Thirty minutes of electroacupuncture (EA) at the Jianshii-Neiguan (J-N) acupoints overlying the median nerve reduce visceral reflex pressor responses and preganglionic sympathetic cardiovascular neuronal activity in the rostral ventral lateral medulla (rVLM). Textbooks report specific clinical responses associated with spinal segments during stimulation of selective acupuncture points. In preliminary studies, we have noted differential time influences between Neiguan and Zusanli acupoints. This study comprehensively investigated the influence of stimulating specific acupoints on the extremities during stimulation of selective acupuncture points. In preliminary studies, we have noted differential time influences between Neiguan and Zusanli acupoints. This study comprehensively investigated the influence of stimulating specific acupoints on the extremities during stimulation of selective acupuncture points. We also studied spinal opioid mechanisms at the T1-2 and T7-8 segments in the splanchnic- and cardiac-induced EA-cardiovascular responses. We compared the influence of six sets of acupoints: J-N, Hegu-Lique (H-L), Pianli-Wenliu (P-W), Shousanli-Quchi (Sh-Q), Zusanli-Shangjuxu (Z-S), and Yongquan-Zhiyin (Y-Z), respectively, overlying the main median nerve, superficial radial, and branches of the median nerves; superficial radial nerve; deep radial nerve; deep peroneal nerve; medial plantar and dorsal digital nerves (terminal branches of the tibial nerves) on the excitatory cardiovascular reflex and rVLM responses during stimulation of chemosensitive receptors in the cat’s gallbladder with bradykinin (BK). We observed substantial point specific differences in responses to 30 min of stimulation with low frequency, low current EA. Premotor sympathetic cardiovascular neurons in the rVLM, responsive to splanchnic nerve stimulation, responded similarly to the reflex responses during convergent input from the acupoints or the underlying nerves, with J-N evoking >Sh-Q>>H-L=Z-S>P-W=Y-Z imp/30 stimuli. In fact, there was a significant linear relationship ($r^2 = 0.7$, $p < 0.05$) between the evoked rVLM response and reflex change in mean arterial blood pressure. In addition, our preliminary data suggest a segmental influence of EA through the opioid system at the level of the spinal cord dorsal horn. Thus, EA at acupoints overlying deep and superficial somatic nerves leads to differential or point specific effects on cardiovascular visceral reflex responses, which may involve segmental spinal input. In a similar manner, premotor sympathetic rVLM neurons that receive convergent input during visceral (reflex) and somatic (EA) nerve stimulation manifest graded responses during stimulation of specific acupoints, suggesting that this medullary region plays a role in site-specific autonomic nervous system responses to electroacupuncture.

**38 GABAPENTIN AND TRAMADOL EFFECT ON NEUROPATHIC PAIN AFTER SPINAL CORD INJURY**

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Study Design: Prospective investigation evaluating the effect of gabapentin and tramadol on neuropathic pain in patients with spinal cord injury (SCI). Objectives: To determine the
effect of gabapentin and combination therapy of gabapentin and tramadol on neuropathic pain in SCI patients with various continuous and paroxysmal symptoms. Summary of Background Data: Gabapentin and tramadol are new drugs that may have a role in the treatment of neuropathic pain. To date, there has been little prospective research on the effect of gabapentin and tramadol on neuropathic pain with varying continuous and paroxysmal symptoms following SCI. Methods: Twenty-seven patients who had suffered from neuropathic pain associated with SCI or cauda equina syndrome were studied. Gabapentin was chosen for first drug for all subjects, and gabapentin was administrated for a 7-day titration period followed by maintenance period at a dosage of 1800 mg/day or the maximum tolerable dose (group I). The efficacy of the administration of gabapentin was gauged by a pain score using a 100 mm visual analogue scale (VAS). In cases that the patients did not report satisfactory pain reduction, tramadol was added; it was used as a maximal dosage of 30 mg/day (group II). The efficacy was checked in the same way. Results: Group I’s mean pain score decreased from 5.7 ± 2.7 and 6.5 ± 1.9 initially to 3.8 ± 2.8 and 3.5 ± 2.4 at the completion of study in continuous and paroxysmal pain, respectively, while group II’s decreased from 6.9 ± 1.3 and 6.8 ± 2.1 to 4.9 ± 1.0 and 3.2 ± 2.5 (p < 0.05). Reported side effects of tramadol were severe constipation, urinary retention, nausea, and vomiting in some patients. Conclusion: Gabapentin and tramadol may be slightly more effective in decreasing paroxysmal neuropathic pain than continuous pain. Gabapentin may be appropriate for first choice drug for neuropathic pain after SCI, because it is unlikely to cause serious adverse effects that limit its use in SCI patients. Tramadol may be appropriate for second choice drug because of its side effects and potential drug addiction, although it showed additionally beneficial effect on neuropathic pain poorly responsive to gabapentin.

39 FUNCTIONAL MAGNETIC STIMULATION FOR RESTORING COUGH IN PATIENTS WITH TETRAPLEGIA
Vernon W-H Lin, Ian Hsiao, Rajinder K. Chitkara

Patients with spinal cord injury (SCI) often have impaired cough due to deprivation of supraspinal control on the expiratory muscles, resulting in frequent pulmonary complications. This study evaluated the usefulness of functional magnetic stimulation (FMS) as a noninvasive technique for assisting cough in SCI patients. Twelve male SCI subjects with injury levels between C4 and C7 were recruited. Pulmonary function tests (PFT) were performed in all subjects, and the following parameters were recorded: maximum expired pressure (MEP), expiratory reserve volume (ERV), and maximum forced expiratory flow (FEFMax). FMS of the expiratory muscles was performed at the end of normal inspiration, using a stimulation of 70% intensity, 20 Hz frequency, and 2 s burst length. Optimal MC placement was determined by moving the center of coil along T6–T12 spinous processes while measuring the changes in airway pressure (DP). This optimal placement was subsequently used for obtaining maximal expired pressures, volumes, and flow rates in these subjects. Results showed that optimal MC placements varied from T9 through T11. Mean maximum expired pressure, volume, and flow rate generated by FMS were 68.2 ± 24.1 cm H2O, 0.77 ± 0.48 L, and 5.27 ± 1.49 L/s, respectively. They were 121%, 167%, and 110% of their voluntary maximum. Eight subjects generated pressures and volumes greater than their voluntary maximum. We conclude that (1) FMS of the expiratory muscles produced a significant expired pressures, volumes, and flow rates when compared with their voluntary maximum efforts; (2) optimal MC placement for expiratory muscle stimulation was between the T9 and T11 spinous processes; (3) the expiratory function produced by FMS was comparable to other existing methods for producing cough in SCI patients, e.g., assisted cough (quad cough) and functional electrical stimulation of the abdominal muscles; and (4) FMS is noninvasive, relatively painless, and well tolerated by all subjects.
40 PERIPHERAL NERVE GRAFTS AND ACIDIC FIBROBLAST GROWTH FACTOR RESTORE PARTIAL HINDLIMB FUNCTIONS IN ADULT PARAPLEGIC RATS

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This study evaluated the degree of functional recovery in adult rats with complete transected spinal cord following an experimental treatment regimen that included implantation of peripheral nerve segments and local application of acidic fibroblast growth factor (aFGF). Rats were randomly divided into five groups: (1) spinal cord transection; (2) spinal cord transection and aFGF treatment; (3) spinal cord transection and peripheral nerve grafts; (4) spinal cord transection, aFGF treatment, and peripheral nerve grafts; and (5) sham control (laminection only). The locomotor behavior of all rats was analyzed by the BBB open-field locomotor test over the 6 months survival time. Immunohistochemistry for neurofilament, somatosensory (SSEP) and motor-evoked potential (MEP) were used to evaluate axon regeneration following the different treatments. The results show four principal findings: (1) Only the combination of peripheral nerve grafts and aFGF treatment improved hindlimb locomotor function after spinal cord transection. (2) The SSEP and MEP demonstrated electrophysiological evidences of both sensory and motor information crossing the damaged site only in the combined nerve grafts and aFGF treatment rats. (3) Immunostaining demonstrated neurofilament-stained axons grow through the graft area and into distal end of spinal cord only in the combined nerve grafts and aFGF treatment rats. (4) Retranssection of recovered rats demonstrated the improvement of hindlimb locomotor activity came from supraspinal control. These results demonstrate the ability of the repair strategy combing nerve grafts and aFGF treatment to facilitate the regeneration of the spinal ascending and descending tracts following spinal cord injury.

41 FUNCTIONAL MAGNETIC STIMULATION—A NEW MODALITY FOR ENHANCING SYSTEMIC FIBRINOLYSIS

Vernon W-H Lin, Arundhati Perkash, Ian Hsiao

Current therapeutic modalities for deep vein thrombosis (DVT) include medications, exercise, intermittent pneumatic compression, and functional electric stimulation (FES). The latter two have been shown to enhance Fibrinolysis. This study investigated whether functional magnetic stimulation (FMS) of the leg muscles could enhance systemic Fibrinolysis. Nineteen healthy volunteers were recruited for this study. The exclusion criteria were a past or family history of venous or arterial thrombosis or cardiac arrhythmias, currently taking medication, or having a cardiac pacemaker or other metallic implants. The subjects were placed in the prone position, and magnetic stimulation was applied to the popliteal region, alternating from side to side every 30 s, for a total duration of 60 min. The dilute whole blood clot lysis time (WBCLT) was used as a global test of fibrinolytic activity and tissue plasminogen activator (t-PA) antigen as a specific component of Fibrinolysis. Blood samples were collected from the veins of the upper limbs immediately prior (baseline), 10, and 60 min post-FMS. The results showed a significant decrease in the mean WBCLT following FMS. The WBCLT decreased from 17 ± 1.3 h before FMS to 12 ± 1.0 and 11 ± 0.8 h at 10 and 60 min post-FMS, respectively. Analysis of the individual responses revealed that FMS of the leg muscles enhanced Fibrinolysis in 75% of the subjects; this group was active but did not exercise regularly and had lower basal Fibrinolysis. The other 25%, who did not show an enhancement, had faster basal Fibrinolysis, perhaps through physical conditioning since this group exercised daily for at least 1 h. This study demonstrated that the FMS-induced muscle contractions of the leg muscles could enhance systemic Fibrinolysis ex vivo. The improvement in Fibrinolysis occurred immediately following FMS and was also observed at 60 min post-FMS; FMS, therefore, appears to produce a sustained
enhancement of systemic Fibrinolysis. Because of this effect FMS may be useful in the prophylaxis of DVT, especially in patients in whom other modalities cannot be used.

42 MOTOR RECOVERY AND ANATOMICAL EVIDENCE IN SPINAL REPAIRED RATS
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We aimed to assess hindlimb motor recovery in complete spinal cord (SC) transected adult rats that received peripheral nerve grafts (PNG) with the application of acidic fibroblast growth factor (aFGF). Rats were randomly divided to three groups (four animals in each group): (1) sham control (laminctomy only), (2) SC transection at T8, and (3) SC transection at T8, aFGF treatment, and PNG. The locomotor behavior and stepping of all rats were analyzed over 3-month survival time using the BBB open-field locomotor test. Motor-evoked potential (MEP), immunohistochemistry for serotonin (5-HT), and anterograde tracing were used to evaluate axon regeneration following the injury and treatment. In addition, sole muscle was weighed for comparison. When compared with transected group, the repaired group showed (1) significant improvement in hindlimb locomotion and stepping, (2) better motor-evoked potentials, (3) presence of 5-HT labeled axons below the lesion site, (4) presence of anterograde tracing in the corticospinal tract axons at the graft site and below, (5) greater muscle weight. We conclude PNG and aFGF treatments improve hindlimb function and facilitate the regeneration of the spinal axons in a T-8 SC transected rat model.

43 SAGITTAL ANALYSIS OF PATIENTS WITH SPINAL CORD INJURY: A RADIOGRAPHIC ANALYSIS AND IMPLICATIONS ON TREATMENT
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Ninety-eight percent of children with SCI develop paralytic scoliosis and, of those, 67% eventually require a spinal fusion. Most spine surgeons fuse and instrument these patients with their sagittal profile in the normal range for able-bodied individuals. This makes posturing and functioning from a wheelchair difficult, because it is not an anatomically correct sitting position. We retrospectively compared the sagittal profile of patients with SCI to the normal sagittal angles of the spine. Methods: In the SCI group, 50 subjects were randomly selected from those with paraplegia or tetraplegia and had to be at least 1 year postinjury, with scoliosis <20° and with no prior fusion for spinal trauma in the thoracic or thoracolumbar region. The sitting erect radiographs were measured for thoracic kyphosis (T2–T12), thoracolumbar kyphosis (T10–L2), and lumbosacral lordosis (L1–S1). Data were compared to that of 102 normal subjects as reported in a review by Bernhardt and Bridwell (Spine, 1989). Results: For thoracic kyphosis, subjects with SCI averaged 40° ± 9°, while the able-bodied individuals averaged 39° ± 8°. For thoracolumbar kyphosis, patients with SCI averaged 19° ± 8°, while the able-bodied individuals averaged 5° ± 10°. For lumbar lordosis, the subjects with SCI averaged 8° ± 12°, while the able-bodied individuals averaged minus 56° ± 9°. Conclusion: There is a significant difference in the sagittal profile of the spine in patients with SCI. There are an additional 15° of thoracolumbar kyphosis and a change of lordosis to actual kyphosis in the lumbar spine. These differences in sagittal measurements should be considered prior to instrumentation and fusion of a patient with paralytic scoliosis secondary to SCI.
44 FUNCTIONAL MAGNETIC VENTILATION

Ian Hsiao, Xiaoming Deng, Vernon W-H Lin

Functional electrical stimulation (FES) of nerves that activate the respiratory muscles has been applied successfully to assist respiration in patients with spinal cord injury. FES, however, is difficult to employ and requires surgery to implant electrodes. It exposes patients to risks such as infection and bleeding that are associated with long-term implants. Continuous magnetic stimulation of inspiratory muscles may be an alternative to mechanical ventilation and FES, without the associated complications. In this study, we successfully provided ventilatory support using magnetic stimulation for up to 2 hours in five C2 spinal cord transected dogs. Magnetic stimulation parameters were set at 80% intensity, 20 Hz, a 1.2 s on and 3.8 s off pulse train. A 20 cm round magnetic coil was centered posteriorly at C5 to C7. The generated inspiratory volumes during ventilation ranged from 0.25 L to 0.75 L. Blood gas data drawn from a femoral artery catheter showed that PCO2 increased from a baseline of 30 mmHg to 75 mmHg, while pH decreased from 7.33 to 6.99 at the end of the 2-hour functional magnetic ventilation period. In summary, functional magnetic ventilation was achieved for 2 hours in dogs with C2 spinal cord transection. Additional refinements in magnetic stimulation techniques are needed to further improve ventilation in animals.

45 IMPROVING GAIT EFFICIENCY WITH FOCAL INJECTION THERAPY IN A PATIENT WITH SPASTIC COCONTRACTION DUE TO INCOMPLETE SPINAL CORD INJURY

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Case Description: A 45-year-old male with left plantar flexor overactivity due to C7 ASIA D incomplete spinal cord injury was referred for focal injection therapy with 98% EtOH to improve gait. Physical examination revealed left ankle dorsiflexor range of motion limited by plantar flexor cocontraction. Assessment/Results: Twenty-one days after injection, the left soleus angle of arrest with slow passive range of motion increased from 88° to 92°. The spasticity grade decreased from 4, nonfatigable clonus without release, with a catch at 83°, down to grade 2, with catch and release at 80°. Functional exercise capacity as measured by the 10-meter walking test increased 32% over baseline for walking as fast as possible, with 17% improvement in striatic length. Comfortable walking speed increased by 27%, with 12% improvement due to increased stride length. Visual inspection revealed improved late stance dorsiflexor passive range of motion to 90°. The patient reported decreased fatigue with ambulation, increased mobility, improved stair climbing and transfers. Conclusion: Focal injection therapy is an inexpensive, safe, and effective technique to decrease dystonia and spasticity grade and significantly improve walking speed, step length, and cadence. A rehabilitation program that incorporates careful gait and spasticity evaluation with appropriate early injection therapy in addition to casting, modalities, and physical therapy can help improve disability.
46 FUNCTIONAL MAGNETIC STIMULATION FACILITATES GASTRIC EMPTYING

Vernon W-H Lin

This study evaluated the effectiveness of functional magnetic stimulation (FMS) on gastric emptying (GE) in subjects with spinal cord injury (SCI) and those without SCI. This is a prospective before-after trial and five able-bodied males and four SCI were recruited in the study. A commercially available magnetic stimulator with a round magnetic coil was placed along the lower thoracic spine. The intensity of the magnetic stimulation was 60%, with a frequency of 20 Hz and a burst length of 2 s. The duration of stimulation was 20 min. The results showed that accelerated gastric emptying was achieved by placing the magnetic coil at T9 of the spinous process in both normal and SCI subjects. The mean ± standard error of means (SEM) of the gastric emptying half-time (GE\(_{t\frac{1}{2}}\)) at baseline and with FMS were 36 ± 2.9 min and 33 ± 3.1 min respectively for the able-bodied subjects, a 8.3% decrease in GE\(_{t\frac{1}{2}}\). The mean ± SEM of the GE\(_{t\frac{1}{2}}\) at baseline and with FMS were 84 ± 11.1 min and 59 ± 12.7 min respectively for the SCI subjects, a 30% decrease in GE\(_{t\frac{1}{2}}\). In both able-bodied and SCI cases, FMS was shown to facilitate GE. This is especially prominent in patients with SCI. We conclude that FMS can be further developed into a non-invasive therapeutic modality for facilitating GE in subjects with and without SCI.

47 SPINAL VASCULAR DISEASES

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ARTERIAL INFARCTION of the spinal cord is usually the result of extramedullary factors such as profound hypotension (shock, cardiac arrest), aortic dissection, or aortic surgery. Damage is heaviest within (and often limited to) the gray matter and typically leads to the appearance clinically of a so-called “anterior spinal artery (ASA) syndrome” (paralysis with loss of pain and temperature perception and sparing of posterior column [position/vibration] sensation).

The term “ASA syndrome” is actually a misnomer in this situation, because there is neither obstruction of the ASA nor infarction within its territory of supply. ASA occlusion, when it occurs, is most frequently the result of atheromatous or fibrocartilaginous embolism. So-called ATHEROSCLEROTIC MYELOPATHY is widely recognized in Europe as a disorder of elderly subjects with a history of heart disease and is said to be characterized by the protracted development of upper and lower motor neuron signs in the absence of sensory dysfunction. Its pathological basis is said to be atheromatous narrowing of feeding vessels or atheromatous embolism to intraparenchymal arterial radicles. FIBROCARTILAGINOUS EMBOLISM occurs both in young adults and in older subjects, and is presumably related to axial stress-induced forcing of intervertebral disc material into the marrow sinusoids and into the arterial circulation. Onset is typically sudden and the resulting neurological deficit permanent. VENOUS INFARCTION of the spinal cord may be either hemorrhagic or nonhemorrhagic. Hemorrhagic infarction is characterized by sudden onset, rapid progression, back pain, relatively short survival (average, 26 days), and a predominance of gray matter involvement. Nonhemorrhagic infarction, by contrast, is characterized by protracted onset (over a period of weeks), slow progression, absence of back pain, a longer survival period (average, 44 weeks), and predominance of white matter involvement. The signs and symptoms of DECOMPRESSION SICKNESS are referable mainly to the cervical and upper thoracic spinal cord. They consist, in milder cases, of paresthesia and numbness and, with more severe disease, of incomplete spastic weakness. A patent foramen ovale is observed in 50% of subjects. Pathologically, there are multiple focal lesions within the white matter of the spinal cord. Although there is considerable debate regarding their pathogenesis, it has been suggested, on the basis of cinevenographic studies, that obstruction of epidural veins levels. Spinal dural AVFs are probably acquired, occur in older subjects, by air bubbles may be a major contributing factor. There appears to be increasing emphasis on the role of impaired venous drainage in the development of myelopathy in cases of subacute or chronic SPINAL CORD COMPRESSION.
(e.g., by epidural neoplasm). The typical appearance of the spinal cord at the affected level is one of multiple, circumferentially distributed, frequently perivenous wedge-shaped foci of coagulative necrosis. SPINAL VASCULAR MALFORMATIONS may be conveniently divided into two groups, arteriovenous malformations (AVMs) and arteriovenous fistulas (AVFs). AVMs are developmental in origin, occur in younger subjects, present typically with hemorrhage, and are seen most commonly at cervicothoracic present most commonly with progressive paraparesis, and are encountered most commonly at thoracolumbar levels; the associated increase in venous pressure leads to a venocongestive myelopathy.