Electrical treatment of coma via the median nerve

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Summary

The median nerve is a portal to interact with the injured comatose brain. Peripheral nerve electrical stimulation has a central nervous system effect. Two to three weeks of right median nerve stimulation (RMNS) can hasten awakening from deep coma by increasing the dopamine levels. Three cases of electrically treated GCS-4 teenagers with acute diffuse brain injuries from motor vehicle crashes are presented by video. Pilot studies of RMNS for acute post-traumatic coma states have been done over the last ten years at East Carolina University and the University of Virginia. The neurophysiological effects of RMNS have been well documented at several neurosurgical centers in Japan using neuroimaging and spinal fluid assays. RMNS is a safe, inexpensive, non-invasive therapy for neuroresuscitation of coma patients. When employed early in the coma, the time in the ICU may be shortened and the quality of the final outcome may be enhanced.

Keywords: Coma; median nerve; electrical stimulation.

Introduction

The median nerve serves as a peripheral gateway to the central nervous system. The sensory distribution of the hand exhibits disproportionately large cortical representation [23, 28]. Within the brainstem, the ascending reticular activating system (ARAS) maintains wakefulness. The spinoreticular component of the median nerve synapses with neurons of the ARAS. Recovery from coma is driven by the electrically induced elevation of dopamine [14, 19, 26]. The right median nerve was chosen as a portal to stimulate the brainstem and cerebrum because increased alertness and better speech have been observed after RMNS [5, 25]. Broca’s motor/speech planning area in the left frontotemporal region has been shown in positron emission tomography (PET) to become more active when a subject moves, or even contemplates moving his/her hand [18]. This process is mimicked in RMNS [25].

My interest in stimulation began 30 years ago with a study involving a paraplegic individual at University of Virginia (UVa) in Charlottesville, Virginia. Radio-linked, implanted electrodes strengthened muscles and produced crude ambulation [2]. From 1987 to 1989 individuals with quadriplegia were helped to use their forearm muscles through voice-activated electrical stimulation. This technique resulted in semi-voluntary hand opening and closing at the Department of Biomedical Engineering at Duke University in Durham, North Carolina [3, 7]. Significant improvement was noted in distal motor abilities in response to electrical stimulation [1, 9]. Proximal voluntary and contralateral arm increases in performance were also noted during strength testing [3].

Similar computerized electrical stimulation was applied to individuals with severe mental/motor delays at Caswell Center in Kinston, North Carolina, in hopes of improving function and awareness [10]. Progressive augmentation of mental awareness was noted. The observed cross-over effect in the quadriplegic population, along with the central arousal of the mentally challenged population, led to the postulation that stimulation of the median nerve causes significant central nervous system activation [5, 11–14].

Materials and methods

The electrical stimulators at the University of Virginia project and East Carolina University projects were Empl battery-powered units. They supplied trains of asymmetric biphasic pulses at an amplitude of 15–20 mA with a pulse width of 300 microseconds at 40 Hz for 20 sec/min. The treatment was done for 8–12 hours daily and 8 hours per day for 2–3 weeks.

The treatment usually started 1–2 weeks after the closed head injury with Glasgow Coma Scale (GCS) [16, 24] less than 8. The trains of pulses were delivered to the volar aspect of the right distal forearm
over the median nerve via lubricated surface rubber electrodes measuring 2.5 by 2.5 centimeters. The pair of electrodes were embedded 2 cm apart in the midline of plastic cuffs from Carolina Ortho Prosthetics, Greenville, North Carolina.

For children and small adults, a setting of up to 15 milliamps is recommended and also for those adults with agitation at the 20 milliamp setting. For safety purposes, a plastic cap or clear tape should be applied over the external power dial on the electrical stimulator to prevent inadvertent over stimulation [6].

The right median nerve motor stimulation was approximately 1.5 times the motor threshold. This usually produced strong right thumb abduction and flexion of the index and middle fingers plus some wrist flexion. Temporary mild elevation of the vital signs is not unusual, but intracranial pressures usually remain stable.

In the first few days of treatment, mirror movements of the unstimulated left hand may occur. This dynamic cross-over effect heralds reactivation of the cerebral hemispheres through the corpus callosum in the electrically stimulated comatose patient. Usually the first simple command that the patient will respond to after one or two weeks of RMNS is a sluggish opposition of the right thumb and index finger.

This purposeful hand response while the brain injury patient still appears to be semi-comatose, demonstrates that the 5 million electrical pulses delivered to the nervous system in the first ten days of treatment have been copied and stored in the hard drive of the brain.

to the right median nerve. Within 1 week of stimulation, she exhibited semi-purposeful movement of her right arm and leg and scored 7 on the GCS. After a total of 2 weeks of stimulation, she was out of coma. This increase of 6 points was consistent with the UVa pilot project observation [4]. One month after the injury, CI followed simple commands. At 2 months post-injury CI could walk with assistance and read aloud. Two years later CI talked and walked well. She resumed dancing and driving. She graduated from college with a "B" average and has been working as a recreation director for two years.

In March of 2000, a 12 year old boy (KF) was struck by a van and had severe brain, intra-abdominal, and multiple extremity fractures including compound fractures of the pelvis. On his initial CT scan there was left frontal contusion, a small amount of subarachnoid hemorrhage in the interpeduncular cistern and a non-depressed skull fracture of the left parietal bone. There was also a fracture of the left temporal bone. On the follow-up scan two days later, there were several contusions (right frontal and left temporal), increased edema with marked effacement of the cortical sulci, and intraventricular hemorrhage. On the scan one week post-injury there was diffuse brain swelling and multiple hemorrhagic sheering injuries and hemorrhagic contusions of the left frontal lobe extending into the temporal lobe. KF underwent several abdominal and orthopaedic operations. He remained comatose with elevated intracranial pressures (over 70 mm Hg) in spite of two courses of barbiturate therapy. Pupils remained unequal. Survival was very questionable. Survival was very questionable. Surface electrical stimulation in the 15 milliamps range to the left median nerve was commenced two weeks post injury. The right forearm was in a cast. After two weeks of daily stimulation, he began to emerge from the coma. He progressively improved and regained his ability to speak. He could use his hands, in spite of a right hemiparesis he could use both hands. Two months post-injury, he was transferred to a rehabilitation center. Electrical stimulation was resumed, but switched to the right median nerve to help reduce the right hemiparesis. He continued to improve and was discharged home six weeks later. He started home schooling and made good grades. Last year he had a "B" average in junior high school and was able to resume some athletic activities.

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3. AT, a 14 year old female, was involved in a motor vehicle collision and sustained a severe closed head injury in 1995. She had a hemothorax and a pulmonary...
contusion. Her right mandibular condyle penetrated the base of her skull through the temporal bone into the middle cranial fossa. CT scan showed haemorrhagic foci in the left cerebral hemisphere. She exhibited alternating decerebrate and decorticate posturing and received a GCS of 4. Within the first week of stimulation she began gripping spontaneously. After 1 week of stimulation her GCS was 6. After 2 weeks of stimulation she began to open her eyes spontaneously and received a GCS of 8. At 2 months post-injury she was eating well and speaking. Within 5 months she was playing volleyball and doing well in school. She recently graduated from college with a "B" average.

Discussion

In the textbook by Wilkins and Rengachary, Neurosurgery, 1996, there is a chapter written by Marshall and Marshall on "outcome prediction in severe head injury" [17]. There were 49 GCS-4 survivors. Seven had a Good outcome (14%), 9 had Moderate Disability (18%), for a total of 32% favorable outcome.

There were 12 GCS-4 survivors treated with RMNS at ECU. They were followed for at least one year. A satisfactory result (Good in 4 patients and Moderate recovery in 3) was reached by one year in 58% of the GCS-4 patients treated with right median nerve electrical stimulation [25].

Through maintenance of existing neuronal circuitry, earlier awakening from coma may lead to a higher final level of function. Increased cerebral activity, as observed in RMNS, may also facilitate synaptogenesis in damaged cerebral cortex [8, 21]. The clinical observations indicate that RMNS has a beneficial effect on the resumption of language capabilities, possibly through stimulation of Broca's motor speech area [22, 25].

The patient may obtain a better outcome as a result of the stimulation [5, 19, 22]. The observations gained from the treated series of patients at ECU, Fujita Health University, Nihon University and the pilot studies at UVa suggest that RMNS may have a positive effect on brain-injured comatose individuals. Noninvasive median nerve electrical stimulation is easily employed with little risk and is cost effective [4, 27]. This new technique can improve neurological outcomes.

References

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