ASSESSMENT OF MUSCLE LAYER THICKNESS OF QUADRICEPS MUSCLE IN INTENSIVE CARE UNIT PATIENTS DURING A PERIOD OF NMES TREATMENT USING ULTRASONOGRAPHY - PRELIMINARY DATA

Gruther W.*, Zöch C.*, Crevenna R.*, Paternostro-Sluga T.*, Spiss C.**, Kraincuk P.**, Kainberger F.***, Peceny R.****, Quittan M.****

* Dept. of Physical Medicine and Rehabilitation, Vienna University Hospital, Austria

** Dept. of Anesthesiology and Intensive Care, Vienna University Hospital, Austria

*** Dept. of Radiology, Division of Osteology, Vienna University Hospital, Austria

**** Dept. of Physical Medicine and Rehabilitation, Kaiser Franz Josef Hospital, Austria

Abstract

Background: Intensive care unit patients (ICUP) show an enormous loss of muscle mass due to immobilization. Neuromuscular electrical stimulation (NMES) has been shown to be an effective method to enhance strength and endurance capacity of the skeletal muscles for patients who are not able to perform active exercise. This pilot study aimed to evaluate effects of NMES on mass of knee extensor muscles in ICUP.

Methods: Thirty-three ICUP (length of stay at ICU: at least 14 days) were enrolled in this randomized, controlled, double-blind pilot study. These patients were stratified into 2 groups based on their immobilization period on the ICU: acute patients (AP <7 days) and longtime patients (LP >14 days). Both cohorts were randomized in stimulation group (SG) and controls (CG) differing in terms of stimulation intensity (strong muscle contractions in SG, sensory input without muscle contractions in the CG). The electrical stimulation was applied via surface electrodes during a period of 4 weeks (session-time up to 60 min, 5 sessions/week). The NMES protocol consisted of biphasic rectangular impulses with a pulse width of 350 μs and a frequency of 50 Hz (on-/off= 8s/24s). Before and after the stimulation period, ultrasonography was performed to quantify muscle layer thickness of knee extensor muscles.

Results: In all AP a significant loss of muscle mass of > 36 % ($p<0.01$) could be observed. The stimulated LP showed a significant increase of muscle mass of 4.9 % ($p<0.05$) in contrast to the LP controls showing a slight decrease in muscle mass.

Conclusion: These findings indicate that NMES with a protocol as used in this small pilot study does not seem to be effective in preventing muscle atrophy in ICUP. Nevertheless NMES seems to enhance muscle mass in long time ICUP.

Introduction

Neuromuscular electrical stimulation (NMES) has been shown to be an effective method to enhance strength and endurance capacity of skeletal muscles for patients who are not able to perform active exercise [1, 2, 3].

Atrophy of skeletal muscles has been observed after space flight, bed rest and immobilization [4, 5]. Most intensive care unit patients (ICUP) show a prolonged catabolic state inducing loss of muscle mass. To our knowledge there are no comparable data about changes in muscle mass and morphology in intensive care patients during immobilization, yet.

To evaluate the physiological muscle morphology of human thigh and leg muscles, several equal imaging techniques as CT, MRI or ultrasound can be employed [6, 7].

This pilot study aimed to evaluate effects of NMES on knee extensor muscle mass (e.g. muscle layer thickness) using ultrasonography - and their time dependency - in ICUP.

Material and Methods

Study design

Prospective, randomized, controlled, double-blind, comparative pilot study of NMES or sham treatment.

Setting

This pilot study was conducted at the ICU as a cooperation of the Dept. of Physical Medicine and Rehabilitation with the Dept. of Anesthesiology and Intensive Care, and with the Dept. of Radiology / Osteology (all Vienna Medical University, General Hospital of Vienna). All procedures were approved by the University Ethics Committee, and informed consent was obtained from all patients.

Study population

Forty-six consecutive patients of an ICU (54±11 years, male/female: 28/5, for patients' characteristics see table 1) were enrolled in this pilot study. Thirty-three patients completed the study. Exclusion criteria were a stay at the ICU shorter than 14 days, age less than 19 years, a muscle layer thickness = MLT total > 25 cm, implanted stimulation devices (PM, ICD), neuromuscular disorders or myopathy, epilepsy, allergic reactions to the electrodes, peripheral edemas, severe ischemia of the lower extremities, obesity/BMI>30, dermatological diseases at the stimulation sites.

Based on their immobilization period on the ICU, patients were stratified 1) in an acute patient group (AP - time between their arrival at the ICU and the beginning of the NMES therapy had to be less than one week), and 2) in a longtime patient group (LP - time between their arrival at the ICU and the beginning of the NMES therapy had to be longer than 2 weeks). After this stratification (AP, LP), a balanced randomization in stimulation group (SG) and control group (CG) was performed using the sealed envelope method (4 blocks, 4 patients each, see table 1).

Group	AP-SG	AP-CG	LP-SG	LP-CG
Sex m/w	7/1	7/1	7/1	6/2
Age *	52 (±10)	48 (±12)	61 (±10)	64 (±8)
Multiple trauma	3	4	2	1
Pneumonia	0	1	1	2
Tumor	1	1	2	2
Transplant	2	1	2	1
Cardiovascular disease	2	2	1	2
Incomplete (Death/Transfer):	1/2	2/1	3	3/1

Table 1: baseline characteristics of ICUP, *Mean ± SD

Treatment

For the NMES stimulation Compex®-P-Sport devices (Medi-Konzept GmbH) were used. Details about the stimulation protocols are given in table 2.

NMES was applied via self-adhesive surface electrodes (2"x2" and 2"x4", Compex®®, Medi-Konzept GmbH) on both quadriceps muscles. The electrodes were placed bilaterally on the ventral aspect of the thigh, medial and lateral, 3 cm proximal of the upper border of the patella and 5 cm distal of the inguinal fold.

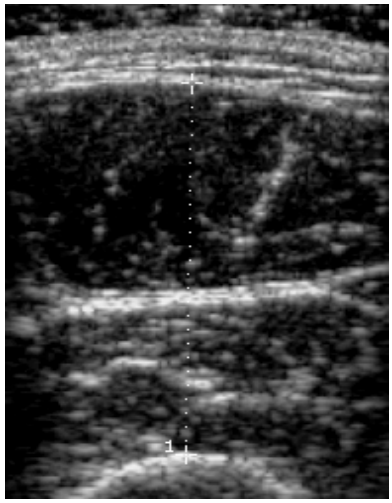
Duration of impulse	0.35 msec biphasic symmetric rectangular
Frequency of repetitive stimulation	50 Hz
Stimulus regime – on/off	8/24 sec
Duration per day	beginning with 30 min. increasing up to 60 min.
Intensity SG	strong tetanic contraction
Intensity CG	above sensory threshold without any palpable or visible muscle contraction

Table 2: Verum stimulation protocol NMES and sham stimulation protocol NoNMES

Patients received either verum treatment (resulting in a strong muscle contraction) or sham treatment (stimulation above sensory threshold, but without any palpable or visible muscle contraction) in identical manner. During a treatment period of 4 weeks, each patient received 5 NMES sessions a week.

Outcome measurement

To detect changes from baseline, muscle layer thickness of the quadriceps muscle was measured by high resolution real-time ultrasonography as described in other studies [4, 8]. All the ultrasound examinations were performed by a single operator with a portable ATL ultrasound system (HDI-1000), using a L7-4 transducer with a 5 cm linear array footprint (see picture 1).



Pic.1: transverse image from the anterior aspect of the thigh

Muscle layer thickness of quadriceps was assessed bilaterally 1) at the border between the lower and upper two thirds, and 2) in the middle of the distance between the anterior superior iliac spine and the upper pole of the patella, with the legs relaxed lying flat in extension. Muscle layer thickness mean (MLT) was calculated by mean of

the four measurements. The coefficient of variation for a single muscle layer thickness measurement is close to the obtained 3% by Bleakney [8]. MLT measurement used in the present study improves the coefficient to 0.25%.

Statistics

Data were analyzed using Statistical Package for Social Sciences (SPSS 12.0 for Windows). Descriptive statistics were calculated and Wilcoxon signed rank test was used to compare the distribution of two related variables. Group comparison was done with Mann-Whitney U-Test. Significant level was set at $p<0.05$.

Results

In AP MLT significantly decreased in SG ($p=0.012$) as well as in CG ($p<0.008$).

In LP MLT significantly increased with NMES ($p=0.036$) but remained unchanged in CG.

Group comparison between AP-SG and AP-CG did not show any statistical significance concerning MLT decrease. In contrast a significant difference in MLT ($p=0.014$) was detected comparing LP-SG and CG (see table 3 and figure1).

	Baseline	4 weeks	D%
MLT AP - SG	28.9 (±6.57)	18.3 (±3.2)	- 36.7 *
MLT AP - CG	32.9 (±9.71)	20.1 (±5.44)	- 38.9 **
MLT LP - SG	18.4 (±4.24)	19.3 (±3.79)	+ 4.9 *
MLT LP - CG	18.6 (±5.87)	18 (±5.76)	- 3.2
group comparison AP - SG/CG			1.4
group comparison LP - SG/CG			8.3 *

Table 3: MLT at baseline and after 4 weeks (mm, mean ± SD); D% = difference in %; *p<0.05; **p<0.01;

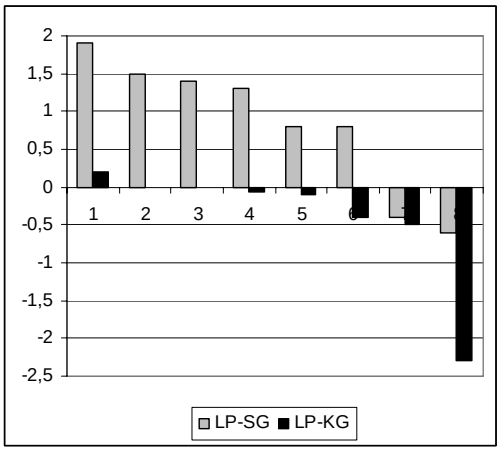


Figure 1. MLT (mm) difference diagram between baseline and 4 weeks in each patient of LP - SG/CG.

Discussion / Conclusion

Especially due to its easy practicability, it was decided to use high resolution real-time ultrasonography for this small pilot study in ICUP because it has been described to be a relatively simple and reproducible imaging [4,8].

Ultrasonography revealed a significant loss of muscle mass of >36% ($p<0.01$) in AP-SG and AP-CG. The LP-SG showed a significant increase of muscle mass of 4.9 % ($p<0.05$) in contrast to the LP-CG showing a slight decrease in muscle mass.

These findings indicate that NMES with a protocol as used in this small pilot study does not seem to be effective in preventing muscle atrophy in ICUP. Nevertheless NMES seems to enhances muscle mass in long time ICUP.

References

[1] Vinge OD et all: Effect of transcutaneous electric muscle stimulation on postoperative muscle mass and protein synthesis. H:S Hvidovre Hospital, kirurgisk gastroentrologisk og rontgendiagnostisk afdeling. 1998 Jan 12;160(3):283-6

[2] Quittan M, Sochor A, Wiesinger GF, Kollmitzer J, Sturm B, Pacher R, Mayr W. Strength improvement of knee extensor muscles in patients with chronic heart failure by neuromuscular electrical stimulation. Artif Organs 1999; 23:432-35 IF:0,919

[3] Nuhr M, Pette D, Berger R, Quittan M, Crevenna R, Huelsman MF, Wiesinger G, Moser P, Fialka-Moser V, Pacher R. Beneficial effects of chronic low-frequency stimulation of thigh muscles in patients with advanced chronic heart failure. Eur Heart J. 2004 Jan; 25(2): 136-43.

[4] Kawakami Y et all: Changes in muscle size and architecture following 20 days of bed rest. J Grav Physiol 2000; 7(3): 53-60

[5] Gibson JNA, Smith K, Rennie MJ: Prevention of disuse muscle atrophy by means of electrical stimulation: maintenance of protein synthesis. Lancet 1988; 1:767-70

[6] Dupont AC, Sauerbrei EE, Fenton PV, Shragge PC, Loeb GE, Richmond FJ: Real-time sonography to estimate muscle thickness: comparison with MRI and CT. J Clin Ultrasound. 2001 May;29(4):230-6.

[7] Walton JM, Roberts N, Whitehouse GH. Measurement of the quadriceps femoris muscle using magnetic resonance and ultrasound imaging. Br J Sports Med. 1997 Mar;31(1):59-64.

[8] Bleakney R, Maffuli N: Ultrasound changes to intramuscular architecture of the quadriceps following intramedullary nailing. J Sports Med Phys Fitness 2002; 42:120-5

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Author's Address

Dr. Wolfgang Gruther
Univ. Klinik für Phys. Med. und Rehab.
Währingerstraße 18-20
A-1090 Wien
Email: wolf1978@gmx.at