



Case report

Neuromuscular electrical stimulation is ineffective for treating quadriceps muscle wasting with ruptured aneurysm: A case report

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ABSTRACT

Introduction: Neuromuscular electrical stimulation (NMES) is a preventive intervention for muscle wasting in patients with aneurysms during the acute phase; however, its efficacy still remains unclear. In this case study, we report the effects of NMES on quadriceps muscle wasting for a patient with ruptured middle cerebral artery aneurysms during the acute phase.

Presentation of case: A 66-year-old woman was admitted because of a ruptured middle cerebral artery aneurysm resulting from intracerebral hematoma with subarachnoid hemorrhage. The following day, the patient started undergoing 60–120-min NMES treatment for both her quadriceps muscles, which was continued for 10 days in 2 weeks. Quadriceps muscle thickness as measured by ultrasonography was decreased in both sides (26% and 35% for the right and left sides, respectively). The compound muscle action potential (CMAP) amplitude in the peroneal nerve was also decreased in both sides (73% vs 76%).

Discussion: The lack of efficacy of NMES in preventing muscle wasting is the decreased CMAP amplitude in this patient, which showed the possibility of existence of critical illness polyneuropathy.

Conclusion: NMES had no effect on quadriceps muscle wasting in a patient with ruptured middle cerebral artery aneurysms who had decreased CMAP amplitude in the peroneal nerve during the acute phase. NMES is not effective for patients with peripheral nerve conduction abnormalities.

1. Introduction

The pathology of muscle wasting in critically ill patients includes critical illness polyneuropathy (CIP), critical illness myopathy (CIM), and combined CIP and CIM (CINM) [1]. Common electrophysiological changes within CIP and CIM include reduced compound motor action potential (CMAP) amplitude and normal to minimally reduced nerve conduction velocity [2]. Generally, recovery is faster from CIM than from CIP and CINM [3]; however, these differences are difficult to identify in clinical settings [4]. Hence, it may be more effective to apply neuromuscular electrical stimulation (NMES) in patients with CIM than CIP. Therefore, we hypothesized that patients who did not benefit from NMES may have peripheral nerve abnormalities.

NMES is an intervention for preventing muscle wasting in patients

in the acute phase [5–7]. Previous studies reported on the efficacy of NMES [5,6]. However, its benefit in the prevention of muscle wasting was inconclusive in a systematic review [7]. After the report, several studies were conducted to prove the efficacy of NMES in critically ill patients [8–10]. A study showed that the NMES is ineffective for muscle strength [8], and another study could not prove its positive effects on muscle wasting [9]. Recently, another study reported on the positive effects of NMES on muscle strength in patients with ICU-acquired weakness (ICU-AW) [10]. Further studies are needed to prove the efficacy of NMES in critically ill patients with muscle wasting [11].

We report herein the efficiency of NMES on quadriceps muscle wasting for a patient with ruptured middle cerebral artery aneurysm who suffered from intracerebral hematoma with subarachnoid hemorrhage during the acute phase.

Abbreviations: NMES, Neuromuscular electrical stimulation; CMAP, compound muscle action potential; CIP, critical illness polyneuropathy; CIM, critical illness myopathy; CINM, CIP and CIM; ICU-AW, ICU-acquired weakness; GCS, Glasgow coma scale; QMT, quadriceps muscle thickness; NCV, nerve conduction velocity; MRC sum score, Medical Research Council sum score; FSS-ICU, Functional Status Score for the ICU; EDB, extensor digitorum brevis; MCVs, motor conduction velocities; VI, vastus intermedius; RF, rectus femoris; CSD, cross sectional diameter

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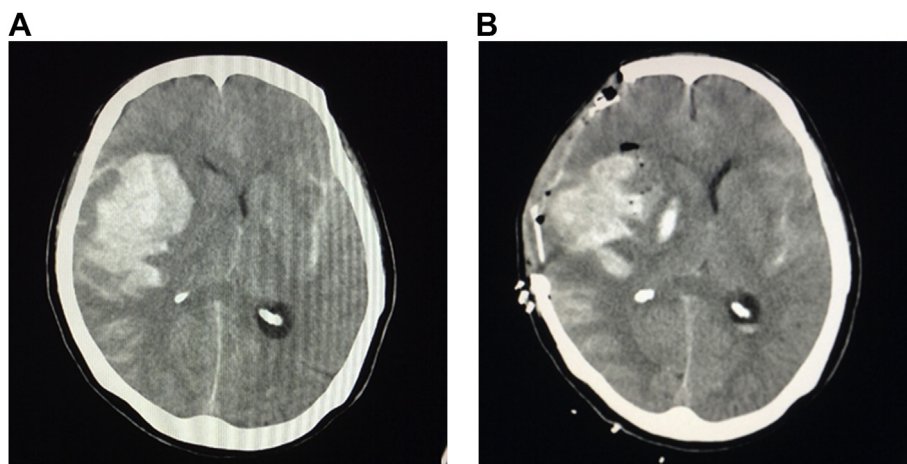


Fig. 1. CT images (Left: on admission, Right: after surgical treatment).

This work has been reported in line with the SCARE criteria [12].

2. Presentation of case

A 66-year-old woman with a history of hypertension was admitted due to sudden severe headache and deep comatose. The patient was diagnosed based on the results of radiographic imaging showing a ruptured middle cerebral artery aneurysm and intracerebral hematoma with subarachnoid hemorrhage (Hunt and Hess Grade: IV, Fig. 1a). The patient received a combination of interventions, including clip ligation simultaneous with hematoma evacuation and decompression surgery after admission on the same day (Fig. 1b).

The next day, she was still in a coma (Glasgow coma scale: GCS = 5). She was unable to move her arms or legs or follow instructions. She also showed decerebrate rigidity, but her right arm moved involuntarily.

The patient had severe muscle weakness and disability. However, both her common peroneal nerves conduction were normal, based on the values on initial examination. She was a candidate for NMES application, because she could not consciously move her limbs. NMES was applied to prevent quadriceps muscle wasting and muscle weakness. In addition, the patient did not use vasopressors and did not present with sepsis or edema, which are often found in NMES non-responders [13].

The outcome measure was bilateral quadriceps muscle thickness (QMT) measured with ultrasonography. Secondary outcome measures were motor nerve conduction velocity (NCV) and compound muscle action potential (CMAP) amplitude measured from the common peroneal nerve bilaterally; the Medical Research Council sum score (MRC sum score) [14] and Functional Status Score for the ICU (FSS-ICU) [15] were used to evaluate muscle strength and functional outcome, respectively. All the examinations were measured prior to intervention (next day from admission) and 14 days after the first measurement by the same physical therapist.

QMT was measured by a single examiner using a frozen B-mode ultrasound imaging system (LOGIQ P5; GE Healthcare Japan, Tokyo, Japan) and an 8-MHz transducer for the evaluation of lower-leg muscle mass. She was placed in the supine position with the hips and knees extended and the transducer was positioned midway between the anterior-superior iliac spine and the proximal end of the patella [16,17].

Motor nerve conduction was measured using NeuroPack MEB-2200 (Nihon Kohden Co., Tokyo, Japan) from the common peroneal nerve for evaluation of lower-leg peripheral motor nerve function. Surface recording electrodes were placed over the belly and tendon of the extensor digitorum brevis (EDB). The motor nerve conduction examination included evaluations of motor conduction velocities (MCVs) and

CMAP amplitudes (the negative peak). MCVs were diagnosed as abnormal when the value was less than 40 m/sec [18]. CMAP amplitude was diagnosed as ICU-AW when the value was reduced by > 25% of the initial value or less than 0.43 mV [19,20].

The total MRC sum score ranges from 0 (total paralysis) to 60 (normal strength). The score is the sum of the MRC score of 6 muscles (3 at the upper and 3 at the lower limbs) bilaterally; each muscle is graded from 0 to 5. The following muscles were examined: deltoid, biceps, wrist extensor, ileopsoas, quadriceps femoris, and tibialis anterior. ICU-AW was diagnosed when the sum score was less than 48 [21].

FSS-ICU is a valid and reliable method for measuring limitations in critically ill patients [15] and includes 5 functional tasks (rolling, transfer from spine to sit, sitting at the edge of bed, transfer from sit to stand, and walking). Each task is evaluated using an 8-point ordinal scale ranging from 0 (not able to perform) to 7 (complete independence). The total FSS-ICU score ranges from 0 to 35.

The patient's initial QMT was 2.76 and 2.69 cm for the right and left, respectively. The initial MRC sum score was 0 out of 60 and the initial FSS-ICU score was 0 out of 35, because the patient was fully unconscious: Glasgow coma scale = 5). The MCVs in common peroneal nerve was 51.3 and 53.9 m/sec and CMAP amplitude was 4.30 and 1.97 mV for the right and left sides, respectively. These results showed that the patient should be diagnosed with nerve conduction abnormalities or ICU-AW.

The ethics committee of our university approved the treatment protocol, and informed consent was obtained from the patient's family member, because she was not able to provide informed consent due to her condition.

NEMS was applied bilaterally to the quadriceps muscle 5 days a week from the day after hospitalization until day 15. The skin was carefully shaved before NMES application. Rectangular electrodes (90 × 50 mm) were positioned on the quadriceps muscles (Fig. 2). An electrical stimulator (ESPURGE, Ito Co., Ltd, Tokyo, Japan) delivered biphasic, symmetric impulses of 80 Hz, 300- μ s pulse duration, 5 sec on and 5 sec off, at intensities able to cause visible contractions and maximal intensity tolerable for the patient. The session lasted for 60–120 min daily.

She was diagnosed with meningitis on day 7. The C-reactive protein levels measured as inflammatory markers were continuously positive; 0.71 mg/dL on admission, 4.47 mg/dL on day 4, 2.32 mg/dL on day 6, and 2.97 mg/dL on day 9 and her daily temperature did not decrease to less than 37.5 °C during the intervention period (her average temperature was 38.2 °C). The patient also had prolonged unconsciousness during the intervention.

During the NMES intervention period, other rehabilitation

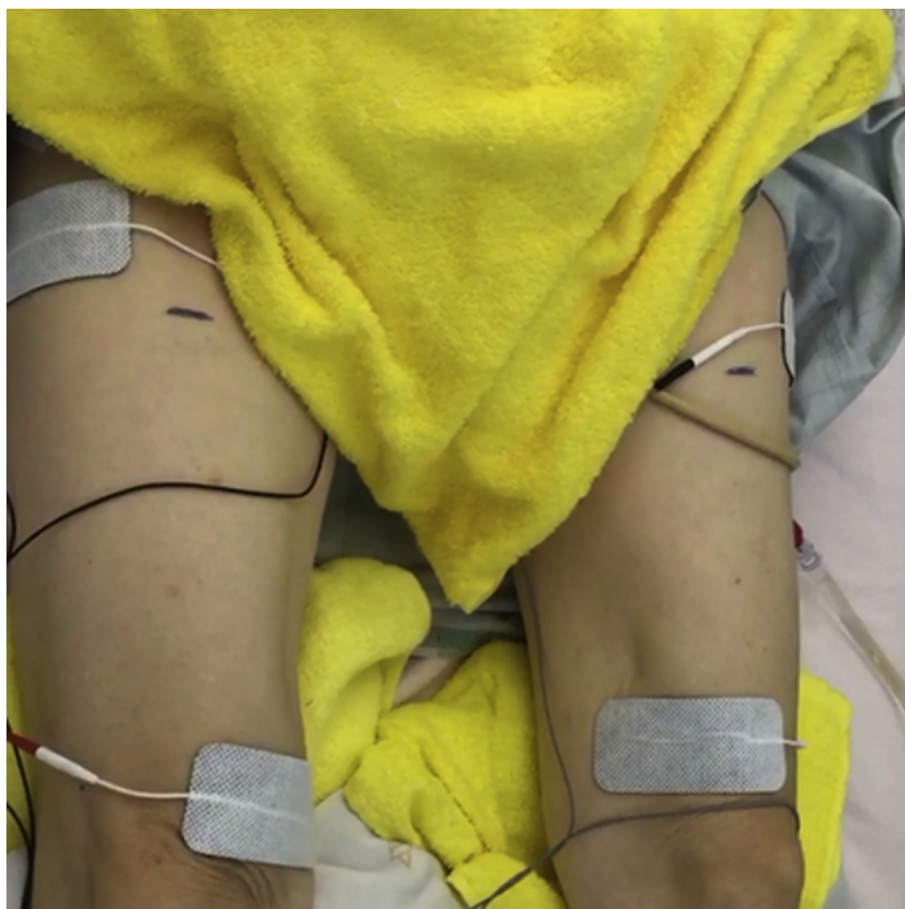


Fig. 2. Rectangular electrode positions for both sides of the quadriceps muscle.

approaches were also performed by a physical therapist 5 times a week. We performed only passive manual mobilization because of severe, prolonged unconsciousness [22]. On day 13, the patient slightly regained consciousness, but was still hardly active and could not transfer to a wheelchair.

Outcome measures were assessed on day 15. QMT in both sides was decreased, particularly in the left side (Table 1). The MCVs of common peroneal nerve in both sides slightly decreased, but within normal limits (> 40 m/sec). The CMAP amplitude decreased in both sides (-73% for right, -76% for left). These electrophysiological changes (not the decrease in MCVs, but $> 25\%$ reduction in CMAP amplitude) showed that the patient should be diagnosed with ICU-AW. MRC sum scores increased on her right shoulder and elbow, which she could move, but could not resist gravity. FSS-ICU was increased, but the patient was almost unable to perform mobilization even when her consciousness improved (GCS = 13).

Three months from admission, the patient was fully dependent (modified Rankin Scale; 5), with low MRC sum score (23 out of 60) and low FSS-ICU score (8 out of 35).

3. Discussion

This case report describes the efficacy of NMES on muscle wasting in a patient with ruptured middle cerebral artery aneurysms during the acute phase. Our clinical results indicated that QMT was decreased in acute phases after applying NMES, even if the patient's CMAP amplitude was decreased. This assumption may demonstrate the pathophysiology of NMES invalidation for critically ill patients.

There have been reports that muscle wasting, particularly in lower limbs, is seen in critically ill patients [16,23] or those with neurological disorders, such as stroke [24]. Parry et al. reported a 30% reduction in vastus intermedius (VI) thickness, rectus femoris (RF) thickness, and

Table 1

Outcome measures of quadriceps muscle thickness, motor nerve conduction, MRC sum score, and FSS-ICU score.

Outcome measure	On admission	After 2 weeks	Differences (2 weeks- admission)	% differences (%)
Right quadriceps muscle thickness (cm)	2.76	2.04	-0.72	-26
Left quadriceps muscle thickness (cm)	2.69	1.76	-0.93	-35
MRC sum score (maximal = 60)	0	4	4	7
FSS-ICU (maximal = 35)	0	2	2	6
Right peroneal MCV (m/s)	51.3	50.7	-0.6	1
Left peroneal MCV (m/s)	53.9	52.3	-1.6	3
Right EDB peroneal CMAP amplitude (mV)	4.30	1.15	-3.15	-73
Left EDB peroneal CMAP amplitude (mV)	1.97	0.47	-1.50	-76

MRC: Medical Research Council, FSS-ICU: Functional status score for ICU, EDB: extensor digitorum brevis, CMAP; compound muscle action potential, MCA: motor nerve conduction velocity.

cross-sectional area within 10 days of admission in critically ill patients [16]. Other studies also reported that the RF cross-sectional area was reduced by 17.7% at day 10 following admission in critically ill patients [23]. In acute stroke patients, it was reported that the reduction of QMT was 20.8% and 15.3% in the paretic and non-paretic sides, respectively [24]. NMES has been applied in clinical studies for muscular atrophy [5–10]. Gerovasili et al. reported the efficiency of NMES on muscle thickness in critically ill patients [6]. They showed the cross sectional diameter (CSD) of the RF decreased 8% in the EMS group but decreased 13.9% in the control group, VI decreased 12.5% in the EMS group but decreased 21.5% in the control group [6]. In the results from the acute stroke patients, QMT of the paretic side was decreased by 12.4% in the EMS group, but by 29.5% in the control group, and QMT of the non-paretic side was decreased by 5.5% in the EMS group, but by 22% in the control group [25]. However, the QMT in our patient decreased by 26% and 35% in the right and left sides, respectively. This reduction was greater than the previous results, in which NMES was applied and the muscle reduction was equal to that in control subjects [7]. We concluded that one of the reasons for the lack of efficacy of NMES in preventing muscle wasting is the decreased CMAP amplitude in this patient, which showed the possibility of existence of CIP or CIP/CIM. In general, the prognoses of patients with CIP or CIP/CIM are not better than patients with CIM [3]. Thus, this may be the reason for invalid NMES results in this patient.

We assumed that other pathological changes may have occurred in this patient. It was reported that stroke patients often have transsynaptic degeneration or inactivity in their peripheral nerves [26–28]. As a result, the CMAP amplitude or the SNAP amplitude is decreased in patients with stroke [29]. In this case, there was a possibility that the same changes occurred. Thus, the patient had severe decreased CMAP amplitude bilaterally, and her MRC or FSS-ICU scores were also low.

4. Conclusion

Considering the outcome seen in this case, we thought NMES is not effective for preventing muscle wasting and disability. The efficacy of NMES for preventing muscle wasting in acute patients depends on whether nerve conduction abnormalities exist.

Consent

Written informed consent was obtained from husband of the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Ethical approval

The ethics committee of Konan Women's University.

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Author contributions

Dr Nozoe help in conceptualizing and designing the study, analyzing the data, writing the manuscript and procuring funds. Drs Nozoe and Ms Kamo helped in the data collection. Drs Nozoe, Shimada, and Mase helped in the project management.

Conflicts of interest

None.

Research registration unique identifying number

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Guarantor

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amsu.2018.09.011>.

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