designing an effective postoperative recovery program, the present study was conducted to ascertain an objective and

・開腹手術患者における下肢筋組織厚の術前・術後の変化
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convenient technique to assess postoperative recovery following laparotomy by measuring the thickness of the four muscular compartments of the lower limb by ultrasound and then identifying the region most affected by recumbency. By measuring the thickness of the four muscular compartments of the lower limb by ultrasound before and after surgery, the purpose of this study was to identify the area that is most affected by recumbency and is consequently most useful for clinically assessing postoperative recovery.

Materials and Methods

Subjects

Subjects were 28 patients aged from 50 to 79 years who were scheduled to undergo moderately invasive laparotomy for stomach or colon cancer. The following exclusion criteria were applied; 1) history of leg paralysis or dyskinesia; 2) impaired activities of daily living and inability to walk independently; 3) heart disease or diabetes requiring drug therapy; 4) metastatic cancer; 5) preoperative radiotherapy or chemotherapy; 6) postoperative complications during the study period; 7) recovery deviating from the clinical path prepared by the ward during the study period; and 8) leg edema.

Ethical considerations

The study objective, protocol and ethical considerations (1: participation in the present study is voluntary, 2: consent can be withdrawn at anytime, 3: equipment safety, 4: protection of privacy, and 5: use of data in report preparation and academic presentation) were explained to subjects orally and in writing. Informed consent was obtained from each patient in writing.

Study period and site

The present study was conducted for 15 months from June 2001. Since treatment plans and nursing care techniques could have affected changes in the thickness of the muscles measured, the study was conducted at one gastrointestinal surgery ward.

Measurements

Muscle tissue thickness was measured twice: 1) 5-7 days before the planned surgery date and 2) within two days of first getting out of bed and standing up after surgery.

Definitions

Muscle tissue thickness: The thickness of muscle tissue from fascia to bone as assessed by ultrasound.
Preservation of muscle tissue thickness: Muscle tissue thickness on the first day out of bed divided by preoperative muscle tissue thickness.
First day of mobilization: The first day when a patient got out of bed after surgery.

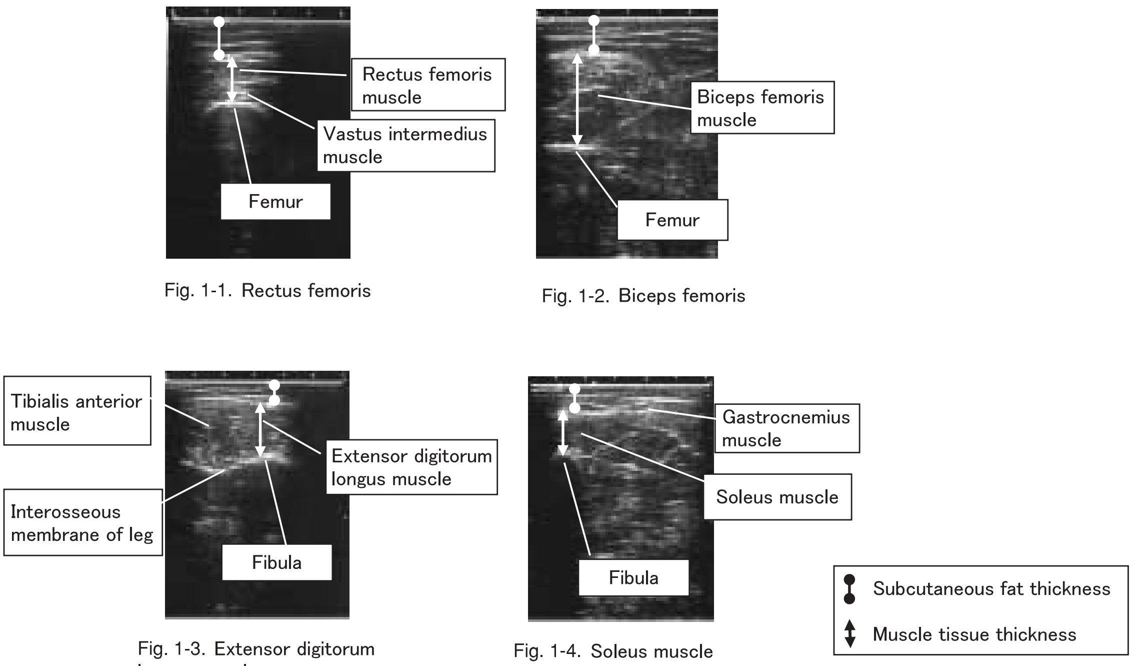

Fig. 1-1. Rectus femoris

Fig. 1-2. Biceps femoris

Fig. 1-3. Extensor digitorum longus muscle

Fig. 1-4. Soleus muscle

Fig.1. Ultrasound imaging of four test areas

Thickness of lower limb muscles

The thickness of each muscular compartment was measured using an ultrasound apparatus (RTfino : GE Healthcare) equipped with a 7.5 MHz probe, by measuring the distance from fascia to bone in terms of the length of a line drawn by a cursor (Figs. 1-1, 2, 3, 4). As far as the selection of muscle tissues was concerned, in order to clarify the effects of recumbency on leg muscle tissues, it was necessary to choose femoral and crural extensors and flexors with which the ultrasound machine could consistently capture the same image. Subsequently, the following four areas were selected : rectus femoris and vastus femoris which are femoral extensors (Fig. 1-1) (hereinafter referred to as rectus femoris) ; biceps femoris which is a femoral flexor (Fig. 1-2); extensor digitorum longus which is a crural extensor (Fig. 1-3), and soleus which is a crural flexor (Fig. 1-4). Muscle thickness was measured where the cross sectional area of the limb was greatest[12]. In the thigh this was half way between the greater trochanter and the lateral tibial condyle while in the calf this was one third of the way along a line from the lateral tibial condyle to the lateral malleolus.

Taking into account the physical condition of each patient on the first day of mobilization, measurements were taken in the supine position as follows: for rectus femoris and extensor digitorum longus, the hip and knee were in extension (Figs. 2-1, 3); for biceps femoris, the hip was in 110 degrees flexion, with the knee flexed (Fig. 2-2), and for soleus, the heel was placed on a box (Fig. 2-4).

Six scans were obtained at each area and thickness was measured by the same individual. The reliability of this ultrasound-based thickness measurement[13] has been documented.

Fig. 2-1. Rectus femoris muscle

Fig. 2-2. Biceps femoris muscle

Fig. 2-3. Extensor digitorum longus muscle

Fig. 2-4. Soleus muscle

Fig.2. Leg positions for four test areas

Data obtained from medical charts

The following data were gathered from the medical records: gender, age, diagnosis, surgical invasiveness (surgical procedure, amount of bleeding, and duration), length of recumbency (from the day of surgery to the first day out of bed), height, body weight (on admission), parenteral nutrition (administration methods, contents, and duration), diet (food type and preoperative food intake), and biochemical data (total serum protein and serum albumin).

Analysis

Average muscle tissue thickness was calculated for each of the four areas. Using the following formula, preservation of thickness for each muscular compartment was calculated.

Preservation of muscle tissue thickness: $S1 / S0 \times 100$ (%)

S0: Preoperative muscle tissue thickness

S1: Muscle tissue thickness on the first day of mobilization

Wilcoxon's signed rank sum test was used to compare preservation rates among the four areas before and after surgery. A Kruskal Wallis test was also used to compare preservation of muscle thickness among the four areas. Statistically significant differences were further analyzed with a Mann-Whitney (multiple comparisons) U test. Next, since the average length of recumbency was 4.4 ± 1.5 days, to calculate average preservation for the four areas, patients were divided into the following three groups with respect to length of recumbency,: ≦ 3 days, 4 or 5 days, and ≧ 6 days. Subsequently, Spearman's rank sum test was used to analyze the relationship between the preservation of muscle tissue thickness and length of recumbency. Statistical analyses were performed using SPSS version 9.0, with a significance level of $p < 0.05$.

Results

Background factors

Subjects comprised 19 men and nine women; average age was 67.3 ± 8.3 years. Operations were as follows: subtotal gastrectomy, n=14; total gastrectomy, n=5; colectomy, n=6; and proctectomy, n=3. Average intraoperative bleeding was 754 ± 812 g, and average duration of surgery was 5.4 ± 1.9 hours.

Of the 28 patients, five fasted before surgery: three with pyloric stenosis, one with large intestinal fistula, and one with ileus. Average preoperative food intake for the remaining 23 patients was 84.2 ± 19.6% of their usual intake. As far as parenteral nutrition was concerned, central parenteral nutrition was performed in 21 patients and peripheral parenteral nutrition in seven. Average preoperative total serum protein and serum albumin were 6.8 ± 0.5 and 4.0 ± 0.4 g/dl, respectively. Average length of recumbency was 4.4 ± 1.5 days. Breakdown of recumbency length was as follows: ≦ 2 days, n=2; 3 days, n=7; 4 days, n=6; 5 days, n=8; and ≧ 6 days, n=5.

Changes in the preservation of muscle tissue thickness for the four areas, and comparison among the four areas

When compared to before surgery, average muscle thickness on the first day of mobilization decreased by 0.25 cm for rectus femoris, 0.22 cm for biceps femoris, 0.12 cm for soleus, and 0.10 cm for extensor digitorum longus. Preservation of muscle thickness was as follows: rectus femoris, 88.0%; soleus, 93.3%; biceps femoris, 93.6%; and extensor digitorum longus, 94.9% (Table 1). Preservation of muscle thickness for rectus femoris was significantly lower than for the other three areas (Table 1).

Table 1. Comparison of preservation of muscle tissue thickness for four areas, and comparison among four areas

Preservation of muscle tissue thickness [a] on the first day of mobilization (%)			Comparison to preoperative value	Comparison among four areas		
Test area	Pts.	Mean±SD	Wilcoxon's signed rank sum test	Mann-Whitney (multiple comparison) U test		
Rectus femoris muscle	28	88.0±6.0	Z = −4.62, p < 0.001	U = 187 p < 0.0033 (Rectus femoris vs. Biceps femoris)	U = 145 p < 0.0033 (Rectus femoris vs. Extensor digitorum longus)	U = 237 p < 0.0167 (Rectus femoris vs. Soleus)
Biceps femoris muscle	28	93.6±4.4	Z = −4.13, p < 0.001			
Extensor digitorum Longus muscle	28	94.9±4.7	Z = −3.56, p < 0.001			
Soleus muscle	28	93.3±7.7	Z = −4.44, p < 0.001			

a) The preservation of muscle tissue thickness for four areas was calculated in relation to the preoperative value (100%).
Pts. : Number of patients

Table 2. Comparison of preservation of muscle tissue thickness for four areas at different lengths of recumbency

Length of recumbency	Pts.	Preservation of muscle tissue thickness [a] for each area (%)			
		Rectus femoris muscle	Biceps femoris muscle	Extensor digitorum longus muscle	Soleus muscle
≦ 3 days	9	91.6 ± 6.4	95.9 ± 4.4	96.2 ± 4.7	94.5 ± 8.3
4〜5 days	14	87.1 ± 5.7	92.5 ± 4.8	93.9 ± 5.2	95.7 ± 6.0
≧ 6 days	5	83.7 ± 1.2	92.3 ± 1.2	95.3 ± 2.4	84.6 ± 5.3

a) The preservation of muscle tissue thickness for four areas was calculated in relation to the preoperative value (100%).
Pts. : Number of patients, mean ± SD

Table 3. Relationship between preservation of muscle tissue thickness and length of recumbency

		Preservation of muscle tissue thickness for each area			
		Rectus femoris muscle	Biceps femoris muscle	Extensor digitorum longus muscle	Soleus muscle
Length of recumbency	rs	−0.437	−0.490	−0.095	−0.383
	p value	0.020	0.008	0.630	0.044

rs : rank correlation coefficient

Relationship between length of recumbency and muscle tissue thickness for the four areas

The preservation of muscle tissue thickness between before surgery and the first day of mobilization was investigated. Of the four areas, the greatest decrease was seen in rectus femoris for both ≦ 3 day recumbency (91.6%) and ≧ 6 day recumbency (83.7%). In addition, thickness of soleus with ≧ 6 day recumbency was 11.2% lower than that with 4 or 5 day recumbency (Table 2). Furthermore, a significant negative correlation existed for the relationship between preservation of muscle tissue thickness and length of recumbency for rectus femoris, biceps femoris, and soleus (Table 3).

Discussion

In a previous study, we reported that the total thickness of leg muscle tissue decreased after laparotomy[13], and since the present study revealed the area that is most affected by recumbency, the study results should prove useful in establishing a clinically useful region for assessing postoperative preservation and in designing an effective postoperative recovery program. While thickness of all compartments decreased significantly due to postoperative recumbency, this wasting was greatest for rectus femoris.

In one study on healthy volunteers who were asked to rest in bed for 20 days[14], the degree of wasting of the leg muscles was the greatest for rectus femoris, followed by gastrocnemius, tibialis anterior and semimembranosus, in this order. While there are differences in the length of recumbency and the muscles analyzed between their study and ours, the order of decrease was similar.

However, the degree of decrease for the four leg areas in the present study was more than twice that observed in this previous study. This was because the present study intervention involved not only recumbency, but also decomposition of body proteins due to surgical invasion. In a CT study of hemiplegic patients (1 month to 5 years after onset)[15], quadriceps femoris and crural flexor muscles were sensitive to usage and were likely to be affected by disuse atrophy on both affected and unaffected sides. The present study also confirmed a significant correlation between muscle tissue thickness and first day of mobilization, thus suggesting that the thickness of rectus femoris and soleus is likely to be affected by recumbency. Also, in a CT study that assessed the cross sectional area of the leg at 2 weeks after a stroke[16], the total cross sectional area of the thigh of the unaffected side was lower than that of the calf (79% vs. 86%), but this difference was not seen 4 and 8 weeks after the onset. As to the chronological changes in muscle thickness, the thickness of rectus femoris began to decrease soon after onset of recumbency, while that of soleus began to decrease more slowly. This suggests that inactivity such as recumbency has divergent effects on different leg muscles. In terms of clinical assessment, rectus femoris is the best of the four areas because the degree of postoperative atrophy is largest and the effects of postoperative recumbency appear early.

It takes three times as long for muscle tissues that have wasted due to disuse atrophy to regain thickness than to regain walking ability[16]. In the present study, when mobilization was delayed, preservation of femoral extensor muscle and the crural flexor muscle thickness decreased to below 85%. While early mobilization following surgery is desired, if walking is not possible, it is necessary to establish an exercise program to minimize wasting of the femoral extensor muscles and crural flexor muscles, e.g., raising the buttocks from the bed, bedside knee extension, and squatting.

In the present study, in order to standardize surgical techniques and postoperative patient management, patients were enrolled from a single ward, and subsequently only 28 patients participated. Before generalizing the study results, it will be necessary to study more patients undergoing other operations at multiple institutions. In addition, as the impact of surgery and recumbency was the largest on rectus femoris, in the future it will be necessary to investigate the validity of assessing recovery following laparotomy based on the thickness of this muscular compartment.

Conclusions

In patients undergoing moderately invasive surgery for either gastric or colon cancer, the thickness of four muscular compartments of the lower limb tissues was measured before and after surgery by ultrasound, in order to identify the area most affected by recumbency following laparotomy. Following laparotomy, the thickness of rectus femoris, biceps femoris, extensor digitorum longus, and soleus decreased significantly. Of the four compartments, this effect was greatest in rectus femoris ; hence, this area was most affected by recumbency. In addition of the longer the recumbency, the greater the degree of decrease in soleus thickness. Accordingly, when measuring the thickness of lower limb muscle tissue by ultrasound, rectus femoris is most suitable. The results of the present study suggest the need to design a recovery program focused on maintaining the thickness of muscle tissue in rectus femoris after laparotomy.

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