REVIEW ARTICLE

Clinical safety of early rehabilitation using electrical muscle stimulation for patients with intracranial hypertension.

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Abbreviations: ICP, intracranial pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; SpO2, arterial blood oxygen saturation.

Abstract
The benefits of early rehabilitation in critically ill patients in the intensive care unit (ICU) have been reported in recent literature. However, there are few reports concerning the safety and the risk of early rehabilitation in ICU patients with intracranial hypertension due to stroke or traumatic brain injury. Immobilized patients with intracranial hypertension cannot attempt to voluntarily move their extremities and body, therefore passive range of motion exercise tends to play a major role in early rehabilitation in the ICU, and it leads to disuse muscle atrophy in a short period of time. Our institution introduced belt electrode-skeletal muscle electrical stimulation (B-SES), which can cause more effective muscle contraction than conventional electrical muscle stimulation (EMS) to prevent disuse muscle atrophy in patients with intracranial hypertension. Although there is currently not enough data available to determine whether B-SES is safe for patients with intracranial hypertension, we applied B-SES to patients who underwent neurosurgical procedures for managing increased intracranial pressure (ICP) in the ICU. This trial revealed that ICP as well as the other vital signs in all patients did not worsen during the B-SES procedure. The purpose of this article is to discuss the safety, the efficacy, the current problems, and the future of B-SES for patients with intracranial hypertension.

Keywords: electrical muscle stimulation, B-SES, early rehabilitation, intracranial hypertension, intensive care unit

1. Introduction

Early rehabilitation can improve activities of daily living (ADL), exercise function, length of hospital stay, and mechanical ventilation (1, 2). However, current evidence is limited as to whether similar benefits of early mobilization apply to patients who undergo neurosurgical procedures for managing increased intracranial pressure (ICP). The expert consensus and recommendations on safety criteria partially recommend active mobilization of mechanically ventilated ICU patients with ICP monitoring without active management of intracranial hypertension (3). Stroke or traumatic brain injury (TBI) patients with intracranial hypertension in an ICU setting cannot attempt to voluntarily move their extremities due to consciousness disturbances or the use of sedatives and analgesic drugs. This can lead to physical deterioration and disuse muscle atrophy, especially in the lower limbs in a short period of time (4). In general, range of motion (ROM) exercise without muscle contraction plays a major role in the early rehabilitation of immobilized patients in an ICU setting. ROM exercise can help patient's joints flexible but cannot effectively prevent their muscle volume loss. Previous studies reported that percutaneous electrical muscle stimulation (EMS) could be an effective method for rehabilitation to resolve the problems for critically ill patients (1, 5-8). However, to the best of our knowledge, no study has examined whether EMS is safe enough to be administered to patients with increased ICP. We applied the belt electrode-skeletal muscle electrical stimulation (B-SES), that is a belt type EMS that induces the contraction of multiple muscles between the belts, and assessed the clinical safety of B-SES for patients with intracranial hypertension by evaluating ICP during the intervention.

The purpose of this article is to consider the benefits of EMS as an alternative treatment option for neurosurgical patients with intracranial hypertension.

2. What is B-SES?

A conventional EMS is the pad type, which induces muscle contractions between electrode pads on the skin. B-SES (AUTO Tens PRO Rehabili Unit; Homer Ion CO., LTD., Tokyo, Japan) uses belt type electrodes, which are wrapped around the waist, both knees, and both ankles to contract all lower limb skeletal muscles simultaneously, and induces repeated contractions of wide and multiple muscles between the belts. It adopts the exponentially climbing wave form, which can produce greater muscle strength with less pain (9). B-SES, which is a newer EMS method, makes it possible for immobilized patients on bedrest to exercise with muscle contractions. This

unit has been shown to be beneficial for patients with acute heart failure (10), orthopedic disease restricted weight bearing (11), and hemodialysis (12), as well as immobilized ICU patients under sedation without associated adverse events.

3. Our management of B-SES.

We introduced B-SES to immobilized neurosurgical patients in the ICU of Tokyo Bay Urayasu Ichikawa Medical Center (Urayasu, Chiba, Japan) in December 2014. B-SES is administered to patients who are considered hemodynamically and neurosurgically stable by the treating neurosurgeon. Patients were excluded if they are predicted to have less possibility to start walking training in the future due to severe damage of the brain, poor general condition, and disuse syndrome before hospitalization.

B-SES is applied to patients on the bed once a day for 20 minutes with silicon-rubber electrode belts wrapped around the distal parts of their bilateral thighs and ankles starting on day 2 after ICU admission (Figure 1). We selected LEG DISUSE MODE, which can produce strong co-contractions in the muscle groups of the lower extremities at a frequency of 20 Hz with a duty cycle with stimulation for 5 seconds and a pause for 2 seconds. A physical therapist determined the output level based on visible muscle contraction of the triceps surae muscle in each patient. If visual inspection is unclear, contraction can be confirmed by palpation of the muscles. The effective intensity was between 20V and 50V.

Figure 1. Belt electrode-skeletal muscle electrical stimulation (B-SES) administered in the intensive care unit. The belt electrodes were wrapped around the distal parts of the bilateral thighs and ankles.

4. Measurement of ICP during B-SES.

A total of 4,915 patients were admitted to the ICU at our institution from December 2014 to April 2020. This included 901 neurosurgical patients, 479 (53.2%) of which were diagnosed with stroke and 101 (11.2%) with TBI. Of those, 35 consecutive patients who underwent emergency neurosurgical procedures for managing increased ICP were evaluated for their ICP and other vital signs during administration of B-SES. This group of 35 patients included 19 men and 16 women, ranging in age from 20 to 85 years old, with a mean of 58.6 years old. Of those, 28 (80.0%) were diagnosed with stroke and 7 (20.0%) with TBI. All patients had an ICP monitoring device placement and ICP was under control within normal range (< 20 mmHg) after neurosurgical procedures.

ICP was measured through either an ICP sensor (CODMAN MICROSENSEOR ICP Transducer) or external ventricular drainage (EVD) from the beginning to the end of the B-SES sessions. Other vital signs, including heart rate, blood pressure, and pulse oximetry findings, were also recorded during administration. Our results demonstrated that EMS intervention by using B-SES was completed without significant change in ICP in all patients and no significant changes in blood pressure, heart rate, and arterial blood oxygen saturation were observed during the sessions.

5. Case Description

A 55-year-old man with a history of liver cirrhosis was found lying unconscious on the floor in his room with bleeding from his right ear and was referred to our hospital. On arrival to the hospital, his Glasgow Coma Scale (GCS) score was 5 (E1V1M3) without anisocoria. A cranial CT scan showed a left acute subdural hematoma (ASDH) and severe brain swelling with uncal herniation (Figure 2). Immediately after the CT scan, the diameter of his left pupil enlarged from 3 mm to 6 mm. He underwent an emergency evacuation of the left ASDH with a decompressive craniectomy and placement of an ICP sensor. The left mydriasis was reversed after surgery and he was transferred to the ICU. He began B-SES on day 2 after admission. His ICP was measured through an ICP sensor and it kept at 15-18 mmHg without significant change during the B-SES intervention (Figure 3). There were no significant changes in blood pressure, heart rate, and arterial blood oxygen saturation.

(A) (B)

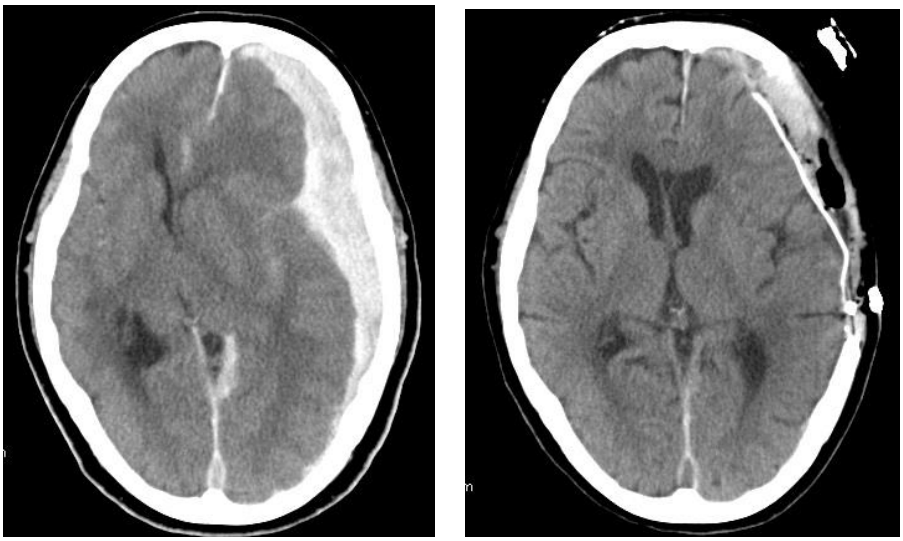

Figure 2. (A) Initial axial non contrasted brain computed tomography scan on admission showing a left subdural hematoma with a midline shift to the right side. (B) Postoperative axial brain computed tomography scan showing a decompressed left frontotemporal craniectomy and complete resection of the hematoma.

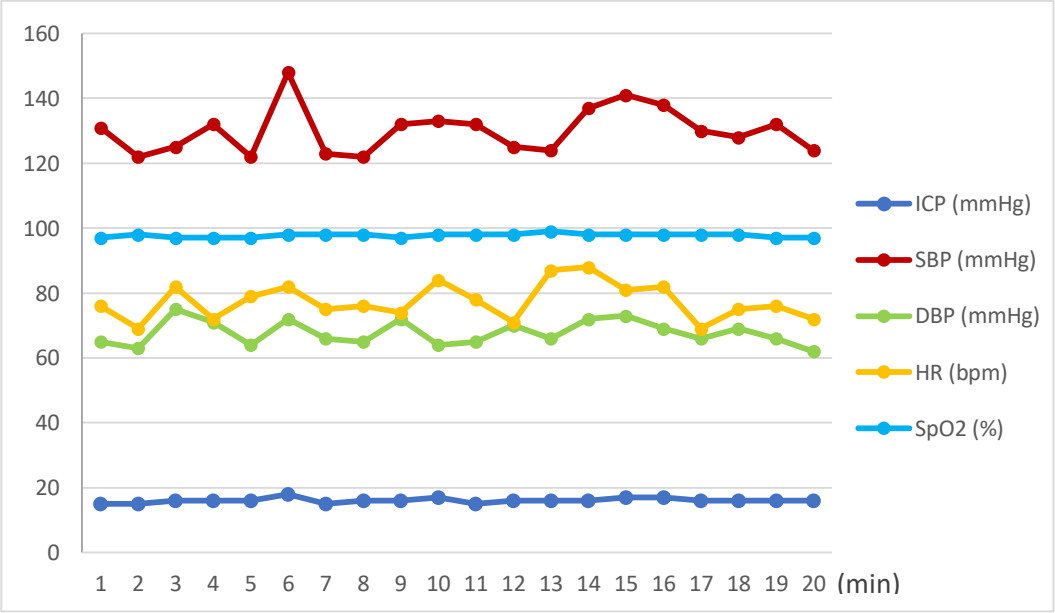

Figure 3. Intracranial pressure (ICP) and other vital signs measured in the ICU starting on day 2 of admission. ICP obtained by an ICP sensor was kept at 15-18 mmHg without significant change during the B-SES intervention.

6. Discussion

Early rehabilitation in ICU patients leads to an improved return to independent functional status at hospital discharge and shorter duration of delirium (1). Japanese guidelines for the management of stroke recommend early rehabilitation for the prevention of disuse syndrome (13). While there are many reports on the beneficial effects of early rehabilitation for critically ill patients in the ICU, some studies have introduced EMS to such patients during the early phase of intensive care. Karatzanos et al. evaluated the effects of EMS by using the Medical Research Council (MRC) score to clinically assess muscle strength in critically ill patients. The overall MRC score was significantly higher in critically ill patients assigned to the EMS group than in the control group (7). Another study reported that ICU patients who underwent EMS for 4 weeks had increased muscle layer thickness of the quadriceps femoris muscle measured by ultrasonography than the control patients (6). Hirose et al. examined the preventive effects of EMS against disuse atrophy of the lower limbs in comatose patients after stroke or TBI in the ICU. There was a significant difference in the percent change in cross-sectional area of the lower limb measured by a CT scanner between the EMS group patients and control patients. They concluded EMS is effective in the prevention of disuse muscle atrophy in patients with consciousness disorders and can be used as an alternative form of exercise (8). These reports suggest that EMS can be applied to immobilized patients effectively as a new training method for early rehabilitation in the ICU.

Few studies concerning the safety and the risk of early rehabilitation for neurosurgical patients with intracranial hypertension have been reported. Invasive neuromonitoring devices and drains, including EVD and lumbar cerebrospinal fluid (CSF) drainage, placed in ICP patients caused delayed mobilization due to fear of catheter dislodgement, raised ICP, and accidental over drainage of CSF during mobilization. EMS is a form of exercise that does not require active participation and volitional effort of the patient. The risk of device dislodgement and inappropriate CSF drainage is estimated to be low during EMS sessions. Thus, EMS may become a practical method of early rehabilitation for patients undergoing neurosurgical procedures. However, there is an important question of whether EMS has significant adverse effects on increased ICP. To date, there has been little research conducted on this topic. Our results may support that EMS is safe for ICP controlled neurosurgical patients.

Through using B-SES for more than five years in our institution, we found some unique characteristics of the unit.

Because B-SES uses percutaneous electrodes, it is noninvasive and easy-to-use, it does not have to be administered by physicians or trained physical therapists, but can be handled by nursing staff who have just learned how to use the device. For that reason, even small-scaled hospitals that have no physical therapists or institutions that are understaffed can actively introduce the unit. However, there is a possibility that motivation of physical therapists towards frequent use of B-SES could be low due to usability without any complicated physical technique for them. There are also some limitations associated with B-SES. It is difficult for patients with excessive obesity to use B-SES due to the size limitation of the electrode belts. To wrap the belts around lower limb or waist of obese patients would be laborious and time consuming, even if the electrode belts can be fitted for them. B-SES is contraindicated in patients with implanted pacemakers and B-SES should not be used for patients who are known or suspected to have a viral infection, like herpes zoster, influenza, norovirus, or recent COVID-19, because direct contact between the belts and patients has a potential risk of spreading the viruses to other patients. Additionally, B-SES should not be applied to patients with infections that stem from multidrug-resistant bacteria, like MRSA, for the same potential risk.

While many reports have indicated that EMS prevents muscle atrophy, some studies showed the metabolic effects of EMS. For example, Miyamoto et al. reported that EMS training attenuates postprandial hyperglycemia in type 2 diabetes patients (14). Furthermore, numerous studies have shown that EMS has an antithrombic effect on venous thromboembolic disease (VTE) prophylaxis which is attributed to the acceleration of venous blood flow in the lower extremities as a consequence of muscle contractions causing compression of the veins (15). Thus, there is a possibility that EMS has some functional effects which can be induced by the same mechanism of usual exercise. Recent research indicates that cerebral neuronal activity and metabolism drive an increase in cerebral blood flow (CBF) during mild to moderate exercise (16). These findings suggest that EMS training can be expected to elicit brain activation and increase CBF of neurosurgical patients with stoke and TBI.

The safety of EMS for neurosurgical patients with intracranial hypertension has not been established. It is impossible to draw reliable conclusions in terms of the effect of EMS on functional outcomes of the patients due to the lack of enough studies. Therefore, large scale randomized controlled trials are required in future studies to further understand EMS characteristics and to optimize the effect in

patients with intracranial hypertension.

5. Conclusion

Early rehabilitation with B-SES may be safe and worth introducing to neurosurgical patients with intracranial hypertension in the ICU.

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6. References

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