
Oral Presentations

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Clinical Trial to Investigate the Efficacy of Acute Sacral Neurostimulation Using a Novel Transdermal Amplitude-Modulated Signal (TAMS) in Subjects with Neurogenic Detrusor Overactivity

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Objectives: Investigate the efficacy of acute sacral neuromodulation using a novel transdermal amplitude-modulated signal (TAMS) to treat neurogenic detrusor overactivity. **Design:** The protocol was approved by the appropriate institutional review board and ethics committee. This was a single-blinded, randomized, cross-over efficacy study in subjects with neurogenic detrusor overactivity who received noninvasive electrical neurostimulation. After baseline cystometrogram (CMG), subjects were randomized into either a sham treatment followed by active treatment or active treatment followed by sham treatment. **Methods:** 20 subjects with neurogenic detrusor overactivity due to spinal cord injury (SCI) or multiple sclerosis (MS) were enrolled at 3 sites. S3 foramina, S2/S3 dermatome, or perineal/genital region of S3 dermatome was stimulated with 5 or 10 Hz signal. Subjects underwent a posttreatment evaluation to assess pain and discomfort VAS. A one-way ANOVA model was used to assess statistical significance. **Results:** Bladder capacity at first leak increased significantly from baseline with 5 Hz signal for all subjects combined (249.7 ± 180.4 cc vs. 219.8 ± 163.3 cc; $n = 20$) and for AIS (American Spinal Injury Association Impairment

Scale) A subjects (220.3 ± 128.5 cc vs 144.6 ± 76.0 cc; $n = 7$). The differences among the 3 subpopulations (MS, SCI non-AIS A, and AIS A) were statistically significant ($P = .0003$). Volume at start of detrusor contraction increased significantly from baseline for AIS A subjects treated with 5 Hz signal (210.6 ± 121.9 cc vs 131.7 ± 73.8 cc; $n = 7$). 5 Hz signal had a much larger incidence of motor response than the control signal. Subjects experienced minimal pain and discomfort throughout the study. Adverse events were mild (9 in 8 subjects) and resolved spontaneously. **Conclusions:** A novel transdermal amplitude-modulated signal (TAMS) shows promising early results in treating symptoms of neurogenic detrusor overactivity in AIS A subjects.

Support: The study was supported by Ethicon Endo-Surgery, Inc.

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Is Renal Tract Ultrasound Alone Effective for Detecting Calculi?

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Objective: There is no consensus on best practice for routine surveillance of the renal tract in spinal cord injury (SCI). Our objective was to establish whether renal tract ultrasound (US) is an effective tool for detecting calculi in SCI. **Design:** Prospective audit and comparison. **Participants/methods:** Individuals with SCI attending yearly urology review were audited. A detailed proforma was completed. A radiologist viewed and reported the US prior to viewing x-rays. **Results:**

527 subjects were included. 7.2% of patients had calculi. Overall, 79.5% of calculi were detected on US and 64% were detected on x-ray. US was more effective at detecting renal calculi, detecting 92% of renal calculi, whereas x-ray detected 50%. In those with bladder calculi, x-ray detected 87% and US detected 60%. Subjects using catheters for bladder drainage (urethral catheter, intermittent catheter, or suprapubic-UC, IC, SPC) were at high risk of bladder stones in particular. 93% of the patients with bladder calculi used a catheter. Overall, 13.8% of the subjects included had an indwelling catheter, but 23.3% of them had a calculus detected. 59% of those had bladder calculi and 41% had renal calculi. X-ray was better at detecting bladder calculi in those with indwelling catheter (UC or SPC), detecting 90% of bladder calculi compared to 70% detected by US. However, US detected 100% of renal calculi compared to x-ray that detected 57% in those with indwelling catheters. **Conclusion:** Overall, US is better at detecting renal tract calculi, but x-ray is better at detecting bladder calculi, especially in those with an indwelling catheter. This may reflect the difficulty of detecting calculi with US in those with an empty bladder.

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Botulinum-A Toxin in the Management of Detrusor Hyperreflexia in Spinal Cord Injured Patients: An Indian Experience

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Objective: We evaluated the efficacy of botulinum-A toxin injection into the detrusor muscle in patients with spinal cord injury who had detrusor hyperreflexia and urge incontinence, resistant to anti-cholinergic drugs. The purpose of treatment was to suppress the episodes of incontinence and increase functional bladder capacity. **Participants/methods:** Included in our open-label, nonrandomized prospective study were 20 patients with traumatic spinal cord injury who emptied their bladder by intermittent self-catheterization. These patients had severe detrusor hyperreflexia and incontinence despite a high dose of anti-cholinergic medication (*Tolterodine*). Pretreatment evaluation included a 7-day voiding diary and a urodynamic evaluation. Under cystoscopic control, a total of 200 units of botulinum-A toxin were injected into the detrusor muscle, sparing the trigone. **Results:** The procedure was uneventful, without any serious side effects. Voiding diary records of 18 patients (90%) showed that they were fully continent after the botulinum toxin-A injection treatment. The volume and the frequency of leakage in the remaining

2 incontinent patients was significantly reduced. Filling cystometry showed a marked reduction in storage detrusor pressures after treatment in all patients. Mean functional bladder capacity and volume at first leakage increased significantly in all patients. Follow-up lasted for 1 year showing beneficial results in most patients to beyond 9 months and in 25% of patients lasting for up to a year after the injection. **Conclusion:** Botulinum-A toxin injections into the detrusor seem to be a safe and valuable therapeutic option in spinal cord injured patients with incontinence, resistant to anticholinergic medication. A dose of 200 units of botulinum-A toxin seems adequate to manage detrusor hyperreflexia. The duration of beneficial effect thus induced by the toxin is an average of 10.3 months, when repeat injections may be given.

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Observations on Changes in Bladder Wall Thickness After Treatment with Tolterodine-ER and Botulinum Toxin in Patients with Detrusor Hyperreflexia After Spinal Cord Injury

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Objective: *Tolterodine-ER* is effective in controlling leaks and detrusor hyperreflexia, but it is unknown to what extent it actually prevents the bladder from the detrimental effects of hyperreflexia. The aim of this study was to assess the changes in bladder wall thickness while on treatment with *Tolterodine-ER* and compare with that of botulinum toxin. **Participants/methods:** In a prospective open-label study, 10 patients were included in each arm. Once chosen, they were assigned to treatment with either *Tolterodine-ER* (4 mg to 8mg) or intravesical botulinum toxin 200 units. Urodynamics and ultrasound examinations were done at baseline, at 6 months, and at 1 year. **Results:** Bladder wall thickness showed an increase with *Tolterodine-ER* from 3.1 mm at baseline to 3.8 mm at 6 months and 4.9 mm at 1 year, while after botulinum toxin it showed a initial reduction from 3.1mm at baseline to 2.9 mm at 6 months and 3.6 mm at 1 year. *Tolterodine-ER* was also less effective in comparison to botulinum toxin in providing complete resolution of hyperreflexia at 6 months (50% vs 90%) but equally effective at 1 year (30% in each arm). **Conclusion:** *Tolterodine-ER* may not always completely protect against the ill effects of detrusor hyperreflexia and the bladder may continue to undergo deleterious morphological changes even while

on treatment. Botulinum toxin seems to provide better control of hyperreflexia. However, the present study is too small to derive effective conclusions.

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Prostato-Sphincter Stent in Patients with Acontractile Detrusor After Spinal Cord Injury: An Indian Experience

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Objectives: Many patients with spinal cord injury often express the desire to avoid clean intermittent catheterization. They change over to voiding by abdominal straining or are even content with the overflow state. We studied the effect that a polyethylene stent placed across the prostate and external sphincter may have on voiding functions in these patients and whether a catheter-free state may be obtained. **Participants/methods:** 20 male patients aged 20 to 40 years having spinal cord injury with acontractile detrusor and nonvoiding status were evaluated after placement of a polyethylene prostato-sphincteric stent under fluoroscopic control. Voiding efficiency, postvoid residue, stent tolerance, and complications were noted at monthly interval for a period of 6 months. **Results:** Failure to void and clot retention occurred in 2 patients immediately after stenting and required removal. Distal migration (15%), proximal displacement into the bladder (10%), persistent hematuria, recurrent infections, stent blockage, and encrustation (40%) were the major complications observed. Only 4 patients had uneventful course with satisfactory bladder emptying. Stent occlusion occurred in all patients, necessitating its removal, between 3 and 6 months. **Conclusions:** Prostato-sphincteric stenting does not improve spontaneous voiding in patients with acontractile detrusor. Clean intermittent catheterization still remains the safest option in these patients.

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Alpha Adrenergic Antagonists—Do they Really Relieve Outlet Obstruction?

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Objectives: Although alpha adrenergic antagonists produce significant improvement in the symptoms

of outlet obstruction, only a limited objective improvement is seen. We evaluated the effects of these agents on pressure flow parameters after 1 year of treatment. **Participants/methods:** From September 2009 to September 2010, 60 patients (mean age 62 years) were treated with alpha adrenergic antagonist (terazosin 2 mg). Patients were evaluated for 1 year at 3-month intervals for improvement in symptoms, uroflowmetry, and pressure flow parameters. **Results:** Majority of patients (70%) had positive symptomatic improvement. Uroflowmetry noted only marginal improvement; mean improvement in maximum flow was 2.6 mL/s. Pressure flow parameters observed minimal improvement in voiding pressures in 75% of cases, though it was statistically insignificant. Deterioration was noted in 25% of cases, necessitating surgery. **Conclusions:** Alpha adrenergic antagonist (terazosin) does significantly relieve symptoms of outlet obstruction, but it fails to improve urodynamic criteria of obstruction.

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Prevention of Long-Term Respiratory Complications of Spinal Cord Injury

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Objective: Determine the efficacy of manual and mechanical assisted cough techniques in preventing community acquired pneumonia (CAP) and other severe respiratory tract infections in persons with chronic spinal cord injury (SCI). **Design:** Prospective, single-blind, randomized controlled trial. **Participants/methods:** Persons with chronic SCI with an ineffective cough (cough peak flows [CPF] <300 L/min) were randomly assigned to either a treatment group using oximetry with manual and mechanical assisted cough (O-MMAC) or an active control group using oximetry with incentive spirometry (O-SPIR). Participants in both groups received pneumococcal and influenza vaccines. The primary efficacy endpoints included a reduction in episodes of CAP and related severe respiratory complications. Pulmonary function tests (CPF, vital capacity [VC], and maximum insufflation capacity [MIC]) were performed at baseline and

follow-up. **Results:** 120 persons with chronic SCI (78% tetraplegia, 22% paraplegia) were enrolled in this study, with 97 followed at least once during the first year (12 month response rate, 81%). Baseline VC, MIC, and CPF was 2.23 ± 0.92 L, 2.34 ± 1.14 L, and 182 ± 55 L/min, respectively. To date, there have been only 3 episodes of pneumonia secondary to other medical complications and no episodes of clinically confirmed CAP. Multivariate tests indicate that the O-MMAC group had modestly improved PCFs at 12 months relative to the O-SPIR group ($\beta = 31.0$, $SE = 14.1$, $P = .03$). **Conclusions:** These results represent year 1 of a 3-year study. The incidence of CAP in our sample was lower than expected and may be attributable to administration of pneumococcal and influenza vaccines. Preliminary analysis suggests that cough effectiveness can be improved by training in assisted techniques and may improve respiratory functioning over time.

Source: NIDRR #H133N060022 and Kessler Foundation

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Abdominal Binder Effect on Respiratory, Voice, and Haemodynamic Outcomes After a Tetraplegic Spinal Cord Injury

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Objective: Investigate effects of an elasticated abdominal binder (AB) on respiratory, voice, and haemodynamic outcomes in motor complete acute tetraplegia during the first year after injury. **Design:** Randomized cross over study. **Participants/methods:** 14 subjects with posttraumatic SCI with a neurological impairment classification according to American Spinal Injury Association (ASIA) of A or B above T2 level were included. Repeated measures at 6 weeks, 3 months, and 6 months after commencing daily use of a wheelchair were taken seated in wheelchair with/without AB. Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV₁), peak expiratory flow (PEF), maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), mean arterial blood pressure (MAP), sustained phonation time (SP), and voice loudness (VL)

were measured. **Results:** An AB resulted in a significant improvement between groups in FVC (weighted mean difference 0.44 L; 95% CI, 0.13-0.75; $P = .005$), FEV₁ (0.32 L; 95% CI, 0.03-0.61; $P = .03$), PEF (0.93L/s; 95% CI, 0.22-1.65; $P = .01$), MIP (7.40 cmH₂O; 95% CI, 1.64-13.14; $P = .01$), and SP (3.75 s; 95% CI, 0.90-6.60; $P = .01$). MEP, MAP, and VL were improved with the AB but not statistically significant. **Conclusion:** An individually fitted elasticated AB significantly improved respiratory and voice parameters in people with newly acquired tetraplegia. Continued use of an AB needs to be directed by the clinician taking into account the individuals breathing, voice, and blood pressure response to an AB. Further study is needed into long-term use of an AB on functional residual capacity, total lung capacity, and respiratory health.

Support: This project was funded by Queensland Health Allied Health Research Scholarship.

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Prediction Models for Lung Function of Individuals with Motor Complete SCI

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Objective: To develop statistical models to predict lung function and respiratory muscle strength in individuals with spinal cord injury (SCI) from personal and lesion characteristics. Models will be published on an open-access Web page to calculate lesion-dependent reference values for lung function and respiratory muscle strength for persons with SCI. **Design:** Cross-sectional, multicenter cohort study. **Participants/methods:** 440 individuals with traumatic, motor complete SCI (time post injury [TPI] ≥ 6 months) performed lung function and respiratory muscle strength measurements. Lung function parameters were forced vital capacity (FVC), forced expiratory volume in 1s (FEV₁), and peak expiratory flow (PEF). Respiratory muscle strength parameters were peak in- and expiratory muscle strength (Pi_{max}, Pe_{max}). Using multilevel regression

models, the effects of personal (gender, age, height, weight) and lesion characteristics (TPI and 4 lesion level groups [C4-C5, C6-C8, T1-T6, T7-T12]) were determined. **Results:** Predictors of all lung function parameters were gender, age, height, weight, and lesion level. A lower lesion or higher weight was associated with higher lung function values. For $P_{i_{max}}$ only, gender, age, weight and lesion level were significant predictors; whereas for $P_{e_{max}}$, gender, age, TPI, and lesion level were influencing parameters. **Conclusion:** Compared to predictive models for able-bodied individuals, lung function parameters of persons with SCI are additionally influenced by weight and lesion level. $P_{e_{max}}$ improves with higher TPI.

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Effects of Spinal Cord Stimulation (SCS) via Wire Electrodes on Expiratory Muscle Activation

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Background: SCS with disc electrodes positioned in the region of the lower thoracic spinal cord results in marked expiratory muscle activation and the development of a physiologic cough mechanism in patients with spinal cord injury (SCI) (*Arch Phys Med Rehabil.* 2009;90:717-725 and 726-732). This technique results in significant reductions in the need for caregiver support and incidence of respiratory tract infections. This technique however is somewhat invasive, requiring laminotomies for disc (4 mm) electrode placement. **Objective:** To evaluate the efficacy of spinal cord wire electrodes that can be implanted less invasively via a percutaneous technique. **Methods:** In 5 anesthetized dogs, airway pressure generation (P) was monitored during airway occlusion and near supramaximal stimulation at the T9, T11, and L1 spinal levels utilizing disc (4 mm) and 6 mm wire electrodes, in separate trials. **Results:** Monopolar and bipolar SCS at T9 and L1 level applied with disc electrodes resulted in P of 85 ± 5 and 77 ± 5 cmH₂O respectively. SCS applied with 2 wire electrodes placed in parallel at the same spinal cord levels resulted in P of 73 ± 9 (monopolar) and 84 ± 2 (bipolar) cmH₂O, respectively (NS compared to disc electrodes). **Conclusion:** These results suggest that epidural SCS with wire electrodes produces a comparable level of expiratory muscle activation and

positive airway generation to that achieved with disc electrodes. SCS via wire electrodes may provide a less invasive, less costly, and more convenient method of expiratory muscle activation to restore cough.

Support: NIH-NINDS (R01NS064157)

Disclosure: Dr. DiMarco is a founder of and has a significant financial interest in Synapse BioMedical, Inc, a manufacturer of diaphragm pacing systems.

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Intramuscular Diaphragm Pacing for Respiratory Support in Tetraplegics: Current Worldwide Status in 2010

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Objective: Direct phrenic nerve pacing to replace ventilators for tetraplegics was initially developed in the 1960s, but through the 2000s less than 5% of the estimated annual 300 to 500 eligible patients utilized the available devices in the United States (HCUPnet database 1997-2004). Intramuscular diaphragm pacing (DP) was first implanted in 2000, and received European approval in 2007 and US approval in 2008. **Design:** Review DP patients worldwide and published literature in 2010. **Participants/methods:** All ventilator-dependent spinal cord injured (SCI) patients who were implanted with DP per country and per state in absolute numbers. **Results:** A total of 65 DP implants were done in 9 countries: Canada, France, Norway, Spain, Switzerland, Australia, Saudi Arabia, Jordan, and the United States. The US total was 43 in 13 states with the majority in only 5 states: Ohio, Colorado, Texas, Illinois, and Georgia. Nine children were implanted worldwide with the youngest age 2. DP technology is being utilized in other respiratory problems, and at the largest US site SCI accounts for less than 30% of DP implants. There were 5 peer-reviewed publications on phrenic or DP in 2010, all with positive results. **Conclusion:** Published research continues to show the clinical benefit of removing patients from mechanical ventilation, yet there is still an overwhelmingly low adoption of phrenic or diaphragm pacing. A disparity of technology utilization exists between countries or states. In the United States, individual state Medicaid programs are an obstacle. Recent reports of DP

utilization by trauma surgeons early after injury will help expand this technology and decrease ventilator associated pneumonias, diaphragm dysfunction, and length of stay. Fortunately, the expanding use of DP in other diseases will maintain this option for SCI patients.

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Life Expectancy After Ventilation in a Spinal Injuries Centre

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Objective: To compare survival of weaned and nonweaned persons with spinal cord injury after acute ventilator support and review causes of death. **Design, Subjects, and Setting:** The case notes of all patients known to have had assisted ventilation at the NWRNIC between the years of 1981 and end of 2005 were reviewed. **Methods:** Kaplan Meyer analysis of survival from the date of ventilation was calculated according ventilator-wean status at discharge after grouping patients into 15 year age cohorts. Risk factors were obtained by Cox regression analysis. Causes of death were ascertained from the Office of National Statistics. **Results:** There were 197 patients ventilated for the first time after traumatic SCI of whom 55 could not be weaned from mechanical ventilation. 56% of deaths in both groups were respiratory in nature. Whilst the mean survival time of weaned patients was numerically greater than ventilated patients within each age group, this was only significantly different within the age group 31 to 45 (19.3 vs 10.5 years; $P = .047$). Mean survival time of patients aged 1 to 30 with diaphragm pacing (13) was 1.8 years longer than those on mechanical ventilation (12) ($P = .142$). **Conclusion:** The survival time for patients with high tetraplegia on long-term ventilation compares with other datasets and older patients have a proportionately greater loss of life expectancy. Self-ventilating patients with tetraplegia remain at considerable risk from respiratory death.

Support: This study was unfunded and the authors declare no conflicts of interest.

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Update on a Phase 1 Safety Trial of Human Embryonic Stem Cell-Derived Oligodendrocyte Progenitor Cells (GRNOPC1) in Subjects with Neurologically Complete, Subacute Spinal Cord Injuries

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Objective: To evaluate the safety of GRNOPC1 in subjects with neurologically complete, subacute spinal cord injuries. **Design:** Multi-center, open-label, phase 1 safety study. **Participants/methods:** 8 to 10 individuals who sustain a traumatic, nonpenetrating SCI, and who are neurologically complete (ASIA Impairment Scale A) with a single neurological level from T3 through T10 will be enrolled. GRNOPC1 must be administered for 7 to 14 days after an SCI via direct injection of 2×10^6 cells into the spinal cord. Subjects will receive immunosuppression via low-dose tacrolimus through 60 days following GRNOPC1 injection. Subjects will be followed for 1 year under the initial protocol and an additional 14 years under a separate protocol. Safety assessments include: physical exam, vital signs, electrocardiogram, neurological exam, International Standards for Neurological Classification of SCI (ISNCSCI) exams, magnetic resonance imaging, pain questionnaire, concomitant medications, adverse events (AEs), laboratory tests for hematology, blood chemistry, and immunosuppression safety monitoring. Efficacy is evaluated via ISNCSCI exams. Exploratory assessments are performed to further evaluate lower extremity motor function, bowel and bladder function, functional ability, and donor-specific immune responsiveness to GRNOPC1. **Results:** The first human subject received GRNOPC1 in October 2010, and currently no AEs related to GRNOPC1 or the injection procedure have occurred. Experience to date in the clinical trial will be presented at the meeting. **Conclusion:** In subjects who have received GRNOPC1, no serious safety issues have occurred to date.

Support: This trial is funded by Geron Corporation.

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The Effect of Nicotine on Functional Recovery and Neuropathic Pain After Spinal Cord Injury in a Rat Model

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Objective: Determine the effect of chronic nicotine and withdrawal of nicotine on functional recovery and neuropathic pain in a rat model of spinal cord injury (SCI). **Design:** Translational SCI research. **Participants/methods:** Twenty-four adult female rats were implanted with osmotic minipumps containing either nicotine (4.47 g/mL) or saline. Seven days later, a 250 kdyn contusion SCI at vertebral level T13 was induced. One group of animals received nicotine administration for the duration of the experiment (chronic group), while in a second cohort the nicotine administration was terminated at 7 days post-SCI (withdrawal group). Locomotor function was assessed using the Basso, Beattie, Bresnahan (BBB) locomotor scale and Catwalk gait analysis. Allodynia was evaluated with Von Frey filaments. On post-SCI day 28, spinal cord tissue was extracted and the number of motor neurons in the ventral horn, percentage of spared white matter, and extent of reactive astrogliosis were evaluated using stereology. **Results:** Animals in the chronic nicotine group exhibited a significant decrease in paw withdraw threshold on post-SCI days 21 and 28 as compared to animals in the nicotine withdrawal or saline groups. No statistically significant differences in locomotor function were observed between groups. Increased reactive astrogliosis was observed in the chronic nicotine group as compared to the saline and nicotine withdrawal groups. **Conclusion:** Chronic nicotine administration increases below-lesion allodynia after SCI, and this effect can be attenuated by withdrawal of nicotine administration and is associated with an increase in reactive astrogliosis.

Support: UAB School of Medicine and Department of Physical Medicine and Rehabilitation

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Patterns of Sensory Preservation and Recovery After Cervical Complete Spinal Cord Injury

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Objective: To determine patterns of sensory preservation and recovery in cervical and thoracic dermatomes after complete cervical spinal cord injury (SCI). **Design:** Retrospective review. **Participants/methods:** Sensory outcomes of the International Standards for the Neurological Classification of Spinal Cord Injury (ISNCSCI) from individuals in the European Multicenter study about Spinal Cord Injury (EM-SCI) database with complete cervical motor level SCI (C4-C6) were reviewed. Light touch and pin prick total score and subscores for cervical (C4-C8), upper thoracic (T1-T5), and lower thoracic (T6-T10) dermatomes were examined at 1, 8 and 24 weeks after SCI. A nonparametric statistical analysis was planned to determine significant differences in light touch and pin prick preservation and light touch and pin prick recovery. **Results:** At 1 week, total light touch score was significantly greater than total pin prick score ($P = .002$). Upper thoracic dermatomes retained significantly greater light touch compared to pin prick sensation ($P = .012$). During recovery, total light touch score significantly increased ($P = .004$). Light touch recovery was significant in cervical and lower thoracic dermatomes ($P = .026$ and $P = .003$, respectively). Significant recovery of pin prick sensation was evident only in the upper thoracic dermatomes ($P = .008$). **Conclusion:** The preservation of light touch and recovery of pin prick after cervical complete SCI resulted in a significant proportion of individuals with sensation (impaired or normal) in upper thoracic dermatomes. Patterns of sensory preservation and recovery remain an important measure of safety in clinical trials that intend to demonstrate efficacy of a therapeutic in individuals with cervical complete SCI.

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Transcutaneous Spinal Cord Stimulation to Augment Locomotor Output in Spinal Cord Injury

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Objective: The lumbar spinal cord contains locomotor neural circuitry that can be activated by tonic stimulation of lumbar afferents with epidural stimulation in humans with spinal cord injury (SCI). Transcutaneous spinal cord stimulation (tSCS) has been developed as a noninvasive method to activate these afferents, and the objective of this study was to use tonic tSCS to augment locomotor output during body weight–supported treadmill stepping (BWSTS) assisted manually or by the Lokomat robotic gait orthosis. **Design:** This was a pilot data collection study in motor complete and incomplete SCI using a novel methodology. **Methods:** Stimulating electrodes were applied paraspinally and over the lower abdomen to generate an electrical field that would activate posterior roots. Continuous electrical stimulation at 10–50 Hz was applied during BWSTS. Muscular activity was recorded by EMG from proximal and distal flexors and extensors of the lower extremities, and joint positions or forces were monitored with goniometers (manually assisted stepping) or the Lokomat respectively. **Results:** In motor complete SCI, tonic tSCS at modest intensities during BWSTS increased leg muscle EMG amplitudes relative to those generated during BWSTS alone. With greater stimulation, rhythmic activities were generated in the leg muscles that could be synchronous in flexors and extensors or alternating but not linked to the gait cycle. Tonic tSCS in motor incomplete SCI with manually assisted BWSTS caused gait-phase appropriate augmentation of motor output by EMG and improved limb kinematics, mostly enhanced flexor activation during swing. In the Lokomat, adding loading and increasing gait speed improved EMG output but this was augmented with tSCS, with increased limb force generation recorded by the Lokomat, and with improved ankle flexor

function during swing. **Conclusions:** tSCS can be used to augment locomotor output in motor complete and incomplete SCI.

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Utility of Monitoring Spinal Cord Conduction During Cell Transplantation in Incomplete SCI

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Objective: Initial clinical trials of intraparenchymal cell transplantation in humans with SCI are recruiting patients with complete injuries. It is likely that greater degrees of benefit may be achieved in those with incomplete injury, but the risk of damage to preserved structure as a result of transplant manipulation is increased. Such injury could cause loss of residual function. It is important to develop methods to minimize procedural injury. In this study, we tested whether retention or loss of electrophysiologic conduction correlates with changes in locomotor function following the injection procedure. **Design:** 15 Yucatan mini-pigs underwent a severe thoracic contusion injury. Baseline and post impact (A) transcranial motor-evoked potentials, (B) somatosensory evoked potentials, and (C) lesion spanning spinal cord potentials were obtained. 14 to 30 days later, the pigs underwent control or cellular injection of volumes of 50 to 150 μ L. The presence or absence of conduction modalities A, B, and C were assessed before and after the injections. In subsequent days, the locomotor function was compared to the pretransplant baseline using the Miami Porcine Walking Scale (MPWS). **Methods:** The correlation between preserved pretransplant and posttransplant walking scores and changes in measured conduction was tested using regression analysis. **Results:** Loss of conducted potentials was associated with posttransplant drops in the walking score. Additional data are needed to confirm validity. Our novel spinal cord surface stimulation method detected conduction when cortically elicited descending and dorsal column ascending potential were absent, indicating that conduction in alternate pathways was elicited. **Conclusions:** Monitoring of conduction during intraparenchymal injection may allow early detection of adverse effects.

Support: The Miami Project to Cure Paralysis. Spinal cord conduction testing device under patent review.

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Effect of Sulfasalazine on Neuropathic Pain Following Spinal Cord Injury

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Objective: The objective of the present study is to determine the effect of postinjury administration of sulfasalazine on neuropathic pain in a rodent model of cervical SCI as well as determine to elucidate the mechanisms underlying this process. Neuropathic pain is a commonly observed chronic pain condition following spinal cord injury (SCI); however current treatment options are of marginal success due in part to a limited understanding of the processes underlying this condition. The anti-inflammatory drug sulfasalazine has been shown previously to decrease hallmarks of neuropathic pain in a rat model of diabetic neuropathic pain. **Design:** Translational SCI research using a cervical hemiconfusion model in adult male rats. **Participants/methods:** 47 adult male rats received a 300 kdyne cervical hemiconfusion SCI with subsequent administration of low or high dose sulfasalazine, or vehicle alone, for 7 days post injury. NF- κ B activity was assessed 72 hours post injury by Western blot. Neuropathic pain behaviors were recorded daily, whereas thermal hyperalgesia and tactile allodynia, hallmarks of neuropathic pain, were assessed once weekly using the Hargreave's method and Von Frey filaments, respectively. Spinal cord tissue was extracted 35 days post injury and processed for immunohistological analysis of glial activation. **Results:** Administration of low- and high-dose sulfasalazine decreased the overall incidence of neuropathic pain behaviors and tactile allodynia in the contralateral hindpaw as compared to vehicle-treated control animals. Development of thermal hyperalgesia was not observed following SCI in any animal groups. **Conclusion:** We conclude from these results that cervical hemiconfusion SCI results in development of tactile allodynia but not thermal hyperalgesia. Additionally, acute postinjury administration of sulfasalazine prevents the development of neuropathic pain behaviors and tactile allodynia following cervical SCI.

Support: Civitan Emerging Scholars grant NS052559

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Training Unsupported Sitting in People with Recently Acquired Paraplegia: A Randomized Controlled Trial

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Objective: To determine the effectiveness of a 6-week intensive training program on the ability of people with paraplegia to sit unsupported. **Design:** Assessor-blinded randomised controlled trial. **Participants/methods:** 32 people with recently acquired paraplegia and limited ability to sit unsupported were randomised to experimental and control groups. Participants in the experimental group received an extra 30 minutes of task-specific training specifically directed at improving unsupported sitting, 3 times a week for 6 weeks. All participants continued to receive usual rehabilitation. Outcomes were taken at baseline and at 6 weeks. The 3 primary outcomes were the maximal lean test (normalized to trunk length), maximal sideward reach test (normalized to arm length), and the performance item of the Canadian Outcome Performance Measure (COPM). **Results:** There were marked and statistically significant improvements over the 6-week study period in all outcomes for all participants. The between-group mean differences (95% CI) for the maximal lean test, maximal sideward reach test, and the performance item of the COPM were -76mm/trunk length (-195 to 43), 6% of arm length (-2 to 14), and 0.5 points (-1.0 to 1.5). **Conclusion:** On average, 6 weeks of intensive training improved the ability of people with paraplegia to sit unsupported, however, it is not clear whether the size of the treatment effect justifies the time and cost associated with providing the additional training. It is possible that additional therapy for unsupported sitting is redundant in patients learning functional activities as part of standard rehabilitation.

Support: Rehabilitation and Disability Research Foundation

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High Incidence of Traumatic Spinal Cord Injury in Estonia from 1997-2007

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Objective: The aim of the study was to provide recent data on the incidence, causes, and severity of traumatic spinal cord injury (TSCI) in Estonia from 1997-2007.

Design: Retrospective. **Patients and Methods:** Medical records of patients with TSCI from all regional, central, general, and rehabilitation hospitals of Estonia from 1997-2007 were studied. **Results:** A total of 595 patients with TSCI (503 men and 92 women) were registered. The mean age at onset of injury was 38.9 years (*SD* 16.9) for men and 39.6 years (*SD* 18.9) for women. The annual incidence rate per 1,000,000 of population was 39.5 (95% CI, 36.4-42.8) for all, 72.4 (95% CI, 66.2-79.1) for men and 11.3 (95% CI, 9.1-13.9) for women. The trend of incidence during the study period was stable. The highest incidence rates were for the age group 25-34 years in men and for 35-44 years in women. The most frequent cause of TSCI was fall (41%; 72% for those >60 years), followed by traffic accidents (29%). Alcohol preceded TSCI in 43% of the cases. Paraplegia (51%) was more frequent than tetraplegia (44%) in the acute stage. In 61% of cases, the injury was incomplete. **Conclusions:** Compared to other studies, the incidence rate of TSCI in Estonia is among the highest in Europe. The rates were significantly higher in men compared to women. TSCI were related to alcohol in 43% of the cases. Falling was the main cause of TSCI. Prevention strategies need to focus on TSCI, especially on those related to alcohol in younger men.

Support: Estonian Science Foundation grant 7868

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Relationship Between Vesico-Ureteral Reflux and Glomerular Filtration Rate in Adults with Spinal Cord Injury

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Objective: To analyze which value, between the glomerular filtration rate (GFR) and the creatinine blood test, is more predictive for early diagnosis of renal failure in SCI patients. **Design:** Observational study considering the results of creatinine blood test, voiding cystourethrography, and renal scintigraphy in a SCI patient population with neurogenic bladder. **Participants/methods:** 61 patients (14 females and 47 males) were included: 41 paraplegic, 18 tetraplegic, and 2 cauda equine syndrome. All the patients were submitted to a voiding cystourethrography to confirm the diagnosis of vesicoureteral reflux and renal scintigraphy. The creatinine blood test completed the evaluation. All the patients were divided in 2 groups: the first with a vesicoureteral reflux and the second without it. We have considered for each patient GFR of each kidney, total GFR, and creatinine blood value. We have used *t* test for statistical analysis. **Results:** In the first group, 19 patients presented vesicoureteral reflux and in the second group 42 patients did not. The GFR of the kidney with reflux was less than the GFR of the kidney without reflux. The total GFR was significantly statistically reduced in the group of the patients with reflux. The creatinine blood value did not present a statistically significant change. **Conclusion:** The results have confirmed literature's data about the loss of normal renal function in the SCI patients after vesicoureteral reflux. The diminished value of GFR in the kidney with reflux compared with the contralateral kidney is a more favourable index for early diagnosis of renal failure than the creatinine blood test.

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Changes in Intrathecal Baclofen Dosage During Long-Term Treatment in Patients with Spasticity Due to Spinal Cord Injuries

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Objective: Determine dosage changes during long-term treatment with intrathecal baclofen in patients with spinal injuries. **Design:** Retrospective investigation of case reports. **Participants/methods:** 13 patients with cervical and 4 with thoracic spinal cord injury received an intrathecal baclofen pump (*Synchromed*) because of severe leg spasticity: ASIA A, n=6; B, n=5; C, n= 3; D, n=3. The pump had been inserted after a median time of 2 years after the injury (range, 0.5 to 37 years). The

effect was estimated by patient/doctor dialogue in order to reach an optimal balance between leg spasticity and weakness in trunk and legs. Patient dialogue occurred at every pump filling, usually 4 to 10 times per year. **Results:** One year after start of intrathecal baclofen, the patients needed a median dose of 256 microgram baclofen per 24 hours (range, 30-725) to reach an optimal balance. After an additional year, the dose was increased by an average of 1% (range, -29% to +33%; 95% CI, $\pm 7\%$). 5 years after start of baclofen, the dose had increased by 13% compared to the first year dose (95% CI, $\pm 12\%$). **Conclusion:** In most patients, the dose needed to reach an optimal balance is unchanged during the first 5 years.

Support: Lars Sullivan Memorial Fund

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Electroejaculation for the Treatment of Anejaculation in Neurologically Impaired Males: 15 Years' Experience

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Objective: Describe our experience over the past 15 years with electroejaculation (EE) in neurologically impaired men. **Design:** Retrospective review. **Method:** The protocol and equipment for EE have evolved since the early 1980s, but the basic elements used over the past 15 years have included: inspection of the rectum for lesions or excess stool, premedication of subjects at risk for dysreflexia, monitoring of vital signs and flushing, and emptying the bladder pre and post EE. We used a specially designed, electrically isolated rectal probe with a built-in temperature gauge that shut off at a preset temperature. Electrostimulation was applied for a maximum of 10 minutes; stimulation parameters ranged from 4 to 17 volts and 100-600 milliamps. **Results:** Between 1995 and 2010, we performed EE on 590 anejaculatory men and obtained ejaculates in all 590 for a success rate of 100%. These individuals had the following diagnoses: 480 men with spinal cord injury (SCI), 44 with retroperitoneal lymph node dissection, 37 with idiopathic diagnosis, 17 with diabetes, 7 with multiple sclerosis, and 5 with spina bifida. The mean age and range of men with SCI was 32.1 years (16-61 years), and for the non-SCI group it was 35.8 years (25-67 years). No adverse effects were reported. Sperm was present in 92% or 543 of the ejaculates. **Conclusion:**

EE is an effective, safe, and repeatable method of sperm retrieval in neurologically impaired males.

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Intermittent Catheterization and Recurrent Urinary Tract Infection in Spinal Cord Injury

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Objective: We studied our population of spinal cord injured (SCI) patients for the association of recurrent urinary tract infections (UTI) with the long-term use of clean intermittent catheterization (CIC) for neurogenic bladder management. **Design:** Retrospective review of medical records. **Participants/methods:** The medical records of 38 SCI subjects with neurogenic bladder were reviewed. Subjects were selected from patients at the Yale Urology Practice Group from the years 2000 to 2010. The patient list was generated with diagnosis codes for "neurogenic bladder" and "spinal cord injury." After review of 450 medical records, 109 SCI patients were identified. 32 male and 6 female subjects managed with CIC and followed for a minimum of 1 year were included in the study. SCI patients with mitrofanoff procedures or those not using CIC were excluded. Subjects with a history of recurrent symptomatic UTIs were identified by their use of medical UTI prophylaxis (PRx) with either oral antibiotics or methenamine/vitamin C. **Results:** 29 (76%) subjects required medical PRx for recurrent symptomatic UTIs (5 [83%] females and 24 [75%] males). There was no statistically significant difference between percentage of males and females requiring PRx. Date of initial PRx use was noted in 27 of 29 subjects, and the results demonstrate 20 (74%) required PRx within 2 years after initiation of CIC. **Conclusion:** Recurrent UTIs remain a major complication of long-term neurogenic bladder management. Although CIC is generally viewed to have the fewest complications compared with other bladder management methods, most SCI patients managed with long-term CIC will require medical PRx for prevention of symptomatic UTI within 2 years after its initiation.

Support: Yale Medical Student Research Fellowship Award

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Pulsed Radiofrequency Denervation at the Lumbar Dorsal Roots Reduces Below-Level Neuropathic Pain in a Rat Model of Spinal Cord Injury

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Objective: Determine the effect of delayed postinjury administration of pulsed radiofrequency (PRF) therapy to the affected lumbar dorsal root on below-level neuropathic pain after spinal cord injury (SCI) in a rat model. **Design:** Translational SCI research. **Participants/methods:** A hemicontusion SCI was induced at vertebral level C5 in 21 adult male rats. At day 25 post SCI, rats were categorized based on neuropathic pain behaviors and then subdivided into either sham or PRF therapy groups. For induction of PRF, the paraspinal musculature over the dorsal root ganglia (DRG) contralateral to the hemicontusion at L3, L4, and L5 was retracted. A curved 10 cm, 22 gauge electrode with a 5 mm active tip was then placed adjacent to the DRG at each level. Radiofrequency current (2 bursts per second of 20 millisecond duration, 500 Hz) was applied for 120 seconds. Sham-treated groups received identical procedures with the omission of the PRF current. **Results:** In a subset of rats, C5 SCI induced a decrease in hindpaw withdraw threshold to Von Frey filaments. In these animals, PRF therapy caused a significant increase in paw withdraw threshold on post-SCI day 35 (1 week after PRF) with no alteration in motor function. In animals with no neuropathic pain behaviors, PRF did not alter the paw withdraw threshold. No differences in paw withdraw threshold were observed in the sham PRF groups regardless of pain category. **Conclusion:** PRF therapy at the DRG innervating the pain-associated lumbar region may be an effective means to reduce below-level SCI neuropathic pain.

Support: UAB Department of Physical Medicine and Rehabilitation

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Implications of Human Distal Sciatic Nerve Fascicular Anatomy for Ankle Control with Nerve Cuff Electrodes

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Objective: Determine the detailed knowledge of the distal sciatic nerve anatomy required for the design of neural prostheses intended to restore standing balance, prevent footdrop, or provide active propulsion during ambulation. **Design:** A descriptive, nonexperimental study employing quantitative histological and anatomical dissections. **Participants/methods:** 3 complete cadaveric sciatic nerves and branches were dissected from the piriformis to each muscle entry point to characterize the branching patterns and diameters. Fascicle maps were created from serial sections of each distal terminus below the knee through the anastomosis of the tibial and common fibular nerves above the knee. **Results:** Similar branching patterns and fascicle maps were observed across specimens. Fascicles innervating primary plantar flexors, dorsiflexors, invertors, and evertors were distinctly separate and functionally organized in the proximal tibial, common fibular and distal sciatic nerves; however fascicles from individual muscles were not apparent at these levels. **Conclusion:** The fascicular organization is conducive to selective stimulation for isolated and/or balanced dorsiflexion, plantar flexion, eversion, and inversion through a single multicontact nerve cuff electrode. These neuroanatomical data are being used to design nerve cuff electrodes for selective control of ankle movement and improve current lower extremity neural prostheses.

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Development of a Porcine Model of Spinal Cord Injury

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Objective: To establish an intermediary large animal model for preclinical testing of experimental spinal cord injury (SCI) therapies, we have developed a porcine SCI model. **Design:** Animal experimental research. **Methods:** Miniature Yucatan pigs weighing 20-25 kg were subjected to a combined contusion and compression injury at T10/11 using a custom-made weight drop device. By varying the height of the weight drop (5, 10, 20, 30, 40, or 50 cm; n = 4-7 per group), the animals were subjected to varying severities of injury. Behavioral recovery was documented for 12 weeks, and then the spinal cords were harvested and evaluated for white and grey matter sparing and axon profiles. **Results:** Hindlimb recovery over 12 weeks was characterized with a novel behavioral scale. Histologically, there were significantly more axons spared in the 20 cm and 30 cm group compared to the 40 cm group at rostral 4 cm, epicenter, and caudal 4 cm. In addition, performance on the behavioral scale was correlated to the cumulative white matter sparing through the injury site. **Conclusion:** To improve upon the chances of successfully translating effective treatments to human patients with SCI, we have developed a large animal model of SCI to serve as an “intermediary” between the standard rodent models and the human clinical setting. This porcine model of SCI allows for testing of neuroprotective therapies and cell transplantation procedures and can be adopted by any institution with a large animal facility.

Support: This project was funded by the Canadian Stem Cell Network and the CIHR.

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Phenotypical Difference of Circulating Monocytes in Spinal Cord Injury (SCI) Patients

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Objective: Early response to traumatic spinal cord injury (SCI) includes injury site infiltration by macrophages, which are comprised of classically activated (M1) or alternatively activated (M2) subsets. These distinct cell types have differing destructive and repairing capacities. Animal studies have suggested that the M1/M2 ratio at the site of injury relates to spontaneous recovery following SCI. We investigated whether circulating monocytes (MOs), cells that are precursors to tissue macrophages, also developed distinct sub-phenotypes during the acute phase of SCI. **Design:** Cohort study in academic medical center. **Participants/methods:** Clinical data from a prospective cohort of 16 patients, including complete or incomplete traumatic SCI, were collected. A blood sample from each patient was obtained 3 to 7 days post SCI. MO phenotype was determined based on cell surface expression of CD14 and CD16 by flow cytometry. **Results:** We found that the size of the inflammatory CD14+CD16+ MO population in SCI was higher than in the nontrauma reference. There were distinct subsets of patients with different frequencies of CD14 (low)CD16+ and CD14 (high)CD16+ MOs, even after adjustment for comparable injury levels and severity. This result reflects different M1/M2 macrophage ratio in 2 subsets of SCI. **Conclusion:** There are detectable sub-phenotypes of circulating MOs in response to SCI. This may have prognostic utility and may represent an easily accessible biomarker in patients with traumatic SCI. Further studies will determine how these observed phenotypic differences relate to functional recovery.

Support: This project is funded by NIDRR (84.133E3).

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An Ontario-Based Cost-Utility Analysis on the Palliative Care of Patients with Metastatic Spinal Cord Cancer: The Standard of Care Versus Direct Decompressive Surgical Resection Followed by Radiotherapy

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Objective: This economic evaluation compares radiotherapy alone (RT) with decompressive surgery and postoperative radiotherapy (S+RT) for palliative care of metastatic spinal cord compression (MSCC). **Design:** Cost-utility analysis. **Patients/methods:** A cost-utility analysis for both treatment options, based on the randomized clinical trial (Patchell et al, *Lancet*. 2005) was performed from the perspective of a public health care insurer. Ontario-based costs were adjusted to 2010 US dollars. **Results:** The S+RT strategy is more costly but more effective than the RT-alone strategy, with an incremental cost-effectiveness ratio (ICER) of US\$ 240,442.48 per quality-adjusted life year (QALY) gained. The Monte-Carlo simulation revealed that, by adopting the S+RT strategy, there would a reasonable chance (approximately 18.11%) of not paying extra for one additional QALY gained at willingness-to-pay of US\$ 50,000. The acceptability curve showed that at the level of US\$ 1,683,000 per one additional QALY, the proportion of ICERs reached the maximum of 91.11%. **Conclusions:** Given the increasing focus on the provision of cost-effective medical care, our results suggest that a change of the palliative treatment protocols for patients with MSCC toward a S+RT approach is more likely to increase the health care costs. However, the gain in terms of patients' quality of life is relatively significant and should be considered by health care policy makers.

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Neurological Outcome After Fast-Track Surgery (<48 h) in Spinal Cord Compression Caused by Vertebral Metastases

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Objective: To evaluate the influence of time of an early surgical treatment (<48 h) on the neurological outcome in incomplete tetra- or paraplegic patients. **Design:** Retrospective study of 35 incomplete tetra- and paraplegic patients with vertebral metastases causing spinal cord compression. **Setting:** Spinal Cord Injury Center, Heidelberg University Hospital, Heidelberg, Germany. **Methods:** Data of 35 patients who fulfilled the criteria of vertebral metastases, spinal cord compression (confirmed by magnetic resonance imaging), and operation were reviewed. These patients were selected into group 1 when surgery was performed within 48 hours after appearance of tetra- or paraplegia and in group 2 when surgery was performed in an interval after 48 hours up to several weeks. All patients were classified among the American Spinal Cord Injury Association Impairment Scale (AIS) preoperatively

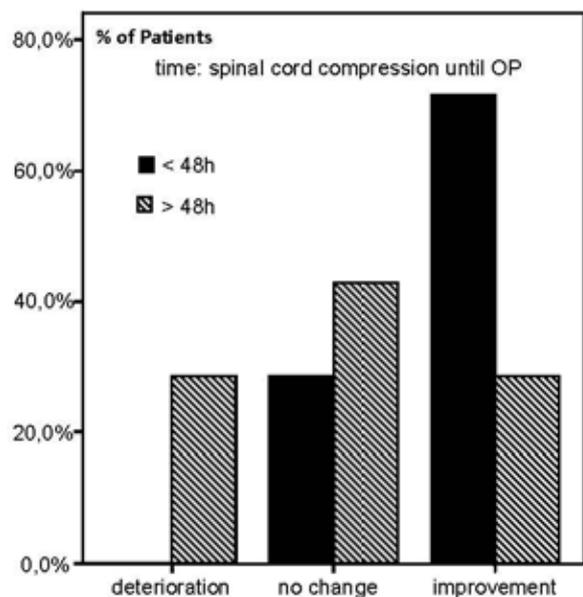


Figure. Percentage (%) of patients who showed in the interval spinal cord compression until operation (<48 h, >48 h) changes in the AIS at T02.

(T0), postoperatively (T1), and at follow-up (T2) 4 to 6 weeks postoperatively. A modified SCIM was performed to evaluate mobility pre- and postoperatively. Data was analysed with SPSS 15.0, and chi-square statistics (exact tests) were computed. **Results:** The pre- and postoperative AIS in group 1 showed improvement in 15 (71.4%), no change in 6 (28.6%), and no deterioration (0%) compared with group 2 who showed improvement in 1 (7.1%), no change in 10 (71.5%), and deterioration in 3 (21.4%) patients ($P = .021$). The same association was found in analysis of preoperative and follow-up AIS ($P = .010$). Modified SCIM showed that 17 (80.9%) of patients maintained or improved their mobility status, whereas 4 (19.1%) of group 1 patients showed deterioration. **Conclusion:** In patients with spinal metastases, an early surgical treatment within the first 48 hours after incomplete tetra- or paraplegia influences sensomotoric function and contributes to improvement of quality of life even in a palliative situation.

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Incidence and Impact of Acute Adverse Events in Patients with Traumatic SCI

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Objective: To determine the incidence and types of adverse events (AEs) occurring in patients with traumatic spinal cord injury (tSCI) during acute care and the impact on length of stay (LOS) and health status. **Design:** Prospective cohort. **Participants/methods:** Patients with tSCI discharged from Vancouver General Hospital between 2008-2009 were identified using the Rick Hansen SCI Registry (RHSCIR). Patient data were obtained from RHSCIR; AE data were collected prospectively using the Spine Adverse Events Severity form. Multivariate analyses were performed to determine whether patient and injury characteristics were associated with number and type of AEs experienced and whether these were associated with LOS and Short Form-36 (SF-36) scores. **Results:** 110 patients with tSCI were included, 78.2% were male, and mean age at injury was 45.8 ± 19.6 years. Follow-up ranged from 11 to 27 months post injury. AEs occurred in 83.6% of patients; 20.0% experienced an intraoperative and 79.1% experienced a pre-/postoperative event. The

most frequent pre-/postoperative events were urinary tract infections (UTIs) (36.5%), pneumonias (34.6%), postoperative neuropathic pain (22.1%), pressure sores (19.2%), and delirium (18.3%). LOS was significantly impacted by pressure sores, delirium, pneumonias, and UTIs ($P < .01$), increasing 1.8 (UTIs) to 2.2 (pressure sores) times compared to patients without the AE. SF-36 mental component score was significantly reduced in patients with UTIs ($P < .05$). **Conclusion:** Over 83% of patients with tSCI sustain an AE during acute admission, which is higher than previously reported. AEs result in significant costs to the health care system, and there is a need to prospectively monitor and prevent them.

Support: Funded by RHI and Health Canada

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Short-Segment Pedicle Instrumentation by Indirect Reduction Without Vertebroplasty for Thoracolumbar Burst Fractures

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Objectives: Thoracolumbar burst fractures are the most common spine fracture treated surgically. Management for these fractures remains a matter of discussion. We evaluated the surgical results of thoracolumbar burst fractures with short-segment pedicle screw fixation without vertebroplasty. **Design:** Prospective consecutive series. **Participants/methods:** This study includes 20 patients with thoracolumbar burst fracture (T11-L3) who underwent surgery by ligamentotaxis procedure using Schanz screws alone. Their implants were removed around 1 year after operation. We measured local vertebral body angle (VBA) and superior-inferior endplate angle (SIEA) before and just after operation, approximately 1 year after initial operation and 6 to 12 months after removal. **Results:** Operation was performed 0 to 9 (mean 3.9) days after injury. Mean operating time and blood loss was 104 minutes and 143 mL. VBA was corrected 9.8° after operation; correction loss was 0.6° before removal and deteriorated 0.4° after removal on average. SIEA was corrected 11.4° after operation; correction loss was 3.3° before removal and deteriorated 7.6° after removal on average. These results mean that kyphosis was advanced by loss of disc height and/or disc degeneration after implant removal though the vertebral body itself did not collapse. **Conclusion:**

Correction loss in fractured vertebra itself was slight, and there was no breakage and/or back-out of instrumentation due to advance of collapse in fractured vertebral body. Meanwhile, correction loss of SIEA was 10.9° and was caused by disc degeneration. No patient had back pain that interrupted their work or ADL after removal and no correlation could be found between correction loss of SIEA and back pain.

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Factors Associated with Outcomes of Patients Who Develop Nontraumatic Spinal Cord Injury Due to Spinal Hemorrhage During Thromboprophylaxis Treatment

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Objective: This study examines the potential factors associated with spinal hematoma among patients who develop central nervous system (CNS) hemorrhage while on thromboprophylaxis treatment. **Design:** Pooled data from a systematic review. **Patients/methods:** 3 reviewers screened publications and extracted data on all cases of a CNS hemorrhage. First, all cases were grouped into brain, posterior fossa, and spinal hemorrhage. Second, the spinal-hemorrhage group was subdivided into complete neurological recovery, incomplete neurological recovery, no neurological recovery, and death. **Results:** Data were extracted from 63 publications detailing 497 patients. The CNS groups were comparable regarding age, sex, prior history of trauma and hypertension, and indication for thromboprophylaxis. Spinal-hemorrhage group had greater antiplatelet use ($P = .014$), lower frequency of supratherapeutic thromboprophylaxis ($P = .03$), later restarting time of thromboprophylaxis ($P = .035$), and more frequent indication for surgery ($P = .001$) than the other CNS groups. All CNS groups were comparable regarding posttreatment complications and functional outcomes. Additionally, outcomes among the spinal-hemorrhage subgroups were not associated with sex, prior trauma, indication of thromboprophylaxis, type of thromboprophylaxis, status of thromboprophylaxis, and management of the CNS hemorrhage and its complications. Nonetheless, individuals who survived

after the management of spinal hemorrhage were older than those who died ($P = .015$). **Conclusions:** Our results suggest that individuals with spinal hemorrhage were treated differently from patients with other CNS hemorrhage. However, site of CNS hemorrhage did not affect the frequency of posttreatment complications and functional outcome. None of the studied factors were associated with outcomes after spinal hemorrhage, but younger individuals were more susceptible to succumb.

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Clinical Results of Surgical Management in Type II Odontoid Fracture

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Objective: The surgical management of type II odontoid fracture remains controversial. This study was conducted to evaluate therapeutic effectiveness of surgical approaches in type II odontoid fracture. **Design:** All patients who underwent surgery for type II odontoid fracture in the neurosurgical units of Mashhad University during 4 years were reviewed retrospectively. **Participants/methods:** 9 patients with anterior screw fixation (ASF) and 20 patients with posterior approaches (PA) were reviewed. Patient demographics, clinical presentation, length of hospital stay, operation time, injury severity score (ISS), preinjury Charlson comorbidity index, fusion rate, and surgical complications were analyzed in these 2 groups. **Results:** Neck pain was the most common clinical presentation in these 2 groups (89.7%). There were no significant differences in ISS and mean length of hospital stay between the groups. Comorbidity index (0.22 in ASF vs 0.9 in PA) and the operation time were different between ASF and PA (56 minutes vs 118 minutes; $P < .05$). There was no major complication related to operation in these 2 groups. Bone union was documented in 8 patients (89%) with ASF and 17 patients (85 %) with PA. **Conclusion:** Surgical management of type II odontoid fracture by both anterior and posterior approaches have shown good outcome in the patients are potential candidates for surgery. In our patients, comorbidity index and the operation time are different in the 2 groups, but differences in fusion rate, length of hospital stay, and

postsurgical complications are not considerable. A long-term follow-up is needed to confirm highly precise results in these 2 groups.

Support: Grant from the Vice-Chancellor for Research at Mashhad University of Medical Sciences

Awards Posters

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Community Needs of People Living with Spinal Cord Injury and Their Family

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Objective: Identify the needs of people living with a spinal cord injury (SCI) and those of their family members the first year post rehabilitation. **Design:** Prospective telephone surveys. **Participants/methods:** Individuals with SCI who have returned to their community the first year after discharge and one family member. Structured interviews with specific questionnaires for both groups. **Results:** 35 individuals with SCI and 21 family members completed the questionnaires. Main needs identified by people with SCI are SCI specialised health care (89%), income support (83%), equipment and technical aids (71%), adapted transport (66%), home support (60%), and adapted housing (60%). For nearly half of the participants, these needs are met. However, other needs less frequently mentioned by participants are often unmet. For example, 51% need support for sport and leisure activities, but only 33% say their need is met. Likewise, 40% of participants have employment, education, and training needs, but only 21% feel these needs are met. For family members, the most frequently mentioned need is for information on social programs and services (52%), however it is met for only 9%. Globally, results show that support from friends and family is an important way in which needs are met. Chi square analyses show a relation between severity of injury and the need for equipment and technical aids, adapted housing, and transportation. **Conclusion:** Many needs of people with SCI and their family members are not met in the first year post

rehabilitation. It is important to better address these needs in order to help them return to their activities and social roles.

Support: This project was funded by the Fonds de Recherche en Santé du Québec.

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Perceived Exercise Barriers and Odds of Exercise Participation Among Persons with SCI Living in High Income Households

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Objective: To define the prevalence of and the degree to which exercise barriers decrease odds of exercise participation among persons with SCI reporting annual household income >\$50,000. **Design:** Cross-sectional. **Participants/methods:** 180 individuals completed a Web survey of personal characteristics and exercise barriers. Over half (n = 89) reported annual household incomes >\$50,000. Chi square and Mann-Whitney *U* identified personal characteristic differences between exercisers and nonexercisers. Odds ratios (OR) determined barriers that decreased odds of exercise participation. Significance was set at $\alpha < 0.05$. **Results:** 87% of respondents were currently exercising (n = 61). No differences discriminated exercisers and nonexercisers by gender, age, race, age at injury, injury level or completeness, education level, and total comorbidities or medications. A higher percentage of exercisers were full-time employed or married. Nonexercisers reported more barriers (4.9 ± 2.4 vs 2.21 ± 1.8). The 5 most prevalent barriers were lack of time (43%), lack of motivation (41%), lack of energy (37%), don't know where to exercise (32%), and program cost (29%). The 5 most impactful barriers were (OR) too lazy to exercise (19.0), lack of motivation (8.9), don't know how to exercise (8.3), lack of interest (5.7), and exercise is boring (4.3). Only 1 barrier was highly prevalent and impactful (lack of motivation). The most impactful barrier, "too lazy to exercise," was the ninth most prevalent barrier (14%). Persons reporting this as a barrier were 19 times less likely to be exercising. **Conclusion:** Among high income households, highly prevalent barriers may not decrease odds of exercise

participation. Knowledge and psychological barriers had the greatest impact on odds of exercise participation.

Support: NIDRR field-initiated grant #H133G080150

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Acromio-clavicular Joint Arthrosis in Persons with Spinal Cord Injury and with Shoulder Pain Compared to Able-Bodied Persons with Shoulder Pain

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Objective: To describe the prevalence and severity of acromio-clavicular joint arthrosis (AC-joint) in persons with spinal cord injuries (SCI) presenting with shoulder pain compared to able-bodied persons. **Design:** Retrospective study. **Participants/methods:** Wheelchair-dependent persons with SCI and a random sample of able-bodied persons who presented themselves with shoulder pain at the outpatient clinic between 2007 and 2010. Shoulder AC-joint arthrosis prevalence was diagnosed with shoulder MRI and severity classified (Shubin-Stein Grade 1-4). **Results:** 71 persons with SCI and 107 able-bodied persons. Persons with SCI were in 77.5% men, 73.2% paraplegic, and 80.3% American Spinal Injury Association Impairment Scale (AIS) A, 8.5% B, 7.0% C, 2.8% D, and 1.4% unknown. Mean age was 51.8 years and mean time since injury (TSI) was 23.5 years. Able-bodied persons were mostly men (65.4%) with a mean age of 52.2 years. In the SCI population, 1.4% were diagnosed AC-joint arthrosis grade 1, 16.9% grade 2, 33.8% grade 3, and 47.9% grade 4. Older age and a longer TSI are associated with a more severe grade of shoulder AC-joint arthrosis (grade 3 or 4). Level and completeness of injury and gender showed no significant relation with severity of arthrosis. In the able-bodied population, AC-joint arthrosis was diagnosed in 9.3% grade 1, 24.3% grade 2, 45.8% grade 3, and 20.6% grade 4. **Conclusion:** AC-joint arthrosis is more severely graded in persons with SCI compared to the able-bodied population. In the SCI population, elderly and those with a longer TSI are at risk to develop more severe AC-joint arthrosis.

Support: None

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Genetic Polymorphisms May Influence the Development and Healing of Sitting Acquired Pressure Ulcers Following Spinal Cord Injury

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Objective: Determine associations between genetic polymorphisms and the development of chronic wounds. Determine possible associations between genetic polymorphisms and the development of sitting acquired pressure ulcers (SAPUs) following spinal cord injury (SCI). **Design:** Case control studies of subjects with venous ulceration. Prospective cohort study of the development of SAPUs following SCI (ongoing). **Participants/methods:** Venous studies: 181 subjects with venous ulcers and 181 control subjects; 241 subjects with previous deep vein thrombosis (DVT); and 119 subjects with varicose veins and 107 subjects with varicose veins and venous ulcer. Current SCI project: 480 subjects with SCI followed for 3 years to assess association with SAPU development. **Results:** Polymorphism in tumour necrosis factor-alpha promoter (308) (TNF- α 308) was associated with venous ulcers when compared to the control group; polymorphism in TNF- α 308 and fibroblast growth factor receptor type 2 were associated with ulcer development in subjects with varicose veins; and hemochromatosis gene polymorphism (HFE) and prothrombin gene mutation (G20210A) were associated with ulcer development following DVT. Recruitment of subjects with SCI is ongoing to determine associations between genetic polymorphisms and the development of SAPUs in this population. **Conclusion:** Genetic polymorphisms have been shown to be associated with the development of chronic wounds and are being evaluated in a prospective study of subjects with SCI to determine possible associations with SAPUs. Genetic polymorphisms may also have an association with wound healing.

Support: Financial support for this work is provided by the National Health and Medical Research Council (Australia) Project grant 634388, the Ontario Neurotrauma Foundation, and the Co-operative Research Centre for Wound Management Innovation (Australia).

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Lab Abnormalities with Late Stage Pressure Ulcers: Are They Really Significant?

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Objective: Investigate the relationships of abnormal lab values of albumin and prealbumin compared to elevated erythrocyte sedimentation rates (ESR) and C reactive proteins (CRP) that are commonly observed with severe pressure ulcers. **Design/methods:** A retrospective chart review of 179 consecutive pressure ulcer surgeries/admissions over a 5-year period at a single institution using the same protocol. **Results:** The mean subject age was 49.4 years. Of the 179 ulcers, 49.7% were ischial, 26.8% sacral, 19% trochanteric, and 4.5% in other locations. 110 surgeries had surgical and discharge albumin and prealbumin values while 80 also ESR and CRP values. From admission to discharge (3 weeks), there was an increase in prealbumin (normal range, 18-42) of 11.6 to 19.3 mg/L and albumin (normal, 3.5-5.7) of 2.99 to 3.29 g/L (both P s < .0001) and a decrease in ESR (normal, 0-15) 81.7 to 64.0 and CRP (normal, 0-0.5) 8.17 to 1.50 (both P s < .0001). The correlations between prealbumin and albumin with ESR were statistically significant at admission, -0.56 and -0.65 (both P s < .0001) and at discharge, -0.29 (P = .015) and -0.36 (P = .0037). There were statistically insignificant correlations between prealbumin (-0.19, P = .099) and albumin (-0.11, P = .33) with CPR at admission. At discharge, CPR did correlate with prealbumin (-0.23, P = .036), but not albumin (-0.05, P = .68). The correlations with wound healing problems and discharge were not significant for ESR (0.5415) or CRP (0.09). The admission prealbumin (P = .2) and albumin (P = .43) also did not correlate with recurrence. **Conclusion:** There is strong evidence that albumin and prealbumin are not good nutritional markers with chronic pressure ulcers but are correlated with the commonly elevated ESR and CRP. Prospective research is needed to determine the predictive value for healing by the use of ESR and CRP.

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How Nutritional Risk Is Assessed and Managed in Patients with Spinal Cord Injuries (SCI): Result from a UK Multi Centre Study

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Introduction: Recognition and treatment of malnutrition (under-/overnutrition) in patients with spinal cord injury (SCI) in SCI centres (SCIC) are not often a priority in clinical practice.¹ **Design:** Prospective, multicentre observational study. **Objectives:** The aims of the study were to (1) investigate how nutritional risk of patients is determined across 12 SCIC in the UK and Ireland; and (2) assess the prevalence of malnutrition using a validated nutrition screening tool (NST), Malnutrition Universal Screening Tool² (MUST), and body mass index (BMI). **Methods:** On admission, the MUST score, baseline clinical data, anthropometric measurements, and blood biochemistry were assessed. Differences between independent groups were assessed with Mann-Whitney test. The risk of undernutrition was defined from MUST score ≥ 1 ; overweight was defined as BMI ≥ 25 and obese as BMI ≥ 30 . **Results:** 11/12 SCIC participated in part 1 of the study, 8 used NSTs, 3 had no dedicated staff member for nutritional care, and 9 units reported they did not have a clinical nutrition team. 4 SCIC, comprising 49% of the total SCI beds in the UK, participated in part 2 of the study during July 2009 to March 2010. 150 patients (aged 18-88, median: 16.9; 30.7% female) were studied after obtaining written informed consent. On admission, 45.9% of patients were overweight and 15.3% were obese; the prevalence of undernutrition was 44.3%. Patients who were at risk of undernutrition were found to have significantly reduced total protein, albumin, magnesium, creatinine, haemoglobin, BMI, and appetite and have significantly higher C-reactive protein and received more prescribed medications. **Conclusions:** The present study shows that malnutrition is common in patients with SCI. The process of nutrition risk assessment varied between SCIC and may lead to underdetection and undermanagement. More effort is needed to implement nutrition screening in daily clinical practice. Further

research on the best combinations of simple clinical indices relevant to patients with SCI is warranted.

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Planning and Structuring Spinal Cord Injury Rehabilitation: The Needs Assessment Checklist (NAC)

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Objectives: To evaluate the Needs Assessment Checklist (NAC) as a clinically appropriate assessment tool for use when planning spinal cord injury (SCI) rehabilitation.

Design: Measurement evaluation. **Setting:** Tertiary care, specialist SCI centre (National Spinal Injuries Centre, Stoke Mandeville Hospital, UK). **Participants/Method:** Psychometric analysis of data obtained during routine clinical assessments from 193 patients admitted to the NSIC during the period September 2007 to November 2009. **Results:** Reliability analyses yielded high internal consistency coefficients (mean $\alpha = .889$, SD 0.051) with all subscales scoring higher than the specified level (0.7). Mean item internal validity correlation was .534 (SD .136). All subscales of the NAC were found to be highly significant to change between administrations (mean $P < .001$). Females were more satisfied than males with the information received on changes in sexual function post SCI; younger patients scored higher on Wheelchair and Equipment and Discharge Coordination; patients with less physical mobility scored significantly lower on Physical Health Care, Activities of Daily Living, and

Bowel Management subscales. There was a significant relationship between pain severity and mood, and those finding pain to interfere with rehabilitation at the first NAC had lower mobility scores on the second NAC. Scores on Psychological Issues were significantly related to scores on ADLs, Skin Care, and Mobility. Questions in the NAC regarding pain interference and sexuality issues highlighted patient concerns; subsequent results suggested improved patient satisfaction.

Conclusion: The NAC is demonstrated to be clinically reliable assessment tool that can be used to structure rehabilitation progress, generating person-centred goals to suit the needs of the individual. The results highlight the importance of assessing psychological issues and pain as this may affect rehabilitation progress.

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Wheelchair Skill Performance of Manual Wheelchair Users with Spinal Cord Injury

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Objective: To examine wheelchair skill performance of manual wheelchair users with spinal cord injury (SCI). **Design:** Cross-sectional. **Participants/methods:** Individuals with traumatic SCI who were at least 1 year post injury, treated at a Model Spinal Cord Injury System (MSCIS), used a manual wheelchair as their primary means of mobility and were nonambulatory except for exercise purposes completed questionnaires (for demographic data) and the Wheelchair Skills Test (v 4.1). 212 participants (168 male, 44 female) from 6 MSCIS participated in this multisite study. Of the participants, 154 had paraplegia, 56 tetraplegia, and level of injury was unknown in 2. The mean age of participants was 38.8 ± 12.2 years and time post injury was 11.1 ± 10.6 years. **Results:** 70.8% (68.8% paraplegia, 76.8% tetraplegia) of participants were unable to ascend and 49.5% (47.4% paraplegia, 55.4% tetraplegia) were unable to descend a 15 cm curb. 39.2% of participants (35.7 % paraplegia, 48.2% tetraplegia) were unable to maintain a stationary wheelie position for 30 seconds.

In addition, over 10% of the participants were unable to successfully complete the following skills: navigate over a 15 cm pothole, ascend a 5 cm level change, turn 180 degrees in a wheelie position, get from the ground to their wheelchair, fold and unfold their wheelchair, and ascend and descend stairs. **Conclusion:** Although wheelchair skills are important for enabling manual wheelchair users to safely and effectively negotiate mobility tasks that they encounter in their natural environments, many of the manual wheelchair users with SCI whom we studied had difficulty performing community- and advanced-level skills. These findings suggest that additional wheelchair skills training may be advantageous.

Support: This project was made possible by funding through the National Institute of Disability and Rehabilitation Research of the US Department of Education (H133N060019, H133N060028, H133N060014).

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Pushrim Kinetics During Advanced Wheelchair Skills in Manual Wheelchair Users with Spinal Cord Injury

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Objective: To assess the peak force during wheelchair propulsion of individuals with spinal cord injury propelling over obstacles from the Wheelchair Skills Test. **Design:** Prospective study. **Participants/methods:** 23 individuals with spinal cord injury who are full time manual wheelchair users were included in the study. A SmartWheel was used to analyze each push while subjects negotiated standardized obstacles used in the Wheelchair Skills Test including tile, soft surface, 5° and 10° ramps, and 2 cm, 5 cm, and 15 cm curbs. **Results:** The mean peak pushrim force generated on 10 m level tile was 101 N and increasing the distance to 100 m the mean peak force was 124 N. The soft surface required 148 N of force. The 5° and 10° ramps required a mean peak force of 138 N and 157 N. Negotiating over a 2 cm, 5 cm, and 15 cm curb, respectively, required 119 N, 155 N, and 232 N of force. When the peak forces

generated to cross all obstacles were compared to the 10 m tile, there was a statistically significant increase in all peak forces (*P* value ranged from .0001 to .0268). **Conclusion:** Advanced wheelchair skills require an increase in force to accomplish each task. The increase in forces ranged from 18% to 130% over that required for level 10 m tile. Past research has identified high peak forces during wheelchair propulsion as a factor contributing to shoulder pain.

Support: National Institute on Disability and Rehabilitation Research, US Department of Education (H133N060017)

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Therapeutic Anti-Nogo-A Antibodies in Acute Spinal Cord Injury: Safety and Pharmacokinetic Data from an Ongoing First-in-Human Trial

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Objective: Nogo-A, a potent inhibitor of neurite growth, severely restricts regeneration and plasticity after central nervous system injury. This ongoing clinical study investigates the technical feasibility of administering the anti-Nogo-A antibody ATI355 intrathecally to patients with very recent spinal cord injury, as well as the safety and pharmacokinetics of ATI355. **Design:** Open-label, multicenter, multiple-cohort study of ATI355 administered as a continuous intrathecal (i.t.) infusion by external pump or as repeated manual i.t. bolus injections. **Participants/methods:** Paraplegic and tetraplegic patients with neurologically complete thoracic or cervical lesions (C5 ≤ lesions ≤ T12) began ATI355 treatment 4 to 28 days post injury. Patients in the first 4 of the 6 cohorts received 5-30 mg/d ATI355 by continuous i.t. infusion for 1, 14, or 14 to 28 days. The fifth and sixth cohorts received 6 i.t. bolus injections of 22.5 mg or 45 mg

ATI355 per injection, respectively, over 4 weeks. **Results:** To date, 51 patients have been treated, 23 by infusion and 28 by bolus injection. ATI355 was well-tolerated overall, with no deaths or ATI355-related serious adverse events (SAEs) reported. Except for 1 moderate skin rash observed approximately 3 days after an initial i.t. bolus injection and investigator-rated as potentially related to study medication, no AEs led to ATI355 discontinuation. Most AEs were mild to moderate and classified as not related to study medication. Infection SAEs ($n = 2$) and mechanical-device complications ($n = 3$) occurred in the infusion-treated groups but none in the bolus-injection groups. ATI355 concentrations declined slowly in serum, with a terminal half-life of about 2 to 3 weeks; estimated half-life in cerebrospinal fluid (CSF) is 2 to 3 days. **Conclusion:** No ATI355-related safety concerns have been reported to date. In comparison to continuous i.t. infusion, repeated i.t. bolus injection appears to improve treatment safety and is supported by pharmacokinetic data demonstrating relevant CSF exposure.

Support: Novartis Pharma AG, Basel, Switzerland

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Proposed International Classification of Pain after Spinal Cord Injury: Preliminary Validation Data

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Objective: To evaluate a newly developed consensus classification of SCI pain by assessing the ability of SCI clinicians who are not pain specialists to assign pain described in a vignette to the correct classification category. **Design:** Internet-administered survey. **Participants/methods:** 47 physicians and other clinicians, mostly members of ASIA and/or ISCoS. Clinicians were randomly assigned to 1 of 3 groups and were asked to classify the pain for 25 vignettes, for a total of 75 vignettes evaluated by at least 14 persons each. The pain type assignments of the SCI pain specialists who developed the classification constituted the gold standard for assessing correctness of classification assignments. The classification offers 10 pain types (including 3 “unknown” categories) and allows for describing pains as having 2 components described with 2 types. **Results:** On a 1 to 5 scale, confidence in type assignments for 1-component pains was 4.0 on

average; for 2-component pains, it was 3.5. Of 1,175 vignettes (47x25), 35.4% were coded incorrect, 62.6% coded correct, and 2.0% were left blank (no pain type assignment); however, investigation of notes of the respondents who left the type blank suggested that frequently they understood what the pain generator, pathology, or syndrome was but failed to assign the correct classification pain type. **Conclusion:** Further analysis is needed to determine whether missing or incorrect type assignments, in spite of generally high confidence in decisions, stems from a problem with the classification and its explanation itself or is an artifact of the mode of administration.

Support: The Paralyzed Veterans of America supported the creation of the new SCI pain classification, and this first evaluation of its utility.

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MRI of Pressure Sores in Spinal Cord Injured Patients

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Objective: Identify key MRI features that have a significant correlation with osteomyelitis of pressure ulcers in spinal injury patients. **Design:** Retrospective review study. **Participants:** Adult patients admitted to the National Spinal Injuries Centre with spinal cord injury and signs of pressure ulceration investigated with MRI. **Methods:** Analysis of MRI examinations and clinical records collected over a 4-year period. Images were independently assessed by 2 experienced radiologists for osteomyelitis based on assigned predictive indicators including cortical bone erosion, soft tissue oedema, deep collections, heterotopic new bone, hip effusion, and abnormal signal change of the marrow. **Results:** 37 patients underwent 41 MRI scans. 41% demonstrated definite signs of osteomyelitis; acute cortical erosion and deep collections were seen in approximately one-third of patients (38% and 31%, respectively); soft tissue oedema was the most prevalent feature (86%); heterotopic new bone 16%; hip effusion 28%; abnormal marrow signal was more prevalent on the STIR sequences (75%) compared to the T1-weighted images (53%). There was a significant association between the prevalence of osteomyelitis and cortical bone erosion (Pearson's $r = 0.84$) as well as between osteomyelitis and abnormal marrow

oedema on T1-weighted images ($r = 0.82$), There was a positive but weaker correlation between osteomyelitis and soft tissue oedema ($r = 0.26$). Deep collections, heterotopic new bone formation, and hip effusion were not of significant predictive value in assessing the risk of osteomyelitis. **Conclusion:** Acute cortical bone erosion and abnormal marrow oedema, in particular on the T1-weighted images, have a strong correlation with osteomyelitis in spinal patients with pressure ulcers.

Support: Thames Valley CLRN

Oral Presentations

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Agreement of Repeated Motor and Sensory Scores at Individual Myotomes and Dermatomes in Young Persons with Incomplete Spinal Cord Injury

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Objective: Evaluate intrarater and interrater agreement of repeated motor and sensory scores at individual spinal levels. **Design:** Part of a larger cross-sectional study to determine reliability at individual spinal levels when applied to young persons. **Participants/methods:** 92 youth with incomplete spinal cord injury (SCI) underwent 4 neurological exams by 2 different raters. Agreement between and within raters for each myotome and dermatome was evaluated for 4 neurological groups: C1-C4 ($n = 47$); C5-T1 ($n = 16$); T2-T7 ($n = 16$); T8-L2 ($n = 13$). Intraclass correlations coefficients (ICCs) and 95% confidence intervals (CIs) were calculated. **Results:** Intrarater: 75 and 50% high agreement (HA) (>0.9) resulted in high (C1-C4) and low (C5-T1) tetraplegia, respectively, with 70 and 40% of myotomes having HA in high (T2-T7) and low (T8-L2) paraplegia, respectively. Pin prick (PP) = poor agreement (PA) (<0.75) in high (93%) and low (82%) tetraplegia and high (60%) and low (61%) paraplegia. LT = PA in high (80%) and low (58%) tetraplegia and high (25%) and low (57%) paraplegia. Interrater: 75 and 55% HA was found in myotomes in high and low tetraplegia subjects, respectively, with 80 and 40% HA in high and low paraplegia respectively. PP = PA in high (95%) and

low (76%) tetraplegia and high (60%) and low (68%) paraplegia. LT = PA in high (66%) and low (44%) tetraplegia and high (25%) and low (64%) paraplegia. **Conclusion:** Overall, HA was found for muscle strength comparisons and PA was found for PP and LT.

Support: Shriners Hospitals for Children Research Advisory Board grant 8956

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Prevalence of Risk Factors for Metabolic Syndrome Among Youth with Spinal Cord Injury

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Objective: Determine the prevalence of metabolic syndrome risk factors in youth with SCI and the relationship between BMI and trunk fat. **Design:** Retrospective chart review.

Participants/methods: Charts were reviewed from all SCI patients admitted to one pediatric SCI unit between January 2007 and September 2009. The prevalence of metabolic risk factors reviewed included: % trunk fat (DXA) >30 male, >35 female; high-density lipoprotein (HDL-C) <45 mg/dL male, <50 mg/dL female; triglyceride levels >100 mg/dL; fasting serum glucose levels ≥ 100 mg/dL; and blood pressure ≥ 95 th percentile for height, age, and gender. **Results:** Of the 85 youth, ages 3-20 years (58% male, 67% paraplegia), the mean number of metabolic risk factors was 1.8 (SD ± 1.2), and 23 subjects (27%) had metabolic syndrome. Trunk fat was strongly correlated with BMI for both males ($r = 0.68$, $P < .01$) and females ($r = 0.64$, $P < .01$). There was not a significant association between level of injury and a BMI ≥ 85 th percentile ($\chi^2 = 1.12$, $df = 1$, $P = .29$), BMI ≥ 95 th percentile ($\chi^2 = 0.56$, $df = 1$, $P = 0.45$), or high trunk fat (males: $\chi^2 = 0.03$, $df = 1$, $P = .86$, females: $\chi^2 = 0.04$, $df = 1$, $P = 1.00$). There was an association between those who had ≥ 3 metabolic syndrome risk factors and BMI ≥ 85 th percentile ($\chi^2 = 14.9$, $df = 1$, $P < .01$) and BMI ≥ 95 th percentile ($\chi^2 = 22.9$, $df = 1$, $P < .01$). **Conclusion:** The prevalence of metabolic syndrome is significant in youth with SCI highlighting the need for early identification and intervention. Further research with a larger study population is needed to better delineate BMI standards to define overweight and obesity in youth with SCI.

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Outcomes of Traumatic and Non-Traumatic Spinal Cord Injury in Children

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Objective: Examine differences in outcomes between youth with traumatic and non-traumatic spinal cord injuries (SCI). **Design:** Cross-sectional survey. **Participants/methods:** 416 youth with SCI ages 1-18. When old enough, youth completed measures of quality of life (QOL; age 5), participation (age 6), and mental health (age 7). For all youth, caregivers completed a demographics form, and injury-related information was gathered from medical records. Comparisons were made between youth with traumatic (vehicular/pedestrian, violence, fall/flying object, sports) and non-traumatic (medical/surgical) injuries using analysis of covariance. **Results:** 273 youth (66%) had traumatic injuries: 57% male, average age 13.16 years (*SD* 4.39), 65% paraplegia, 68% complete injuries, and average age at injury 9.02 years (*SD* 5.65). 143 youth (34%) had non-traumatic injuries: 56% male, average age 9.24 years (*SD* 5.15), 67% paraplegia, 27% complete injuries, and average age at injury 3.74 years (*SD* 5.06). Youth with traumatic injuries were significantly older at interview ($P < .001$) and injury ($P < .001$) and were more likely to have complete injuries ($P < .001$). After controlling for age and injury severity, youth with traumatic injuries participated in fewer activities ($P = .030$) and reported lower school QOL ($P = .022$). There were no differences on mental health measures, yet caregivers of youth with traumatic injuries reported their children were more likely to be receiving counseling/psychiatric services ($P = .049$) and taking medications for emotional, psychological, or behavioral reasons ($P = .002$). **Conclusion:** There are differences in outcomes between youth with traumatic and non-traumatic injuries. Attention should be paid to the nature of injury in pediatric rehabilitation.

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Effects of Cycling on Bone and Muscle in Pediatric Spinal Cord Injury

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Objective: Determine the effect of cycling with and without functional electrical stimulation (FES) on bone mineral density (BMD), muscle volume, and stimulated strength in children with spinal cord injury (SCI). **Design:** Randomized controlled trial. **Participants/methods:** 30 children, ages 5 to 13 years, were randomized to FES cycling (FESC), passive cycling (PC), or electrically stimulated exercise (ES) and exercised 1 hour, 3 times per week for 6 months. BMD was examined via dual-energy x-ray absorptiometry (DXA), muscle volume via magnetic resonance imaging (MRI), and isometric stimulated strength on a computerized dynamometer. **Results:** The FESC group increased in hip, distal femur, and proximal tibia BMD of 32.4%, 6.62%, and 10.3%, respectively. The PC group increased at the hip (29.2%) but not at the distal femur (1.5%) or proximal tibia (-1.0%). The ES group had no change at the hip (-0.24%) and distal femur (3.3%) and declined at the proximal tibia (-7.06%). Normalized muscle strength increased in the quadriceps (FES 103.7%, PC 28.9%, ES 86.3%) but decreased in the hamstrings (FES 11.9%, PC 26.5%, ES 36.1%). Normalized muscle volume increased for the quadriceps (FES 17.3%, PC 4.7%, ES 16.8%) and hamstrings (FES 13.3%, PC 0.5%, ES 23.3%). There were no differences between groups over time, and the only significant within-group change was hip BMD for the FESC group. **Conclusion:** Although statistical significance was not obtained, some gains made were greater than anticipated due to growth. Variability was large between subjects, which decreased the overall study power.

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Change in Socio-Economic Status Related to Psychosocial Factors Among Youth with Spinal Cord Injury

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Objective: Examine relationships between changes in financial situation and psychosocial factors of youth with spinal cord injury (SCI) and their caregivers.

Design: Outcomes research. **Participants/methods:** Participants were 167 youth ages 2-20 years with SCI and their caregivers. Youth completed the Pediatric Quality of Life Inventory (PedsQL), Revised Children's Manifest Anxiety Survey, and Children's Depression Inventory. Caregivers completed the parent-report PedsQL, Beck Anxiety Inventory, Beck Depression Inventory, and a project-specific demographics questionnaire including a question about the family's financial situation over the past year. Independent-samples *t* tests evaluated differences between participants reporting no change and participants indicating a financial change for the worse. **Results:** Participants were 56% male, average age at interview was 12.27 years (*SD* 4.84), 70% had paraplegia, and average age at injury was 6.21 years (*SD* 5.67). 82% of primary caregivers were mothers, 12% fathers, 5% grandmothers; 63% had some college experience. Of the 167 participants, 97 (58%) had no financial status change. Of the 70 (42%) who reported a change, only 49 indicated the type of change with 45 (92%) stating that their financial situation had worsened. Change in financial situation was related to 5 outcomes. Those reporting a worse financial status had lower parent-report of child social QOL [$t(135) = 2.52, P = .013$], higher child anxiety [$t(47) = -2.40, P = .020$], increased child depression [$t(36) = -2.32, P = .026$], higher caregiver anxiety [$t(132) = -2.36, P = .020$], and increased caregiver depression [$t(131) = -2.03, P = .044$]. Interestingly, financial changes showed no relationship to any demographic or injury-related factors. **Conclusion:** Change in financial situation and financial stressors within the family system affect both parent and child outcomes.

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Prevalence of Malnutrition in Paediatric Patients Admitted to UK Spinal Injury Centre: A Pilot Result

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Introduction: Childhood malnutrition needs to be addressed in all forms of common agenda as it affects growth and development, increases susceptibility of nutrition-related complications, and increases health care costs.¹ Different methods have been used to assess nutritional status in children admitted to hospital, and there is no agreement as to which method best reflects nutritional status.²⁻⁴ Current data on prevalence of malnutrition (undernutrition and overnutrition) in children with spinal cord injuries (SCI) is limited.

Design: Prospective observational study. **Objective:** The aim of this study was to determine the prevalence of malnutrition in paediatric patients with SCI. **Method:** Undernutrition was defined by using screening tool for the assessment of malnutrition in paediatrics (STAMP)² (moderate risk: STAMP score ≥ 3 ; high risk: STAMP score ≥ 4). Overnutrition was defined by using BMI centile chart (overweight: > 91 st centile; obese: > 98 th centile). **Results:** After obtaining ethics approval, data for weight and height on 46 children (mean aged 10.6 years \pm 4.8) were studied during January to June 2010. The most common cause of SCI in this sample group were non-traumatic cause (53.5 % of all SCI cause) followed by road traffic accident (37.2%), sports injury (6.9%), and assault (2.3%). On admission, 37 (86%) were screened by STAMP [measured weight (93%) and estimated height (86%)]. 45.9 % of children were at risk of undernutrition (STAMP ≥ 3) and 18.9% were at high risk of undernutrition (STAMP ≥ 4). 51.3% were overweight, and 29.7% were obese. Only 38.4% of at risk patients were referred for nutritional assessment. **Conclusion:** Children with neuro-disabilities (SCI) are vulnerable to malnutrition, given the adverse consequences for short- and long-term health and well-being. A valid and practical tool for nutritional screening is needed in this high-risk group. Further research to validate the current paediatric nutrition-screening tool with a larger sample size is being conducted.

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Prevalence of Vitamin D Deficiency in Youth with Spinal Cord Injury

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Objective: Determine the prevalence of vitamin D deficiency in youth with spinal cord injury (SCI). **Design:** Retrospective chart review. **Participants/methods:** Youth with SCI who are currently followed at Shriners Hospital for Children, Chicago. 25-hydroxyvitamin D [25(OH)D] levels were obtained during routine follow-up, with levels of <32 ng/mL indicating suboptimal and <20 ng/mL indicating deficiency.

Results: Of 69 individuals (ages 3-21 years, mean age 14 years, 52% male, 72% white), 81% had suboptimal and 40.5 % deficient vitamin D levels. There were no significant differences in vitamin D levels in relation to level of injury (paraplegia/tetraplegia) ($\chi^2 = 0.174$, $P = .9165$) or gender ($\chi^2 = 0.0895$, $P = .9562$). There was a trend toward significance for race with white subjects at lower risk than non-white. This did not reach statistical significance ($\chi^2 = 4.47$, $P = .1070$). **Conclusion:** Suboptimal vitamin D levels are common in youth with SCI. Further study is needed to assess the significance of race and vitamin D levels and to assess the relationship of vitamin D levels with geographic latitude, body fat percentage, bone density, occurrence of fractures, and calcium/vitamin D consumption. Diagnosis and management of vitamin D deficiency is particularly important in the pediatric population because of the extensive bone formation that occurs with growth.

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Diffusion Tensor Imaging of the Pediatric Spinal Cord: Preliminary Evaluation

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Objective: To evaluate the clinical utility of Diffusion Tensor Imaging (DTI) in children; to examine reproducibility of the DTI measures; and to compare DTI parameters in children with and without spinal cord injury (SCI). **Design:** Cross-sectional, repeated measures. **Participants/methods:** 10 typically developing (TD) youths (mean age, 16.1 years) and 10 youths (mean age, 13.2 years) with chronic cervical SCI. 3.0T Siemens Verio MR scanner was used. High-resolution axial DTI images were acquired to cover the cervical SC (C1-C7). To test for reproducibility of the DTI measures, all subjects returned within 2 to 9 hours for a second scan. DTI indices were obtained [fractional anisotropy (FA), mean diffusivity (MD), transverse diffusivity (TD), and longitudinal diffusivity (LD)] and reported at each disk level of the cervical SC as well as the upper, middle, and lower portions of the cervical vertebral body. Statistical analysis was performed to compare averaged DTI indices between the TD and the subjects with SCI and to test for reproducibility of the DTI measures. **Results:** Statistically significant differences were seen between the TD averaged FA ($P < .0001$) and LD ($P < .01$) values compared to the youths with SCI. Subjects with SCI showed reduced FA and increased LD compared to the controls. However, no statistical differences were seen in MD ($P = .09$) and TD ($P = .73$). Test-retest reproducibility showed an inter-class correlation (ICC) of >0.9 in both groups for all DTI parameters. **Conclusion:** DTI measurements in the pediatric population were obtained using a newly developed and optimized iFoV sequence. The differences in diffusion metrics between normal and patients with SCI were demonstrated. Reduced FA and increased LD were seen in patients with SCI in comparison with controls. Test-retest showed excellent reproducibility. This study suggests promise for DTI as an imaging method to evaluate SCI in youths.

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“NO OBSTACLES”: A Return to School Program for Spinal Cord Injured Adolescents

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Objective: Presentation on a unique return to school program for adolescents with spinal cord injury. **Description:** Adolescents (age 17 years and younger) have unique physical and emotional needs compared to the adult population. Physical and psychosocial development occurs at a rapid pace during these years. Most are still attending school and rely on peer approval for much of their self-esteem. Many students are apprehensive about going back to school because of the stigma issues of having a disability. The “No Obstacles” program was developed to help adolescents have a smooth transition back to school and to educate others of the individual needs of each teenager. Once the student agrees to participate in the “No Obstacles” program, an individualized presentation is prepared. This includes anatomy, physiology, medical issues, equipment, and sports and leisure. The depth to which these topics are covered is determined by the severity and location of injury and the target audience. Additional information related to the student’s activity during the school day is reviewed. In conjunction with the school, the student determines who will attend the presentation. This may include peers, faculty, administration personnel, and parents. The audience has ranged from a small group of teachers up to a student assembly. This program has helped over 250 students return to school with confidence and graduate with their class.

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Functional Recovery in Adolescent Males with Incomplete Spinal Cord Injury Following Intensive Activity Based Restorative Therapy

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Objective: Demonstrate functional recovery associated with intensive activity-based restorative therapy (ABRT)

in adolescents with incomplete spinal cord injury (SCI). **Design:** Retrospective case series. **Participants/methods:** 3 male adolescents with incomplete SCI participated in 2 to 3 hours of physical therapy a day, 6 days per week. Subject 1: age 15, T10 AIS B, 10 days post injury; Subject 2: age 15, C1 AIS C, 3 weeks post injury; Subject 3: age 20, T10 AIS C, 6 weeks post injury. All patients were nonambulatory and unable to bear weight through their lower extremities at initial evaluation. Interventions included functional electrical stimulation ergometry, neuromuscular electrical stimulation, partial body weight-supported treadmill training, gait training, aquatic therapy, functional mobility, supported standing, and therapeutic exercises. Standardized outcome measures to assess recovery included the Physical Ability and Mobility Scale, Walking Index for SCI II, Pediatric Functional Independence Measure, and the Spinal Cord Injury Measure. **Results:** At discharge, 2 patients were ambulatory without an assistive device. The third patient had full recovery of 3 limbs and ambulated with a walker and right KAFO. All patients resumed independent living, returning to home and school. **Conclusion:** Intensive ABRT is useful to facilitate optimal functional recovery of patients with incomplete SCI. Additional research is required to better define specific treatment protocols that are the most efficacious.

Support: None

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Use of Attendant Care in Individuals with Pediatric-Onset Tetraplegia

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Objective: Describe medical and psychosocial factors associated with attendant care in individuals with pediatric-onset tetraplegia. **Design:** Cross-sectional survey. **Participants/methods:** Adults ages 24 to 45 years ($M = 31.6$, $SD = 5.5$) who sustained tetraplegia prior to age 18 ($M = 14.9$, $SD = 3.1$) completed a structured telephone interview regarding medical complications and psychosocial status and standardized measures: Patient Health Questionnaire-9, Satisfaction with Life (SWL) Scale, SF-12 Health Survey. *T* tests and chi-square analyses were conducted. **Results:** 223 adults participated (68% male), with 177 (80%) reporting at least 1 hour of paid or unpaid attendant care. Of those

with attendant care, total care received per 24-hour period was 4.8 hours ($SD = 4.1$; 1-24). Individuals received 3.1 hours ($SD = 3.1$; 0-19) of paid and 1.7 hours ($SD = 2.8$; 0-20) of unpaid care. Half received only paid care, 22% only unpaid care, and 29% received both paid and unpaid care. Compared to individuals without attendant care, those who received care were less likely to be married ($P < .05$) and more likely to live with parents ($P < .01$), be unemployed ($P < .05$), and receive Medicaid ($P < .05$). They were more likely to have a complete injury ($P < .001$), pressure ulcers ($P < .05$), urinary tract infections ($P < .05$), and dysreflexia ($P < .01$). They more frequently utilized a power chair ($P < .001$) and reported lower physical health ($P < .001$) and SWL ($P < .05$). Fewer differences were found between those with paid versus unpaid care. Individuals with paid care were less likely to be married ($P < .001$) and more likely to live alone ($P < .05$), have a complete injury ($P < .05$), and experience dysreflexia ($P < .01$). **Conclusion:** Use of attendant care in individuals with tetraplegia is common; however, hours of care received are minimal. Medical complications and social factors impact likelihood of attendant care.

Support: Shriners Hospitals for Children, Chicago

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Evidence Favoring Daily Exercise for Enhanced Fasting and Postprandial Glucose and Lipid Homeostasis in Paraplegia

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Objective: Compare fasting and postprandial glycemia and lipemia in exercise-conditioned individuals with paraplegia at 12-16 hours and 48 hours post exercise.

Design: Treatment comparison, internal control.

Participants/methods: 6 males/1 female aged 20-53 years with chronic paraplegia (T4-L1, AIS A/B) underwent 6 months of circuit resistance training 3 times a weekly. Comparisons were conducted on bloods drawn in (1) month 5, 12 to 16 hours after last exercise, and (2) month 6, 48 hours after last exercise. Overnight fasted glucose, triglycerides, and free fatty acids (FFA) were assessed during an 8-hour mixed-composition

prandial challenge [fast-food breakfast plus *Trutol* (75mg) and re-feeding at procedure hour 4]. The percent of total energy expenditure attributed to whole body fat oxidation (%WBFOx) was determined by indirect calorimetry. Areas under curve (AUC) were computed for the same variables. **Results:** Fasting glucose, triglycerides, and FFA were 5.1%, 5.4%, and 8.8% lower 12 to 16 hours after exercise, respectively, than 48 hours post exercise. During the prandial challenge AUCs were lower for glucose (16%), triglycerides (51%), and FFA (32.6%). The attenuated postprandial lipemic response was explained by a 40.3% higher caloric expenditure and 42.1% higher %WBFOx 12 to 16 compared to 48 hours after exercise. **Conclusions:** Fasting and postprandial benefits of exercise in persons with paraplegia are preserved the day after afternoon/evening exercise but less so 48 hours post exercise. An evidence-based exercise prescription after paraplegia would be refined by performing daily exercise, when fasting and postprandial nutrient disposal and fat oxidation are still preserved by carryover from acute exercise.

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Inpatient and Post-Discharge Rehabilitation Services Provided in the First Year After Spinal Cord Injury: Findings from the SCI Rehab Study

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Objective: Examine the amount and type of therapy services received in inpatient and postdischarge settings during the first year after spinal cord injury (SCI).

Design: Prospective observational longitudinal cohort design. **Participants/methods:** 493 individuals with traumatic SCI admitted to 6 rehabilitation centers. Inpatient data were collected prospectively by clinicians providing treatment; postdischarge service data were

collected retrospectively by patient self-report during follow-up interviews. **Results:** Participants received 56% of their physical therapy and 52% of their occupational therapy after discharge, but only a minority received any postdischarge services from other rehabilitation disciplines. While wide variation was found in the total hours of inpatient treatment across all disciplines, the variation in the total hours of postdischarge services was greater, with the interquartile range of postdischarge services being twice that of the inpatient services. **Conclusions:** SCI rehabilitation is often given in a care continuum with inpatient rehabilitation being only the beginning. Reductions in inpatient SCI rehabilitation length of stay are well-documented, but the postdischarge services that may replace some inpatient treatment appear to be greater than previously reported. The availability and impact of postdischarge care should be studied in greater detail to capture the wide array of postdischarge services and outcomes.

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Multifactorial Tissue Health Assessment of At-Risk Users and Effects of Weight Shifting with a Dynamic Cushion

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Objective: Determine tissue health changes in the seating area of adults with SCI using a dynamic cushion compared to standard weight shifting. **Design:** Longitudinal repeated measures ANOVA, analysis of blood flow with short-time Fourier transform. **Participants/methods:** Adult individuals with SCI without a current pressure ulcer. Multifactorial tissue health assessed using (1) interface pressure mapping, (2) transcutaneous gas measurements (TcPO₂), and (3) skin blood flow measurements. **Results:** Multifactorial tissue health assessment indicated differences between unaided pressure relief with a standard cushion and pressure relief from a dynamic cushion. Interface pressures and tissue perfusion in the ischial region were inversely related for most patients. Cyclic inflation of the dynamic cushion had immediate effects on interface pressures and TcPO₂. Unaided pressure relief produced

similar changes only if maintained for a full 3-minute period and primarily affected blood flow at initiation of pressure relief. **Conclusion:** When pressure relief is not maintained, TcPO₂ change is only short term. The increase in skin blood flow might be due to movement artifacts with shifting. A longer period of active pressure relief is recommended for at-risk individuals with SCI.

Support: This work was funded by the National Institute on Disability and Rehabilitation Research (NIDRR), Rehabilitation Engineering Research Center (RERC) on Spinal Cord Injury, grant H133E070024.

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The CONECISI Trial: A Randomized Controlled Trial of a Multidisciplinary Cognitive Behavioral Program for Coping with Chronic Neuropathic Spinal Cord Injury Pain

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Objective: To evaluate a multidisciplinary cognitive behavioral treatment program for coping with chronic neuropathic SCI pain. **Design:** Multicenter RCT. **Participants/methods:** 61 people were randomized to either the intervention group or the waiting list control group in 4 Dutch rehabilitation centers. Primary outcomes were pain intensity and pain-related disability (Chronic Pain Grade). Secondary outcomes were mood, participation, and life satisfaction. Measurements were performed at the start and end of the intervention and at 3 months follow-up. Random coefficient analysis was used. **Results:** Significant changes over time were seen in pain intensity and pain-related disability, anxiety, and participation. Significant intervention effects (time x group interactions) were found for anxiety and participation in activities, but not for the other outcomes. Paired *t* tests showed significant changes in the intervention group that were not seen in the control group: decrease of pain intensity, pain-related disability, and anxiety and increase of participation in activities.

Conclusion: This study implies that a multidisciplinary cognitive behavioral program might have beneficial effects on people with chronic neuropathic SCI pain.

Support: This study is performed within DALI for PAIN, a national programme that focuses on neuropathic pain care optimization. DALI for PAIN is an initiative of Pfizer. This project is supported by an unrestricted grant from Pfizer.

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A Comparison of Relative Performance of Various Skin Protective Wheelchair Seat Cushions in Real Life Use

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Objective: Determine the expected life span of wheelchair seat cushions within real world use, identify the most important predictors of cushion degradation, develop a clinically relevant tool to assess the need for cushion replacement, and obtain data to assess the appropriateness of current insurance guidelines for cushion replacement. **Design:** 3 phase design: Phase 1, clinical and lab testing to identify the expected lifespan of wheelchair seat cushions and the significant predictors of cushion failure with real life use; Phase 2, identify test criteria with the greatest clinical relevance; and Phase 3, test the identified assessment tool in the clinical setting. **Participants/methods:** The study cohort consisted of 141 individuals who regularly use a skin protective wheelchair seat cushion. Each cushion was assessed for material integrity and cleanliness through a visual inspection. Performance characteristics of each cushion were evaluated, including loaded contour depth, acceleration dampening, and interface pressure mapping. Additional variables were collected that assessed the participant's tissue health, unique postural characteristics, and general cushion use. **Results:** 202 skin protective cushions were tested for a total of 343 data sets. Of these data sets, there were 202 first visits, 91 second visits, 40 third visits, and 10 fourth visits. Of the 202 cushions, there were 35 different models from 12 manufacturers; the top 3 cushion models, J2, Roho HP, and Varilite Evolution, comprised 60% of all cushions tested. The ages of the cushions tested spanned from new to 16.25 years. The average age of the cushions tested was

2.7 years and the median age was 2 years. Hours of usage per day varied from 1 to 22 hours. Data collected from this study indicated that within the top 3 cushion models tested, minimal to no significant changes in performance over time/usage hours were noted. **Conclusion:** There are many factors that can affect the degradation of a cushion, including age of cushion and hours of usage per day, cushion materials, pelvic deformities, weight of individual, exposure to environmental elements, and cushion maintenance. Of these factors, subject weight tends to be the most consistent element affecting the wear of a cushion. Cushions comprised primarily of foam tend to decrease in their pressure reduction effectiveness more rapidly than cushions made of non-foam materials. Presence of a pelvic obliquity showed a higher rate of degradation on the affected side of most cushions tested.

Support: This project was funded by the US Department of Education-NIDRR as part of the Spinal Cord Injury Model Systems (SCIMS): Georgia Regional Spinal Cord Injury System grant H133N060009 and NIDRR Wheeled Mobility RERC H133030035.

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Feasibility and Efficacy of a Robotic, Home-Based Locomotion Therapy: Results of a Baseline Study with Chronic, Incomplete Spinal Cord Injured Subjects

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Objective: In incomplete spinal cord injured (iSCI) subjects, task-oriented training regimes are applied for enhancement of neuroplasticity to improve gait capacity. For continuation of the automated locomotion training at home, the compact, pneumatically driven orthosis *MoreGait* has been developed. The device generates the key afferent stimuli for activation of the spinal gait pattern generator in a safe, semirecumbent patient position. The objective of this study is to test its feasibility and efficacy. **Design:** Prospective open cohort study with intraindividual baseline control. **Methods:** 21 chronic (10 female, 11 male; mean age, 43.8 ± 12.9 years; date of injury, 4.8 ± 4.7 years) SCI (4 tetraplegic, 17 paraplegic) iSCI individuals (8 ASIA C, 13 ASIA D;

mean lower extremity motor score, 28.7 ± 10) have been included. Baseline status has been obtained 8 and 4 weeks before training onset. Training was performed for 8 weeks (45 min/d for a minimum of 4 d/wk). Primary outcome measures were 10 m, 6-minute walk tests and WISCI. **Results:** All participants performed the training on a daily basis at their home. Only 1 adverse event (pressure sore) directly related to the device occurred during 900 training sessions. A significant ($P < .025$) increase of the mean self-selected gait speed (4 weeks: 21%; 8 weeks: 46%) compared to baseline has been observed. Mean gait endurance improved by 24% (4 weeks) and 52% (8 weeks). 3 patients improved in the WISCI (8 weeks). 3 months after the end of training, some patients continued to improve. **Conclusion:** A home-based robotic training with the novel *MoreGait* is feasible and well accepted by the users. The outcomes in iSCI individuals are at least comparable to those of complex locomotion robots used in clinics.

Support: This project “MotionTherapy@Home - An automated gait trainer for home use” is supported by the German Federal Ministry of Education and Research (BMBF grant 01EZ601, 01EZ0602).

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Clinical and Urodynamic Outcomes with Intradetrusor Injections of OnabotulinumtoxinA in Patients with Neurogenic Detrusor Overactivity Related to Spinal Cord Injury

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Objective: We assessed the effects of onabotulinumtoxinA on clinical/urodynamic variables in spinal cord injury (SCI) patients with urinary incontinence (UI) due to neurogenic detrusor overactivity (NDO). **Design:** Subanalysis of 2 multicenter, double-blind, randomized, placebo-controlled studies. **Participants/methods:** Patients with UI (≥ 14 episodes/week) due to NDO were randomized to intradetrusor injection of placebo ($n = 110$) or onabotulinumtoxinA 200U ($n = 97$) or 300U ($n = 103$). Primary efficacy variable was change

from baseline in UI episodes/week (week 6). Secondary endpoints included urodynamic assessments (maximum cystometric capacity [MCC] and maximum detrusor pressure [MDP] during first involuntary detrusor contraction [IDC]) and Incontinence Quality of Life (I-QOL) at baseline and week 6. Adverse events (AEs) were monitored. Efficacy and safety were analyzed in the SCI subpopulation. **Results:** 310 SCI patients were enrolled (71% male, mean age 41.0 years, 34% had T1-T6 lesions, 60% took anticholinergics, 85% used intermittent catheterization at baseline). At week 6, decreases in UI episodes/week were greater with onabotulinumtoxinA 200 U and 300 U (-19.6 and -18.2) than placebo (-6.4 ; $P < .001$); 31%, 36%, and 7% of patients, respectively, did not demonstrate UI. Increases in MCC and I-QOL and decreases in MDP during first IDC were significantly greater with both onabotulinumtoxinA doses than placebo. Duration of onabotulinumtoxinA effect was ~ 9 months. AE incidence was low; no gross hematuria occurred. **Conclusion:** Compared to placebo, intradetrusor onabotulinumtoxinA (200 U and 300 U) significantly reduced UI and improved urodynamic parameters and QOL in SCI patients, with no clinically relevant differences between onabotulinumtoxinA 200 U or 300 U doses.

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Effects of Nicotine on Spinal Cord Injury Related Pain: A Randomized, Double-Blind, Placebo-Controlled Crossover Trial

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Objective: Previous case reports and neurobiological studies implicate the potential effect of nicotine on spinal cord injury (SCI)-related pain. The present study is an extension of a previous pilot trial among persons with SCI in order to clarify the nicotine-pain relationship. **Design:** Randomized, double-blind placebo-controlled crossover trial using nicotine and placebo gum. **Participants/methods:** A total of 103 pain sites from 42 smokers and nonsmokers with SCI were evaluated across trials. There were 101 pain sites included in final analysis and were classified as musculoskeletal ($n = 42$), neuropathic ($n = 39$), and mixed ($n = 20$). Pain ratings

were measured via a numeric rating scale at 30 and 90 minutes during each trial. **Results:** In the placebo arm, main effects for smoking and pain type emerged but no interaction for placebo dose. In the nicotine arm, there was a significant pain type by smoking interaction. On average, smokers appeared to experience an increase in mixed and neuropathic pain but no change in musculoskeletal pain, while nonsmokers experienced a decrease in mixed pain only with increasing nicotine dosage. **Conclusions:** Should this study be replicated, it implies potentially different treatment strategies for smokers and nonsmokers who experience SCI-related mixed and neuropathic forms of pain.

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Motor and Gait Improvement in Incomplete Spinal Cord Injury with High Frequency Repetitive Transcranial Magnetic Stimulation

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Objective: To assess the effect of high-frequency repetitive transcranial magnetic stimulation (rTMS) on lower extremities muscle strength (LEMS) and gait in motor incomplete spinal cord injury (SCI) subjects. **Design:** Prospective longitudinal randomized, double-blind study. **Participants/methods:** 12 SCI subjects ASIA D were studied. We assessed the LEMS, the Modified Ashworth Scale (MAS), the 10 meters walking test (10MWT), WISCI II scale, step length, cadence, and Timed Up and Go (TUG) at baseline, after the last session of rTMS, and 2 weeks after. 7 patients were included in the active rTMS and 7 in sham stimulation group. Both groups were homogeneous for age, sex, time since injury, etiology, and ASIA scale. Active rTMS consisted of 15 days of daily sessions of 20 trains of 40 pulses at 20 Hz and an intensity of 90% of resting motor threshold for the biceps brachii muscle. rTMS was applied with double cone coil to the leg motor area. **Results:** There was a significant improvement in the LEMS in the active group (27.7 at baseline and 32.7 after stimulation; $P = .004$) but not in the sham group

(30.5 at baseline, and 30.3 after stimulation; $P = .6$). A significant improvement in the MAS, 10MWT, cadence, and TUG was also observed in patients after 3 weeks of active stimulation but not in sham stimulation except step length; this improvement was maintained 2 weeks after active stimulation. No changes were observed in the WISCI II scale in both groups. **Conclusion:** High-frequency rTMS over the leg motor area can improve LEMS and gait in patients with motor incomplete SCI.

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Do Risk Factors for Mortality After SCI Parallel Those from the General USA Population?

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Objective: To use mortality risk models developed in the general population to directly guide the development of a mortality risk model after SCI. Although recent studies have identified a broader set of risk factors for mortality after SCI, they have not directly replicated models developed within the general population. **Design:** Prospective cohort study. **Participants/methods:** 1,386 adults with traumatic SCI, at least 1 year post injury at time of assessment, were enrolled in study. Mortality status was determined using the National Death Index. A logistic regression model using person-year data was developed to estimate the chance of dying in any given year, and variables identified by Lantz et al¹ were entered simultaneously into the model. **Results:** There were 270 deaths. Each of the following factors was significantly related to diminished life expectancy in this analysis and the Lantz et al study,¹ including low income, current smoking, former smoking, underweight, and injury severity. Self-reported general health was marginally associated with early mortality. Unlike Lantz et al,¹ drinks per month, residence, education, and physical activity were not significant. Using the example of a 20-year-old white male with C1-C4, nonambulatory SCI, life expectancy was an additional 36.0 years under favorable conditions (ie, no risk factors) but decreased substantially with added risk factors. Most notable were low income (LE = 28.1), current smoking (LE = 27.6), and being underweight (LE = 29.9). **Conclusion:** The pattern of risk factors observed in the general population was, for the most part, observed with SCI. One of 2 socioeconomic status indicators (income) was significant, even after controlling for disability, behaviors, and health.

Support: This project was funded by NIDRR grants H133N50022, H133B090005, and H133G0501651 and NIH grant 1R01 NS 48117.

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Expectations of Risk, Benefit, and Preclinical Scientific Rigor in Experimental Treatments for Spinal Cord Injury: A Survey of SCI Individuals

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Objective: To characterize the perspectives of individuals with spinal cord injury (SCI) to clinical trials of experimental therapies. Specifically, we sought to determine what potential benefits they would anticipate, what risks they would deem acceptable, and what expectations they would have for the extent of preclinical research done on therapies prior to their translation. **Design:** Survey of individuals with SCI. **Methods:** A survey was distributed to SCI individuals identified through a provincial database. Approximately 200 respondents with cervical or thoracic SCI and baseline AIS of A, B, C, or D completed the survey. **Results:** Individuals with SCI expressed their expectation that experimental therapies were tested in large animal studies and their efficacy independently replicated prior to being advanced into human trials. The majority listed their expectations for “percent chance of recovery” as either 5% to 25% or 25% to 50%. For invasive cell transplantation trials, while most would require the risk of spinal cord damage, cancer, infection, and nerve pain to be 1% or less, a considerable proportion (15%-20%) would participate regardless of the risk of these complications. **Conclusion:** Although they may not understand the details of the science, individuals with SCI have high expectations about the level of preclinical evidence that is supporting therapies that go into clinical trial, although the receptivity to such trials is high. While most of our current trials focus on safety, the respondents of our survey expressed high hopes for the possibility of neurologic benefit. A considerable proportion of individuals are anxious

to participate in invasive stem cell trials “regardless of risk,” highlighting their vulnerability to commercial enterprises selling unproven therapies.

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Comparison of Respiratory Muscle Training Methods in Individuals with Motor Complete Tetraplegia

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Objective: To compare the effects of inspiratory muscle training (IMT) and isocapnic hyperpnea (IH) versus incentive spirometry (placebo) on respiratory function, thorax mobility, and quality of life in individuals with motor complete tetraplegia. **Design:** Randomized controlled trial. **Participants/methods:** 24 individuals with postacute, traumatic tetraplegia (C5-C8), AIS A, 6 to 8 month post injury completed 90 repetitions of IMT, 10 minutes of IH, or 16 repetitions of placebo training. Subjects were randomly assigned to 1 of the 3 groups. They completed 32 supervised training sessions over 8 weeks. Before and after the training period, the following tests were performed: bodyplethysmography, in- and expiratory muscle strength, subjective breathing parameters, thorax mobility, and an adapted SF12 quality of life questionnaire. A Friedman 2-way analysis of variance and Cohen’s effect sizes for IMT and IH versus placebo were calculated using the differences between pre- and posttraining values. **Results:** Compared to placebo training, IMT showed high effect sizes for inspiratory muscle strength ($d = 1.19$), cleaning the nose ($d = 0.99$), and the physical component of subjective quality of life ($d = 0.84$), whereas IH compared to placebo training showed only medium and low effect sizes. The Friedman analysis showed only a significant effect for IMT on inspiratory muscle strength ($P = .030$). Neither lung function nor thorax mobility was significantly improved by one of the tested training methods. **Conclusion:** In individuals with motor complete tetraplegia, inspiratory muscle strength can be improved by IMT. Therefore, IMT is advantageous compared to IH and incentive spirometry during the first year post injury.

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A Longitudinal Study of Depression After Spinal Cord Injury

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Objective: Assess probable major depression (PMD) over a 5-year period in persons with spinal cord injury (SCI) and assess environmental and behavioral risk factors for PMD over time. **Design:** Prospective cohort study. **Participants/methods:** A mail-in questionnaire was filled out by 1,543 adults with SCI between 2002 and 2003, and 993 of those responded again in 2008-2010. The Older Adult Health and Mood Questionnaire was used to assess PMD, with a score of 11 or more. Generalized estimating equations using repeated measures were used to assess risk of PMD. **Results:** 22.1% and 20.2% at the first and second time points, respectively, had PMD. Of those with PMD at time 1, 55.7% still had PMD at time 2. Of those not depressed at time 1, 8.2% had PMD at time 2. While controlling for demographic and injury characteristics, both decreased years of education and income were associated with PMD. After including behavioral variables, education and income were no longer significant. Taking pain medication and exercise were related to increased risk of PMD, while increased hours out of bed and days out of the house were associated with decreased risk of PMD. **Conclusion:** Behavioral factors are very important in the risk of PMD. Participation in activities that require a person to get out of bed and out of the house could reduce the risk of PMD.

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The European GRASSP Responsiveness Study: Advanced Insights in the Recovery of Patients with Cervical Spinal Cord Injury

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Objective: To relate changes in segmental motor-sensory function and prehension to the outcome in independence in individuals with tetraplegia. **Design:** Prospective longitudinal multicenter cohort study. **Participants/methods:** More than 60 individuals with acute tetraplegia out of 6 European SCI centers entered the study. Assessments were performed at 1, 3, and 6 months post injury using the Graded and Redefined Assessment of Strength, Sensibility and Prehension (GRASSP) and the Spinal Cord Independence Measure (SCIM III). Changes over time in GRASSP were tested using Friedman and Wilcoxon signed rank test. Correlations between GRASSP and SCIM III were tested using Spearman rank correlation test. **Results:** Interim analysis (n = 12) revealed that strength, sensibility, and prehension scores significantly ($P < .05$) improved in all time intervals, with exception of the sensibility score which remained stable between 3 and 6 months. All parameters showed that the greatest improvement occurred within 1 and 3 months after injury. The correlation showed that changes detected by GRASSP corresponded significantly with changes measured by the SCIM III. Correlation analysis between changes in GRASSP in relation to independence and quality of life (Lisat 11) will be presented after completion of a larger sample size. **Conclusion:** Preliminary results show that the main recovery occurs within 3 months after injury and the GRASSP is predictive of the outcome of independence in acute tetraplegia.

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Impact of Underwater Treadmill Training on Walking Performance in Adults with Incomplete Spinal Cord Injury

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Objective: To document the effects of underwater treadmill training on walking performance in adults with incomplete spinal cord injury (SCI). **Design:** Pretest, posttest design. **Participants/methods:** Preferred and rapid walking speed (PWS, RWS), 6-minute walk distance (6MWD), and daily step activity (DSA) over a 7-day period were assessed in 11 adults with incomplete SCI (7 males, 4 females; age 48 ± 14 years; 5 ± 8 years post injury) before and after 8 weeks (3x/wk) of underwater treadmill (UT) training. During each session, participants completed 3 walks at personalized levels of water height and walking speed. Body weight support remained constant for each participant and ranged from 29% to 47% of land body weight. Conversely, increases in speed and duration were imposed in a gradual fashion on alternating weeks. **Results:** Repeated-measures analysis of variance demonstrated significant ($P < .05$) increases in PWS ($0.41 \pm 0.27 \text{ m}\cdot\text{s}^{-1}$ to $0.55 \pm 0.28 \text{ m}\cdot\text{s}^{-1}$), RWS ($0.44 \pm 0.31 \text{ m}\cdot\text{s}^{-1}$ to $0.71 \pm 0.40 \text{ m}\cdot\text{s}^{-1}$), 6MWD ($97.3 \pm 80.2 \text{ m}$ to $177.0 \pm 122.3 \text{ m}$), and DSA (593 ± 782 steps to 1310 ± 1258 steps) following UT training. **Conclusion:** Statistically significant and clinically meaningful improvements in preferred and rapid walking speed, walking endurance, and daily step activity can be observed following a structured program of UT training featuring individually selected levels of body weight support and carefully staged increases in speed and duration. From a clinical perspective, these findings highlight the potential of this specialized form of gait therapy to improve functional mobility in persons following incomplete SCI.

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Driving for Happiness: Modified Vehicles and Health-Related Quality of Life After Spinal Cord Injury

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Objective: To examine ownership of a modified vehicle and driving of a modified vehicle by persons with spinal cord injury (SCI) and to assess the relationship between these characteristics and aspects of health-related quality of life (HRQOL). **Design:** Cross-sectional survey. **Participants/methods:** Participants with SCI enrolled in the National Spinal Cord Injury Database (NSCID) with a most recent follow up interview between April 2004 and November 2009 ($N=8,552$). The following main outcome measures were examined from the interviews: ownership of a modified vehicle; driving of a modified vehicle; HRQOL indicators: satisfaction with life, self-perceived health status, health status compared with 1 year ago, severity of depressive symptoms, social integration, and occupation. **Results:** 34.0% of people drive a modified vehicle after SCI, 17.0% own a modified vehicle that they do not drive, and 49.0% do not own a modified vehicle. Drivers of modified vehicles typically have seen more time elapsed since their injury, are male, Caucasian, non-Hispanic, older (≥ 30 years), working, and better educated. They have a greater satisfaction with life, better self-perceived health status, less severe depressive symptoms, less often a major depressive disorder, and greater social inclusion than individuals who own but do not drive their modified vehicle and individuals who do not own one. Results regarding health compared with 1 year ago and occupation contradicted these findings, in whole or in part. **Conclusions:** These findings should push physicians to set driving as a long-term goal for their patients and to incorporate independent activities away from the home into their rehabilitation program when possible. If more people are able to use private transportation in the form of a modified vehicle, significant positive lifestyle changes can be made.

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Alterations in Body Composition and Spasticity Following Neuromuscular Electrical Stimulation Training in Spinal Cord Injury

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Objective: Unfavourable body composition changes following spinal cord injury (SCI) are considered a risk factor for cardiovascular disease in this population. Spasticity following SCI can have a profound impact on the individual. The objective of this study was to determine the efficacy of an 8 week home-based neuromuscular electrical stimulation (NMES) training program on altering lean body mass (LBM) and objective and subjective changes in spasticity in the lower limbs. **Design:** Prospective cohort study. **Participants/methods:** 14 sedentary adults with acquired paraplegia (T4 –T11; ASIA A/B; time since injury: 10.01 ± 11.26 years) were recruited from the National SCI database. Participants attended 3 test sessions; pre-control (T1), pre-intervention (T2), and post-intervention (T3). 4 electrodes (175 cm²) were placed bilaterally on the proximal and distal quadriceps and hamstrings muscle groups, and sub-tetanic contractions were elicited using an NMES device (NT2010, Biomedical Medical Research [BMR], Galway, Ireland). LBM was measured using dual energy x-ray absorptiometry (GE Healthcare, USA). Spasticity was measured using Spinal Cord Assessment Tool for Spastic Reflexes (SCATS) and visual analogue scales (VAS). Verbal and written feedback was obtained to subjectively evaluate spasticity. **Results:** A statistically significant increase in LBM (ie, muscle tissue) ($P = .022$) and a reduction in SCATS ($P = .01$) score indicating reduced spasticity were observed (T2-T3). Subjective responses were positive. **Discussion:** Improvements in body composition and SCATS scores indicate that this form of NMES training elicits favourable responses and may have important clinical implications for an SCI population.

Support: This research was funded by Enterprise Ireland and BMR.

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Disparities in Wheelchair Type, Wheelchair Skill Level, and Community Participation by Payer Source

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Objective: Determine disparities in wheelchair prescriptions and payer sources, the differences in wheelchair skill levels, and the relationship to community participation. **Design:** Multicenter cross-sectional study of 6 SCI Model System Centers. **Participants/methods:** 192 participants using a manual wheelchair for primary means of mobility 1 year or longer after the SCI participated in a structured interview to collect payer source, wheelchair breakdown, and activity limitations. A Wheelchair Skills Test (WST) was administered to collect functional mobility. **Results:** Participants with a K0009 had a higher total score in the WST of 84.5%, specifically in higher level skills including wheelies and stairs. 36.7% of the participants with private insurance received a K0009 manual wheelchair. Self-pay participants had the highest rate of K0004 (25%) and Medicaid had the highest rate of K0005 (81.8%). The K0005 wheelchair group also had the highest rate of breakdowns (53.5%) with a higher rate of injuries, missed work, and missed medical appointments. **Conclusion:** Medicaid participants showed a higher rate of K0005 wheelchairs compared private insurance, along with lower wheelchair skills and more breakdowns effecting community participation and safety, respectively.

Support: This project is funded by NIDRR grant H133N060028, The National Capital Spinal Cord Injury Model System.

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Causes of Death Following Spinal Cord Injury

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Objective: Determine why life expectancy following spinal cord injury (SCI) has not improved among 1 year survivors over the past 25 years by examining trends in causes of death. **Design:** Inception cohort study. **Participants/methods:** 45,516 persons with traumatic SCI injured since 1936 (99.5% injured since 1970) who were treated at a model system or Shriners hospital. Current survival status was determined by routine follow-up, searches of the Social Security Death Index and National Death Index (NDI), online state vital statistics files, and newspaper obituary files. Causes of death were determined from a search of the NDI, death certificates, hospital discharge summaries, or autopsy reports. Trends in annual cause-specific mortality rates and standardized mortality ratios (SMR) were calculated. **Results:** 10,025 deaths occurred among 543,348 person-years of follow-up. The leading causes of death were respiratory disease (usually pneumonia) (21%), heart disease (19%), septicemia (11%), cancer (10%), and unintentional injuries (6%). Virtually all causes of death had significantly elevated SMRs. Septicemia (typically associated with urinary tract infections, pressure sores, or pneumonia) had the highest SMR, followed by pulmonary embolism and pneumonia. The SMR for septicemia was highest for all ages, genders, injury severities, times post injury, and calendar decades. **Conclusion:** The causes of death with the greatest impact on life expectancy continue to be septicemia, pulmonary embolism, and pneumonia.

Support: National Institute on Disability and Rehabilitation Research; Paralyzed Veterans of America; and South Carolina Spinal Cord Injury Research Fund

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Bladder Cancer After Spinal Cord Injury: Mortality Risk and Risk Factors

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Objective: To assess whether bladder cancer mortality is increased in persons with spinal cord injury (SCI) and whether the increased mortality varies by demographic and clinical characteristics. **Design:** Cohort study. **Participants/methods:** Data and statistics were retrieved from the National SCI Statistical Center and National Center for Health Statistics. The mortality experience, as of December 2009, of 45,516 persons with traumatic SCI injured since 1936 (99.5% injured since 1970) treated at a model system or Shriners hospital was compared to the general population, using standardized mortality rate (SMR). To identify risk factors, the SMR was further stratified by age, gender, years since injury, and neurologic impairment. **Results:** Of total 10,577 deaths over 543,348 person-years of follow-up, 94 deaths (0.89%) were known to be caused by bladder cancer. Had persons with SCI had the same bladder cancer mortality as the general population, the expected number of deaths from bladder cancer would have been 14.8 ($SMR = 94/14.8 = 6.4$). The increased bladder cancer mortality was observed for female and male ($SMR = 11.6$ and 5.7 , respectively), those with motor complete injuries ($SMR = 6.0, 14.3,$ and 12.1 for C1-C4, C5-C8, and T1-S5 injuries, respectively), persons with 10 or more years of injury ($SMR = 8.7$), and particularly those of age 30 to 59 years ($SMR = 19.3$). The bladder cancer mortality was not significantly increased for ventilator users, those with motor incomplete injuries of any level, or those injured less than 10 years. **Conclusion:** Our study findings highlight the need of prevention, early screening, and intervention for bladder cancer to improve life expectancy after SCI.

Support: National Institute on Disability and Rehabilitation Research; Paralyzed Veterans of America; and South Carolina Spinal Cord Injury Research Fund

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Gains in Life Expectancy After SCI by Preventing Individual Causes of Death

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Objective: Determine gains in life expectancy after spinal cord injury (SCI) that could occur by preventing each cause of death. **Design:** Inception cohort study. **Participants/methods:** 45,516 persons with SCI injured since 1936 (99.5% injured since 1970) who were treated at a model system. Survival status was determined by routine follow-up, searches of the Social Security Death Index, and National Death Index (NDI). Causes of death were determined by the NDI or death certificate. Analyses were conducted by eliminating each cause of death, considering persons who had that cause of death withdrawn alive, and recalculating life expectancy accordingly. **Results:** 10,025 deaths occurred among 543,348 person-years of follow-up. Increases in years of life expectancy for white males with a C1-4 complete injury at age 25 by prevention of each cause of death were 3.1 for pneumonia, 2 for septicemia, 0.8 for accidents, 0.3 for suicide and urinary diseases, 0.2 for pulmonary embolus, and 0.1 for ischemic heart disease. For a similar individual with paraplegia, the gains were 2 years for septicemia, 1.5 years for pneumonia, 1.1 years for accidents and ischemic heart disease, 0.9 years for suicide, 0.6 years for urinary disease, and 0.4 years for pulmonary embolus. **Conclusion:** Causes of death with the greatest impact on life expectancy are septicemia and pneumonia.

Support: National Institute on Disability and Rehabilitation Research; Paralyzed Veterans of America; and South Carolina SCI Research Fund

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Health, Secondary Conditions, and Life Expectancy After Spinal Cord Injury

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Objective: To evaluate the association of health status, secondary health conditions, and hospitalizations

with risk of mortality and life expectancy after spinal cord injury (SCI). **Design:** Prospective cohort study. **Participants/methods:** A total of 1,386 adults with traumatic SCI, all of whom were at least 1 year post injury at the time of assessment were enrolled in the study. Mortality status was determined through 2007 by routine follow-up using the National Death Index. A logistic regression model using person-year data was developed to estimate the chance of dying in any given year, the same methods widely used to identify differential life expectancy related to demographic and injury characteristics. **Results:** There were 270 deaths. Several secondary health conditions were significantly related to diminished life expectancy including chronic-constant pressure ulcers, amputations, symptoms of infections, and a depressive disorder. Hospitalization within the year prior to assessment was also associated with early mortality. Using the example of a 20-year-old with C1-C4, nonambulatory SCI, life expectancy was an additional 39.0 years under favorable conditions (ie, none of the risk factors) but decreased substantially with secondary conditions, particularly either amputation (LE = 28.0) or chronic pressure ulcers (LE = 21.2). Declines in the presence of a depressive diagnosis were less substantial yet still important (LE = 32.7). **Conclusion:** Secondary conditions represent a significant risk factor for early mortality. Although chronic pressure ulcers and amputations are rare, they are associated with greatly diminished life expectancy.

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Building a Health Progression Model to Evaluate Long-term Outcomes for People with Traumatic SCI

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Objective: Develop a health progression model (HPM) to measure the long-term patient and system outcomes for traumatic spinal cord injury (SCI). **Design:** Computer simulation of an individual's life upon discharge to the community until death for people with acute traumatic SCI. **Participants/methods:** A discrete

event simulation model was developed to describe characteristics of persons with traumatic SCI at the time of discharge into the community (eg, type of injury, age), events/experiences occurring in the community (eg, acquiring secondary complications, re-admission to hospital, death), and long-term outcomes (eg, quality-adjusted life years [QALYs], incidence of complications, days in hospital, return to work/volunteer, life expectancy). Sources of data for the HPM include the Rick Hansen SCI Registry, expert opinion, and the literature. Multivariable regression models were used to predict QALYs using the Short Form 6D. Logistic regression models were utilized to predict secondary complications and estimate re-admissions to hospital and days in hospital. A Cox proportional hazards model drawn from the literature was applied with Canadian life-table data to predict mortality. **Results:** This model produces estimates of health-related and economic consequences of SCI, with lifetimes being simulated multiple times to generate long-term outcomes such as QALYs, years experiencing secondary complications, and health care costs. Preliminary HPM estimates have demonstrated earlier than expected mortality due to high secondary complication rates. **Conclusion:** The HPM appears to be a valid model for evaluating long-term health outcomes and economic consequences for persons with traumatic SCI.

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Survival and Life Expectancy After Spinal Cord Injury: A Fifty-Year Study

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Objective: To analyse survival experience, mortality patterns, and estimated life expectancy of individuals with traumatic SCI. **Design:** Cohort of incident cases from 1955-2006. **Participants/methods:** Data of patients with traumatic SCI admitted to a spinal unit in Sydney, Australia, over a 50-year period were collated with deaths confirmed. Cumulative survival probability was estimated using life-table techniques

and mortality rates calculated from number of deaths and aggregate years of exposure. Standardised mortality ratios (SMRs) were estimated and life expectancy derived using attained age-specific mortality rates. **Results:** From 1999 total, 90 persons with tetraplegia (8.4%) and 38 persons with paraplegia (4.1%) died within first 12 months after injury, with the highest death rates occurring in those with complete and high cervical (C1-4) lesions. Among first-year survivors, the overall survival rate at 40 years post injury for persons with tetraplegia is 47% compared to 61% for those with paraplegia. SMRs were highest for C1-4 tetraplegia (ASIA A-C lesions), estimated to be 4.7 (95% CI, 3.4-6.1) overall, but ranging between 5.7-9.4 at younger ages (<50 years), reducing to 3.9-4.1 in middle age (50-70 years) and 2.1 in 70-80 year olds. Estimated life expectancies from 25 to 65 years ranged between 71%-68%, 74%-65%, 87%-91%, and 97%-96% for C1-4 ASIA A-C, C5-8 A-C, T1-S5 A-C, and all ASIA D lesions, respectively. **Conclusion:** Survival related strongly to neurological level/severity. Research should now focus on identifying personal or environmental contextual factors that may interact with age and impairment to further reduce life expectancy after SCI.

Support: None

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Electromyographic Characteristics and Muscle Involvement Patterns of Phasic Spasms in Patients with Spinal Cord Injury: Background Study to Determine Applicability of Implantable High-Frequency Nerve Blockade for Spasm Control

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Objective: To determine electromyographic (EMG) characteristics and muscle involvement patterns of phasic spasms in patients with spinal cord injuries to determine applicability of implantable high-frequency nerve blockade for spasm control. **Design:** Prospective experimental study. **Participants/methods:** Individuals with incomplete tetraplegia. Spontaneous spasms and elicited spasms are recorded in various muscles using an 8-channel amplified surface EMG recording apparatus. Various techniques for eliciting spasms are employed.

Surface EMG recordings from various muscles are analyzed in a time-locked manner using a custom-made computer program. **Results:** Both spontaneous and elicited spasms have a detectable ramp-up period prior to the full amplitude muscle contraction. Spontaneous spasms vary in frequency among different patients; for a given patient, they vary in amplitude and duration but tend to involve similar muscle groups. Elicited spasms are highly variable among different patients in terms of number of muscles involved, amplitude, and duration of spasms. These spasms tend to involve similar muscle groups for a given technique to elicit the spasms. For spasms involving multiple muscle groups, reproducible muscle involvement patterns exist with certain muscles contracting at staggered start times. We are continuing to study additional patients using these techniques. **Conclusions:** Spasms in patients with spinal cord injuries have a detectable EMG ramp-up period that is long enough in duration to potentially trigger and employ a high-frequency nerve blockade prior to full amplitude muscle contraction. Based on the timing between the spasm trigger and the start of muscle contractions, we may be able to identify likely neural pathways involved. These spasms are variable among patients but demonstrate predictable muscle involvement and timing patterns in a given individual.

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Effect of 6 Weeks Aerobic Exercise Using the Motor Driven Rowing Machine in Persons with Spinal Cord Injury

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Objective: We developed a motor-driven rowing machine (ROWmotor) that moves forward and backward using motor. This study aimed to evaluate the effect of 6 weeks aerobic exercise training with ROWmotor in persons with spinal cord injury. **Design:** One group pretest-posttest designs. **Participants/methods:** Participants were 12 paraplegic subjects (male = 10, female = 2; mean age = 36 years old; injury duration = 11.4 months). Pre-post test was applied to investigate the effect of ROWmotor exercises on oxygen consumption (VO_2), upper extremity strengthening (shoulder, elbow, grip) using a dynamometer, and the blood lipid profile (fasting blood sugar [FBS], total

cholesterol [TC], low-density lipoprotein [LDL]). Participants underwent progressive rowing exercise, 30 minutes per session, 3 to 5 times per a week for 6 weeks. Pre and post maximal exercise capacity were evaluated with arm ergometer, during which heart rate and VO_2 were measured at work rate increments from baseline to fatigue. **Results:** After 6 weeks of rowing exercise, exercise capacity increased from 74.2 to 79.2W ($P = .034$) and VO_2 increased from 5.4 to 8.7 mL/kg/min ($P = .099$) and maximal heart rate decreased from 141.9 to 138.7 bpm ($P = .099$). TC decreased from 191.7 to 165.0 mg/dL ($P = .023$), and LDL decreased from 112.9 to 102.2 mg/dL ($P = .041$). Body fat percentage decreased 23.4% to 20.1% ($P = .021$) and FBS decreased 84.9 to 80.5 mg/dL ($P = .09$). The power of shoulder, elbow, and grip strength were increased ($P < .05$). **Conclusion:** After 6 weeks of aerobic exercise training with newly developed ROWmotor machine, the blood profile, body fat percentage, and exercise capacity were improved as well as upper extremity muscle power. These results suggest that the ROWmotor is effective exercise tool, especially for the persons with weak or paralyzed lower extremity.

Support: This research was supported by a grant (08-B-03, 10-B-01, 11-B-01) by the National Rehabilitation Center Research Institute.

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Robotic Treadmill Training Improves Peak Exercise Capacity in Chronic Incomplete Spinal Cord Injury: A Pilot Controlled Clinical Trial

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Objective: To assess the effectiveness of robotic treadmill training (Lokomat) exercise in improving cardiovascular fitness as measured by peak oxygen consumption (VO_2 max) in chronic motor incomplete spinal cord injury (MISCI). **Design:** Prospective randomized, controlled trial of 3 months of robotic treadmill training exercise versus a stretching control paradigm. **Participants/Methods:** Individuals with MISCI between C4 and L1 at least 1 year post injury.

11 participated in 3 months of 3 times weekly Lokomat training and 6 participated in 3 months of a home stretching program. Participants underwent peak exercise oxygen consumption (VO_2 max) testing while using the Lokomat and during arm cycle ergometry at baseline and after intervention. Studies were performed at least twice at each time point. VO_2 max values were normalized for total body mass. **Results:** On average, treatment group improved VO_2 max from 20.0 to 22.6 ml/kg/min ($P = .016$) while the control group improved from 13.0 to 16.7 ($P = .332$) with Lokomat testing. Control results may have been influenced by one outlier. VO_2 max measured with arm cycle ergometry did not improve after treatment compared to control. **Conclusion:** Robotically assisted treadmill training is an effective method of improving cardiovascular fitness as measured by peak VO_2 in persons with MISCI. This effect appears to be task specific, as it does not carry over to testing using arm cycle ergometry. **Support:** This study was funded by a Department of Veterans Affairs Rehabilitation R&D Service Merit Review Award B40271.

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Neuromuscular Electrical Stimulation for Aerobic Training in Spinal Cord Injury

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Objective: Previous studies have utilised functional electrical stimulation (FES) techniques to enhance fitness in an SCI population. The objective of this investigation was to evaluate the efficacy of a novel neuromuscular electrical stimulation (NMES) system in increasing VO_2 peak in individuals with spinal cord injury. We hypothesised that this NMES system could produce increases in aerobic fitness comparable to current FES systems. **Design:** Prospective cohort study. **Participants/methods:** 13 sedentary participants with acquired paraplegia (T4-T11; ASIA A/B; age: 44.84 ± 8.19 years; time since injury: 11.68 ± 12.0 years; height: 1.67 ± 0.08 m; weight: 72.82 ± 13.30 kg) were recruited from the National SCI database. Each participant undertook a familiarisation session and an 8-week home-based NMES training programme. 4 electrodes (175 cm²) were placed bilaterally on the proximal and distal quadriceps and hamstrings muscle groups, and subtetanic contractions were elicited using an NMES

device (NT2010, Biomedical Medical Research [BMR], Galway, Ireland). An incremental treadmill protocol was developed to determine VO_2 peak, which was measured pre and post the training programme. Data were analysed using PASW Statistics 18. **Results:** A statistically significant increase in VO_2 peak ($P = .002$) using Wilcoxon signed rank test was observed following the 8-week training programme. **Conclusions:** This novel form of NMES is an effective method of improving aerobic fitness in a SCI population. The device can be utilized independently at home with minimal set-up requirements for the user. Larger studies with this form of NMES are now warranted.

Support: This research was funded by Enterprise Ireland and BMR.

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A More Active Lifestyle Is Associated with a Better Physical Fitness and a Reduced Risk of Cardiovascular Disease in Persons with a Recent Spinal Cord Injury

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Objective: To study the relationship between objectively measured physical activity level and physical fitness and lipid profile in persons with a recent spinal cord injury (SCI). **Design:** A prospective cohort study. **Participants/methods:** Data of 30 persons with a recent SCI were collected at the start of active rehabilitation, 3 months later, at discharge from inpatient rehabilitation, and 1 year after discharge. Physical activity level (duration of dynamic activities as percent of 24 hours) was measured with an accelerometry-based activity monitor. Regarding physical fitness, peak oxygen uptake ($\text{VO}_{2\text{peak}}$), and peak power output (PO_{peak}) were determined with a maximal wheelchair exercise test, and upper extremity muscle strength was measured with a handheld dynamometer. Fasting blood samples were taken to determine the lipid profile. **Results:** An increase in physical activity level was significantly related to an increase in $\text{VO}_{2\text{peak}}$ and PO_{peak} , a trend

was found for a relation with muscle strength, and an increase in physical activity level favourably affected the lipid profile. **Conclusion:** Physical activity seems to play an important role in the fitness and health of persons with SCI. An increase in physical activity level was associated with an increase in physical fitness and with a lower risk of cardiovascular disease.

Support: Johanna Child Fund, Child Fund Adriaanstichting (grant no.2002/0067), ZONmw Rehabilitation program (grant no.1435.0003)

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Effects of Sensation and Autonomic Function on Reactive Hyperemia Following Pressure With and Without Cooling in People With Spinal Cord Injury

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Objective: Our previous study used reactive hyperemia to quantify the tissue tolerance with local cooling intervention. We found that cooling had a protective effect on ischemic tissue in people with and without spinal cord injury (SCI). The objective of this study was to investigate the relationship of sensation and autonomic function to reactive hyperemia after loading. **Design:** Repeated measures design with 3 test conditions: pressure only (60 mmHg), pressure with fast cooling ($-4^{\circ}\text{C}/\text{min}$), and pressure with slow cooling ($-0.33^{\circ}\text{C}/\text{min}$). **Participants/methods:** 33 participants were recruited (19 with SCI and 14 controls). Outcome measures were normalized peak skin blood flow (SBF) and perfusion area following loading. Regression analysis was used to test the predictors. **Results:** There were no predictors of the reactive hyperemia for pressure only. With fast cooling, autonomic function and sensation predict the normalized peak SBF [$\beta = -.547$ ($P = .014$) and $.489$ ($P = .026$), respectively; $R^2 = .203$, $F = 3.812$, $P = .033$] and the perfusion area [$\beta = -.618$ ($P = .004$) and $.611$ ($P = .004$), respectively; $R^2 = .281$, $F = 2.872$, $P = .007$]. With slow cooling, only autonomic function predicts the normalized peak SBF [$\beta = -.338$ ($P = .043$); $R^2 = .225$, $F = 4.399$, $P = .043$] and the perfusion area [$\beta = -.408$ ($P = .013$); $R^2 = .167$, $F = 6.801$, $P = .013$]. **Conclusions:** The existence of autonomic function decreases the reactive hyperemic response with both cooling interventions, while the

existence of sensation increases the response with fast cooling. The reasons for these differences were not clear and further investigation of both neurological functions might assist in understanding the changes of vascular control after injury and pressure ulcer risk.

Support: This work was funded by NIDRR, RERC on Spinal Cord Injury, grant H133E070024.

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A Comparison of Medicare Patients in the SCI Model System Database and the National Medicare Databases

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Objective: To compare the characteristics of Medicare patients with a new spinal cord injury (SCI) in the Model Systems database with the national inpatient rehabilitation facilities (IRF) Medicare database. **Design:** Secondary analyses of data using the SCI Model Systems database and national Medicare databases. **Participants/methods:** 222 patients discharged from an SCI Model System and 2,989 Medicare patients discharged from 832 inpatient rehabilitation facilities. **Results:** Model System database patients, when compared to national Medicare patients, were younger (37.4% vs 56.5% were 75 and older), more likely to be male (70.3% vs 50.6%), and more likely to be married (64.0% vs 53.8%). In both groups, half of the patients had a diagnosis of tetraplegia incomplete (51.4% and 52.3%); a higher percentage of the model system patients had tetraplegia complete (13.1% vs 2.0%). **Conclusions:** Medicare patients in the SCI Model System database are not representative of the national Medicare population with a new SCI. **Support:** This work was funded by the US Department of Education, National Institute on Disability and Rehabilitation Research - Midwest Regional Spinal Cord Injury Care System, Chen, PI (Award H133N060014).

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Outcomes of Lower Limb Fractures After Spinal Cord Injury

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Objective: To evaluate the impact of lower limb fractures in people with chronic spinal cord injury (SCI). **Design:** Postal questionnaire survey. **Participants/methods:** 408 persons with SCI, known to have had lower limb fractures, were sent a postal questionnaire. **Results:** 298 persons (74.3%) returned valid responses, reporting on 485 fractures, ranging from 1 to 6 fractures per person. Mean age at fracture was 45.27 years and mean duration of SCI was 17.94 years. The most common fracture site was the shin (43.5%), followed by femur (34.7%), hip (11.1%), and foot (10.7%). 56.5% of fractures required hospitalisation and 32.2% were surgically fixed. Short-term complications occurred in 27.3% of the fractures. Pressure sores were the most frequent (15.2%), followed by infection (7.9%) and deep venous thrombosis (3.4%), and 5.8% had more than one. Long-term complications occurred in 47.8% of fractures, malalignment being the most common (24.7%), followed by limited joint movement (16.1%), loss of function (9.4%), and nonunion (6.1%). 18.2% had more than 1 long-term complication. Permanent changes to life style (eg, altered care needs, equipment change) were reported after 28.9% of the fractures. Fewer people who went to a spinal unit had short-term complications ($P < .001$), long-term complications ($P < .023$), or permanent changes ($P < .003$) or needed help during convalescence ($P < .005$), compared with those who went to a general hospital. **Conclusions:** Nearly half of the lower limb fractures resulted in long-term complications and nearly one-third in permanent changes to life style. Reported complications differed between context of in-patient care.

Support: Supported by United Kingdom Spinal Cord Injury Research Network (UKSCIRN) and Buckinghamshire Healthcare Charitable Trust Funds

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Upper Limb Motor Control After Tendon Transfer in Tetraplegia

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Objective: The biceps brachii (BB), brachialis (B), and brachioradialis (Br) muscles are synergists in elbow flexion. After cervical spinal cord injury (SCI), surgical transfer of a strong Br to the paralyzed flexor pollicis longus (FPL) restores pinch strength. This study investigates postoperative control strategies for activating the transferred Br in its new role to perform lateral pinch. **Design:** Static group comparison. **Participants/methods:** 7 subjects included 3 non-impaired (NI) and 4 SCI (C5-7, complete), 1 year post Br-FPL transfer. The postoperative coordination between the BB, B, and Br during submaximal pinch versus elbow flexion was investigated with fine-wire electromyography (EMG) as isometric and ramp contractions were performed. Recruitment and firing rate data were obtained by EMG signal decomposition. Functional magnetic resonance imaging (fMRI) identified neural adaptation after Br-FPL transfer during the performance of elbow flexion and lateral pinch in SCI ($n = 2$) compared to NI ($n = 3$) participants. **Results:** In 3/4 SCI participants, postoperative maximal pinch forces were 15 to 48N, and motor units identified from the transferred Br were not active during submaximal elbow flexion, but were activated independent of B and BB during submaximal pinch. One participant produced lower pinch force (2N) with no independent control of the transferred Br. Functional MRI showed an extended motor network in patients versus control participants, including bilateral and secondary motor area activation associated with planning and complex motor tasks. **Conclusion:** EMG and fMRI data demonstrate new muscle synergy patterns and neural adaptation to tendon transfer procedures. Muscle re-education involving Br transfers may be facilitated with activities to modify the coordination of elbow flexor synergists.

Support: Department of Veterans Affairs, CDA-2 Award

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The Role of Post-Traumatic Stress Disorder Symptoms in Spinal Cord Injury-Related Chronic Pain

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Objective: Evidence indicates there is a link between posttraumatic stress disorder symptoms (PTSS) and the development of chronic pain. Work-to-date has not examined this relationship in spinal cord injury (SCI). **Design:** Cross-sectional telephone survey. **Participants/methods:** Community-dwelling adults with traumatic SCI completed the Secondary Condition Scale – Modified (SCS-M), Beck Depression Inventory (BDI-II), Post-Traumatic Stress Disorder Checklist – Civilian Version (PCL-C), and Brief Pain Inventory (BPI). **Results:** The chronic pain item on the SCS-M was used to divide the sample into a SCI-related chronic pain group ($n = 140$; mean BPI = 5.9; $SD = 1.9$) and SCI without pain group ($n = 113$). The pain group reported higher BDI scores ($M = 7.7$; $SD = 7.4$; $t(236.7) = 5.31$, $P = .000$) than the no-pain group ($M = 3.6$; $SD = 4.6$). There was a positive association between scores on the PCL-C and BDI ($r = .65$, $P = .000$). After controlling for scores on the BDI, PCL-C scores were higher ($P < .05$) in persons with pain ($M = 27.1$; $SD = 8.9$) than those without ($M = 22.3$; $SD = 6.3$). **Conclusion:** The findings indicate that the occurrence of PTSS and pain are associated in persons with traumatic SCI, raising the possibility that the 2 are mutually maintaining or that they are both maintained by a common, yet to be identified, underlying vulnerability factor. Targeting PTSS may serve as a potential clinical intervention for SCI-related chronic pain.

Support: Physician Services Incorporated Foundation

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Ultraviolet-C Irradiation (UVC) Improves Wound Healing in Persons with Spinal Cord Injury (SCI)

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Objective: Evaluate UVC effects on wound healing. **Design:** Double-blind, placebo-controlled trial. **Participants/methods:** Subjects with SCI and stage II-IV ulcers were randomized to active or placebo-UVC using stratification for ulcer location: pelvis (sacroccocyx, ischium) or lower extremity (heel, trochanter, malleolus). Ulcers were irradiated 3 times weekly until closure; dosage was based on ulcer depth and appearance. Ulcers were measured weekly. Primary outcomes were weekly healing rate, reduction in wound size, and weeks to closure. **Results:** 44 individuals (58 ulcers) entered the study; 26 individuals (32 ulcers) exited the study before wound closure. Median weekly healing rate for stage II ulcers was 35.9% for UVC and 5.8% for placebo-UVC (achieved significance level [ASL] = 0.063); greatly exceeding minimal clinically important difference (MID). Stage II pelvic ulcers benefited most: UVC-treated ulcers averaged 66% of initial size after 1 week and 28% after 8 weeks while placebo-treated ulcers averaged 120% to 180% during the same period (ASL = 0.0377 to 0.0914). Between-group healing rates were similar for stage III-IV pelvic ulcers; however, closure averaged 6 weeks using UVC and 9 weeks using placebo-UVC (ASL = 0.067). UVC accelerated healing of stage II-IV lower extremity ulcers: during weeks 1 to 6, ulcer size reduction was approximately 15% greater each week using UVC compared with placebo-UVC. Although not statistically significant, these differences exceeded MID at weeks 1, 2, 4, 5, and 6. **Conclusion:** UVC was effective particularly for stage II pelvic ulcers. The high variance associated with individual mean weekly healing rates, small sample size, and different healing endpoints at discharge compromised comparison between treatments. Future studies should stratify subjects based on ulcer stage in addition to location.

Support: Ontario Neurotrauma Foundation; Mount Sinai Hospital, Toronto

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To Work or Not To Work After SCI: Labour Market Participation of People with Spinal Cord Injury Living in Switzerland

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Objectives: The objective of this project is to establish basic labour market participation (LMP) figures of persons with SCI living in Switzerland and to investigate determinants and consequences of working. **Design:** Observational, cross-sectional survey. **Participants/methods:** A survey among members of the Swiss Paraplegic Association (SPA) was performed. Inclusion/exclusion criteria were SCI with acute onset, at least 18 years old at time of survey, and living in the community after SCI for at least 1 year. A total of 559 (27%) persons with SCI returned the questionnaire. Analysis was performed using *t* tests and contingency tables with chi-square tests and appropriate association coefficients. **Results:** 64.3% of the respondents of working age were in gainful employment. No significant difference between para- and tetraplegic persons (64.7%/63.4%) was observed. The found reasons why persons in SCI work or do not work are social and health related. Employment was significantly associated with gender, education, employment before SCI onset, better health, better social integration, less pain, and higher income. **Conclusions:** The findings show a relatively high percentage of LMP among persons living with SCI in Switzerland. In our study, the persons with tetraplegia have almost the same LMP as persons with paraplegia. The integration measures taken in Switzerland seem especially successful for severely disabled persons.

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Relationship Between Heart Rate Variability and Sacral Skin Perfusion in People with Spinal Cord Injury

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Objective: Heart rate variability (HRV) has shown a potential for quantifying residual sympathovagal regulations following spinal cord injury (SCI) and may be used to assess the effect of autonomic dysfunction on skin microcirculation. We hypothesized that people with SCI have an impaired sympathovagal response to postural changes, thus contributing to impaired skin perfusion responses. **Design:** Pretest-posttest design. **Participants/methods:** We recruited 26 people into this study, including 12 people with SCI and 14 healthy controls. R-R intervals and sacral skin perfusion were continually recorded during 10-minute upright and 10-minute prone postures using electrocardiogram and laser Doppler flowmetry, respectively. The sympathovagal balance was defined as the ratio of the power of the low frequency to the high frequency of HRV. **Results:** The results showed that healthy controls had a significant change in the sympathovagal balance in response to postural changes; lower sympathovagal balance was associated with higher skin perfusion ($P < .05$). People with SCI did not show a significant change of HRV and skin perfusion in response to postural changes. **Conclusion:** We have demonstrated for the first time that sympathovagal balance assessed by HRV was associated with the skin vasoconstrictive response to postural changes.

Support: This project was funded by the Christopher and Dana Reeve Foundation (JA2-0701-2) and the National Institutes of Health (R03HD060751).

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Autonomic Dysreflexia Following Spinal Cord Injury: Translating Knowledge into Best Practice for Health Care Practitioners

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Objective: Knowledge regarding the recognition and management of autonomic dysreflexia (AD) among emergency medical personnel caring for individuals with spinal cord injury (SCI) is lacking. The objective of this study was to examine clinician knowledge of various aspects of AD utilizing an “ABC of AD” certification course with an associated pre- and postcourse survey to determine course effectiveness. **Design:** A prospective multicentre study. **Participants/methods:** A total of 133 participants (28 MDs, 46 RNs, 39 residents, and 20 paramedics) from three major medical centers in Toronto, Vancouver, and Winnipeg attended the course. A weighted scoring system was used to grade the survey responses. **Results:** 85% of ER personnel and all paramedics rated their knowledge of AD as either “fair” or “poor.” 40% of ER personnel and 25% of paramedics were not able to correctly define AD. Only half of ER personnel and less than a third of paramedics were able to distinguish the 3 most common causes of AD. Clinicians attending the course had a significant increase in their AD knowledge, as evidenced by changes in their test scores. **Conclusion:** AD is a life-threatening emergency for individuals with SCI. Our study has demonstrated extremely alarming results and indicates significant gaps in knowledge of this condition among emergency health care practitioners.

Support: Rick Hansen Institute grant 2009-42

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Autonomic Dysfunctions in Individuals with Acute Spinal Cord Injury: Experience Using the International Autonomic Standards Form

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Objective: To examine the utility of the “International Standards to document remaining autonomic function after spinal cord injury (SCI)” (2009) in clinical practice at a specialized SCI rehabilitation centre. **Design:** Retrospective chart review of the inpatients admitted with traumatic SCI to the specialized unit. **Participants/methods:** All individuals admitted to the center with traumatic SCI over a 1-year period were examined. At admission and discharge, autonomic dysfunctions were evaluated using the table proposed by the International Autonomic Standard Form 2009 (IASF09). **Results:** Evaluation IASF09 forms from 52 acute traumatic SCI cases on admission revealed the following: dysrhythmias were present in 20% of individuals, with 43% of abnormalities in arterial blood pressure. There were 30% individuals with temperature, 27% individuals with sweating, and 13% individuals with respiratory abnormalities. On admission, urinary bladder dysfunctions were documented in 67% individuals, bowel dysfunctions in 80% individuals, and sexual dysfunctions in 37% individuals. At discharge, frequencies of cardiovascular, bladder, bowel, sweating, and temperature dysfunctions were very similar to those at admission. However, there was an increase in the frequency of the documented sexual dysfunctions among individuals with SCI. **Conclusions:** This is a first experience of our unit with use of the IASF09 in clinical practice. Medical personnel of the unit felt strongly that there was more attention paid to the autonomic dysfunction during the evaluation of the patients during the admission and discharge with the use of the form.

Support: None

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A Model of Cardiovascular Regulation by Thoracic Spinal Cord Centers*Amiram Catz, MD, PhD^{1,2}*¹Loewenstein Rehabilitation Hospital, Raanana;²Tel-Aviv University, Tel-Aviv, Israel

Objective: To investigate the ability of a suggested theoretical model of neural centers and circuits in the spinal cord to explain results of experiments examining the contribution of the thoracic spinal cord to cardiovascular regulation. **Design:** A comparative analysis. **Participants/method:** A hypothetical model of 2 upper thoracic spinal cord vasomotor centers at the T1-4 and at T7-8 segments and their neuronal connections is suggested. The model was compared with findings of a series of published experiments in which 13 healthy control subjects, 10 patients with T4-T6 paraplegia, and 11 with C4-C7 tetraplegia were examined. Among these, blood pressure decreased in tetraplegia but increased in mid-thoracic paraplegia and healthy subjects during head up tilt; postprandial hypotension presented in midthoracic paraplegia but not in tetraplegia; there was no change in cerebral blood flow velocity after a meal; blood pressure increased in tetraplegia and healthy subjects but not in paraplegia during cold application to the hand; heart rate increased in healthy persons but decreased in patients with spinal cord injuries during cold application to the foot. **Results:** A diagram of the model is presented. Responses expected based on the model were found to be similar to experimental findings. **Conclusion:** The suggested model can explain the contribution of the thoracic spinal cord to cardiovascular regulation.

Support: The experiments were supported by the Unit of Medical Services, Rehabilitation Department, Israel Ministry of Defense, and by the Tel-Aviv University Research Fund. Rimed Ltd, Raanana, Israel, lent the TCD device for the experiments.

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Assessment of Severity of Autonomic Lesion in Complete Spinal Cord Injury Patients*Jean G. Previnaire, MD,¹ Jean M. Soler, MD,² Valerie Leclercq, MD,¹ and Pierre Denys, Prof³*¹Fondation Hopale, Berck sur Mer; ²Centre Bouffard Vercelli, Cerbère; ³Hôpital Raymond Poincaré, Garches, France

Objective: We aimed to study relationship between the level and completeness of the spinal cord injury (SCI) lesion and the degree of autonomic dysfunction. **Design:** Prospective study. **Participants/method:** SCI patients presenting with a motor and sensory complete lesion above T6 were enrolled. They took a battery of tests that included pressor stimuli above (mental arithmetic, hand cold pressor test, sympathetic skin responses [SSR]) and below the lesion (foot cold pressor test, abdominal electrical stimulation), and Valsalva manoeuvre. **Results:** 26 consecutive traumatic SCI patients took part in the study (14 tetraplegics and 12 paraplegics). All patients showed abolished feet SSR, while a significant rise in systolic blood pressure in at least one of the pressor tests below the lesion was seen in all but one paraplegic patient. Hands SSR and blood pressure overshoot at the end of the Valsalva manoeuvre were abolished in all tetraplegics, whereas at least one of those responses was seen in each paraplegic. Hand cold test and mental arithmetic induced cardiovascular changes in most patients. **Conclusion:** A complete loss of supraspinal control was observed in all, with a reflex isolated spinal cord in all but one patient. We confirm that in most SCI subjects there is concordance between the impairment of sympathetic function and somatic impairment. To assess autonomic dysfunction, a battery of tests should include SSR, abdominal electrical stimulation, and Valsalva manoeuvre, as they combine pressor stimuli above and below the lesion and assess both cholinergic and sudomotor pathways.

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Autonomic Dysreflexia: A Spinal Network and Health System Challenge

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Objective: To encourage evidence based best practice across New South Wales (NSW) health system using a multilayered, systemic approach to reduce preventable morbidity and mortality from autonomic dysreflexia (AD). **Design:** Pre-post systems/outcomes evaluation. **Participants/methods:** Easy-to-use educational tools, catering to clinicians, consumers, and carers, were developed for statewide dissemination in conjunction with release of a Safety Alert by NSW Health Department. Key stakeholders were identified at every level within NSW Health system to access preexisting education pathways and resources to ensure that information reaches target audience in a cost-effective manner. A review of current practices was undertaken in process. **Results:** Successful education strategies for clinicians and consumers included face-to-face and distance (self-paced and just-in-time) Web-based learning. Pre-post evaluation, health professional feedback, and consumer experiences demonstrated positive outcomes. Review of 50 recent spinal cord injury unit (SCIU) readmissions in 41 individuals related to or associated with AD found most frequent causes were urinary (55%) or bowel (23%) related, but also multifactorial and complex presentations. The first-line medication used was *glyceryl trinitrate* (GTN) spray, tablet or patch (n = 42), epidural or GTN infusion (n = 2), with secondary medications including metoprolol/labetalol (n = 5), morphine/endone (n = 4), clonidine (n = 4), phenoxybenzamine (n = 3), and others. Common interventions were catheter changes, antibiotics, adding/increasing dose of anticholinergics, and modifying bowel aperients/ regime, with numerous procedures performed. **Conclusion:** The SSCIS network has strategically utilised many aspects of the health support system to raise awareness of this critical condition and its management. A targeted implementation strategy utilising networks to translate policy into practice may be effective.

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United States (US) Multi-Center Study to Assess the Validity and Reliability of the Spinal Cord Independence Measure (SCIM III)

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Objective: To assess the validity and reliability of the SCIM III in measuring functional ability in persons with spinal cord injury (SCI). **Design:** Multi-center, prospective, cohort study. **Participants/methods:** Functional ability was measured with the SCIM III during the first week of admittance into inpatient acute rehabilitation and within 1 week of discharge from the same rehabilitation program in 390 subjects with any level of SCI due to traumatic or nontraumatic causes. Motor and sensory neurologic impairment was measured with the ASIA Impairment Scale. The Functional Independence Measure (FIM) was used as a comparison standard for the SCIM III. Statistical analyses were used to test the validity and reliability of the SCIM III. **Results:** Total agreement between raters was above 70% on most SCIM III tasks and all kappa coefficients were statistically significant ($P < .001$). The coefficients of Pearson correlation between the paired raters were above 0.81, and intraclass correlation coefficients were above 0.81. Cronbach's α was above 0.7, with the exception of the respiration task. The coefficient of Pearson correlation between the FIM and SCIM III was 0.8 ($P < .001$). For the respiration and sphincter management subscale, the SCIM III was more responsive to change than the FIM ($P < .0001$). **Conclusion:** Overall, the SCIM III is a reliable and valid measure of functional change in SCI. However, improved scoring instructions and a few modifications to the scoring categories may reduce variability between raters and enhance clinical utility.

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Graded Redefined Assessment of Sensibility Strength and Prehension (GRASSP): Psychometric Development of an Upper Limb Impairment Measure for Individuals with Traumatic Tetraplegia

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Objectives: To develop a scoring system for the GRASSP; to establish interrater and test-retest reliability, construct/concurrent validity; and to determine relationships of domains within GRASSP and GRASSP to upper limb function. **Design:** A cross-sectional multicentre trial with repeated administration of the GRASSP by multiple examiners and single administration of validation measures was conducted in 4 centres in North America and 3 sites in Europe. **Participants/methods:** The International Standards of Neurological Classification for Spinal Cord Injury (ISCSCI), Spinal Cord Independence Measure III (SCIM), Capabilities of Upper Extremity Function (CUE), and repeated GRASSP (x3) were administered on a sample of 72 individuals with chronic tetraplegia. Guttman scaling to develop the scoring system; intraclass correlation coefficients to establish reliability, Pearson correlation coefficients to establish validity with SCIM and CUE were used. Structure equation modeling was used to establish relationships between GRASSP domains and function. **Results:** GRASSP subtests defined individuals' impairment and demonstrated cumulative predictive pattern 80% of the time. Interrater and test-retest reliability ranged from 0.83 to 0.99. Construct validity was confirmed by level of agreement (kappa statistic 0.412-0.511); these findings defined the GRASSP sensation and strength testing to be more sensitive than the comparative measures. GRASSP subtests demonstrated concurrence with the SCIM and CUE. Impairment showed the strongest concurrence with self-perception of function (0.57-0.83; $P < .0001$). Quantifying impairment showed that sensation and

strength have different direct and indirect influences on upper limb function. **Conclusion:** The GRASSP is reliable, valid, and sensitive in defining upper limb function. GRASSP should be used to track neurological functional changes longitudinally.

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Spinal Cord Injury Classification: Comparison of Human and Computer Algorithm for ASIA Impairment Scale Grades

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Objective: Compare American Spinal Injury Association Impairment Scale (AIS) grade determined by investigators to that generated by a computer algorithm using data from the Spinal Cord Injury Model Systems (SCIMS). **Design:** Comparative study of SCI classification at admission to system. **Participants/methods:** Demographic and initial neurological data were abstracted from the SCIMS database. Subjects with complete level and AIS information and a single neurological level above T11 were included. An algorithm modified to accommodate the lack of sensory scores and sacral sparing information was used to generate an AIS grade. Results were compared to the original classifications. Percentage reclassification by initial AIS grade was made and reasons for discrepancies identified. **Results:** 3,344 subjects had useful data. 80% were male; 57% were White, 29% Black, and 14% Other. 32% had paraplegia and 68% tetraplegia. The algorithm reclassified AIS grade in 328 (9.8%). Reclassification rate for tetraplegia was 12.1%, for paraplegia 5%; rate for original A was 2%, B was 13%, C was 34%, and D was 6%. **Conclusion:** Classification of SCI is subject to human error. Classification algorithms can identify many errors but are limited if data are missing and may misclassify those with uncommon patterns of deficits. Using algorithms to alert classifiers of potential errors would improve the quality and consistency of SCI databases.

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Confusion in Conversion

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Objective: To predict the ASIA Impairment Scale (AIS) conversion rate in subjects with traumatic sensorimotor complete SCI (cSCI) and to characterize the value of conversion in terms of walking ability. **Design:** Retrospective, longitudinal study. **Participants/methods:** Data from 142 tetraplegic and 217 paraplegic cSCI subjects from the EM-SCI Study Group were analyzed using logistic regression to find predictors for conversion in AIS. Neurological level, sensory level, pin-prick and light-touch, ASIA motor score, and Spinal Cord Independence Measure (SCIM), obtained within 0-40 days after injury, were considered as potential predictors of conversion rate over the first year after cSCI. WISCI II was used to evaluate walking function in the chronic phase after cSCI (>6 months). Subjects were scored as “independent” walkers (able to walk without assistance; WISCI = 20) or “dependent” walkers (required canes/crutches or braces; WISCI > 15). **Results:** 49 tetraplegic and 44 paraplegic cSCI subjects converted in AIS grade. Logistic regression revealed no predictors for conversion. In tetraplegic subjects, about 10% (13/142) converted to AIS D, however only 2 subjects became independent walkers and 2 dependent walkers. In paraplegic subjects, 4% (8/217) converted to AIS D, but only 4 subjects became independent walkers and 4 became dependent walkers. **Conclusion:** In cSCI individuals, AIS conversion cannot be predicted. The overall conversion rate in AIS A patients is comparable between data sources with a mean rate of 30% in tetraplegia and 20% in paraplegia. The value of AIS conversion rate in terms of walking ability may be questionable as it seems not to be associated with functional scores. The use of clinical or functional scores may be preferable over AIS conversion as primary or secondary outcomes in clinical trials.

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Evaluation of Item Banks of Daily Routines and Participation for Patient Reported Outcomes Following Spinal Cord Injury Using Computer Adaptive Testing Platforms

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Objective: To evaluate the psychometric properties of an item bank for daily routines and participation for child and parent reported outcomes following spinal cord injury (SCI) using computer adaptive testing (CAT); to evaluate validity of item banks; and to compare simulated CAT scores to the scores from the full item banks. **Design:** Large-scale calibration study of newly developed item banks designed to evaluate daily routines and participation. **Participants/methods:** Parents and youths with SCI (n = 381), mean age of 15.5 years; slightly more than half (57.6%) had paraplegia and complete injuries (54.2%). Daily routines item bank consisted of 196 self-reported items, and participation item banks consisted of 102 items. Confirmatory factor analysis (CFA) model fit was assessed by Comparative Fit index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error Approximation (RMSEA), and residual correlations. Local independence was evaluated by inspecting the residual correlations between items. The Functional Independence Measure (FIM), Shriners Pediatric Instrument for Neuromuscular Scoliosis (SPINS), PedsQL, and Children’s Assessment of Participation and Enjoyment (CAPE) were used to evaluate validity. Pearson correlation coefficients were used to test the accuracy of 5, 10, and 15 item CAT scores with the full item bank. **Results:** CFI for activity performance and participation item banks ranged from 0.864 to 0.986; TLI between 0.928 and 0.963 and; RMSEA between 0.102 and 0.089. 75% and 76% of variance was accounted for in daily routines and participation, respectively. The 5, 10, and 15 item CAT scores were highly correlated with scores from the full set of items. Concurrent validity of the daily routine scores was supported by the moderately high (≥ 0.8516) correlation between the full item bank and the scores from FIM, SPINS, and PedsQL. **Conclusion:** Evaluation of these item banks meets IRT assumptions, and they have the potential to develop into CAT for parent and children reported outcomes following SCI.

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Evaluation of Functional Recovery in a Spinal Cord Injured (SCI) Population, Using the Spinal Cord Independence Measure III (SCIM III)

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Objective: To evaluate the functional gains of all individuals with spinal cord injury (SCI) who underwent an inpatient comprehensive rehabilitation program in CMRRC in the time period between January 1 and December 31, 2010. **Design:** Prospective study using admission and discharge data including etiology, level, and completeness of SCI, Motor Score (MS) according to American Spinal Injury Association Impairment Scale (AIS), and SCIM III. **Methods:** Participants were divided in neurological level subgroups (C1-C4, C5-C8, T1-S1). Median AIS, MS, and SCIM III (total and subgroups) changes between admission and discharge were calculated, and data were analyzed using the SPSS (version 18) program. **Results:** 47 of the 72 admissions met the inclusion criteria. Median Self-Care, median Respiratory and Sphincter Management, and median Mobility SCIM subgroups all improved from admission to discharge (11 to 18, 19 to 33, 11 to 20, respectively). Significant functional improvement was observed between admission and discharge across all subgroups except C1-C4. AIS upper limb MS correlated highly with the SCIM Self-Care (Pearson .890). AIS lower limb MS correlated highly with SCIM Mobility (Pearson .790). **Conclusion:** SCIM III was found useful and practical in assessing functional gains in SCI individuals in a spinal injury program in the Centre Region of Portugal. This was only found not to be applicable in the C1-C4 subgroup.

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