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IV. Spinal Cord Injury

A. General

Clinical Evaluation of External Devices for Urinary Care of Incontinent Women

David E. Johnson, Ph.D. and Jodie L. O'Reilly, R.N., B.S.N.

Veterans Administration Medical Center, Infectious Diseases Research Laboratory, Baltimore, MD 21218

Sponsor: VA Rehabilitation Research and Development Service

Purpose—Chronic urinary incontinence, a frequent complication of spinal cord injury, multiple sclerosis, neurological defects affecting frontal lobe cortex, and advancing age, may be the pivotal factor determining whether a patient requires long-term institutional care. An estimated 2.4 million American women are incontinent of urine and that number is likely to exceed 3 million by the year 2000. This report summarizes our ongoing studies into the development of comfortable and effective external devices for women as alternatives to indwelling urethral catheters and/or absorbent products.

The customary methods for management of chronic urinary incontinence in women, the use of indwelling urethral catheters or diapers, invariably lead to bacteriuria or infected decubiti in nonambulatory patients. An external device that was comfortable to use, and effective in collecting urinary output without leakage, may prevent some of the complications (e.g., bacteriuria and infected decubiti) associated with management of chronic urinary incontinence.

Progress—We have entered into joint studies with device manufacturers for development and clinical evaluation of external urinary incontinence devices for women. These joint studies include fabrication of prototype devices by the manufacturers, and our clinical evaluation of prototypes in healthy volunteers and urinary incontinent inpatients and outpatients.

Since our last report, we have clinically evaluated five types of external urine-incontinence devices for women. Three of those device types were designed for use by ambulatory women and two of those

devices were designed for use by non-ambulatory women.

We have evaluated 256 applications of external devices in 13 ambulatory, urine-incontinent women. Time of device use per day varied and was determined by individual patient needs. Devices were evaluated on the basis of ease of application and removal by the patient, adverse consequences of device use including unacceptable urine leakage from the devices, and patient comfort during device use. Patients were able to self-apply and remove devices without consequence.

Results—Forty percent of device applications resulted in urine collection without leakage and 10 percent of applications resulted in sufficient urine leakage to force the patient to temporarily use an alternative method of urinary care.

We have clinically evaluated 116 applications of external devices in 14 bedridden women. Preliminary studies were conducted using healthy volunteers confined to bed for 8 hours per day for 5 days, for device evaluation. Periurethral irritation was not observed during device use, and devices remained *in situ* without urine leakage for 97 percent of the evaluation period.

We have also evaluated 63 applications of an external device for 125 patient days on 7 bedridden, urine-incontinent nursing home patients. Five patients used the device continuously for 21 days, and 2 patients used the device continuously for 10 days. Devices were allowed to remain *in situ* while effective (i.e., collecting urine without leakage) for a maximum of 48 hours, but were replaced if leakage occurred. Mean effective wear time (\pm S.D.) of the

device was 45.6 (\pm 5.7) hours. Periurethral irritation was not observed in those nursing home patients during device use.

Future Plans—Evaluation of device modifications in ambulatory, urine-incontinent women. Evaluation of continuous device use in bedridden, urine incontinent women for up to 6 months.

Electrical Stimulation for the Prevention of Pressure Sores: Blood Flow Measurements

Simon P. Levine, Ph.D.; Ronald L. Kett, M.S.; Milton D. Gross, M.D.; Jack E. Juni, M.D.;
Barbara A. Wilson, B.S.

Rehabilitation Engineering Program, Department of Physical Medicine and Rehabilitation, University of Michigan Medical Center, Ann Arbor, MI 48109 and Nuclear Medicine Service, Ann Arbor Veterans Administration Medical Center, Ann Arbor, MI 48105

Sponsor: VA Rehabilitation Research and Development Service

Purpose—Pressure sores (decubitus ulcers, ischemic ulcers, etc.) represent a severe and costly problem for many disabled individuals. This is particularly true for those who are wheelchair-dependent and have sensory loss. A research program has been implemented to determine whether electrical muscle stimulation (EMS) can be used to prevent the formation of pressure sores.

Pressure sore etiology is a complicated event, involving many parameters, but most investigators agree that a primary event leading to pressure sore formation is blood flow occlusion. Occlusion of lymph flow and disturbance of interstitial fluid flow are also important factors. The current study investigates the effects of EMS on tissue blood flow.

Progress—The scope of the current project is to investigate those “immediate/dynamic” effects of EMS for preventing pressure sores. One of the hypothesized mechanisms whereby EMS may be effective is that tissue undulation and variations in the seating interface pressure will permit increased blood flow. Previous reports have documented that EMS can produce substantial interface pressure changes. This is true even at low stimulation intensities easily tolerated by sensate subjects. It has also been shown, using an ultrasonic image acquisition system, that EMS will produce appreciable tissue shape changes.

Preliminary Results—Blood flow in the skin and muscle during stimulation has been studied by injecting a radioactive tracer into the tissue. These blood flow studies have been performed on eight able-bodied (AB) and nine spinal cord injured (SCI)

subjects. All SCI subjects had acute injury at level T10 or above. One individual had incomplete injury; the rest were sensory and motor complete. None had a history of pressure sores at their ischial tuberosities (IT).

Bilateral stimulation of the gluteus maximus muscle was performed using surface electrodes and a commercially available neuromuscular stimulator. The stimulation protocol for the AB subjects was as follows: a) 30 minutes, no stimulation; b) 12 minutes, alternating 2 minute periods of stimulation and rest; c) 30 minutes, no stimulation. Protocol for the SCI subjects differed only in that the initial and final 30 minute rest periods were reduced to 20 minutes. Pressure measurements were also recorded during the trial for comparison of blood flow with the magnitude of muscle contraction.

Blood flow was measured by injecting $^{133}\text{Xenon}$ at the site of the IT. Each subject received a subcutaneous injection on one side and an intramuscular injection contralaterally. A gamma camera with collimator was positioned under the subject. Sequential scintigraphic images of the injection site were recorded throughout the trial. Following imaging, a time-activity semilogarithmic plot of the $^{133}\text{Xenon}$ washout was obtained where the slope is proportional to the blood flow. For the AB subjects, blood flow in the muscle was increased significantly ($p < .05$) when compared to blood flow preceding or following EMS intervention. The SCI subjects showed the same trend; however, statistical significance was reduced ($p < .15$). This technique was ineffective for measuring subcutaneous blood flow due to the lipophilic nature of xenon.

Future Plans/Implications—Measurement of skin blood flow is an important part of evaluating the potential efficacy of EMS for pressure sore prevention. However, $^{133}\text{Xenon}$ has proved ineffective in measuring subcutaneous blood flow. Consequently, an alternate material, $^{99\text{m}}\text{Technetium}$ will be used. Trials have already begun with intradermal injections of this new radioactive material. Clinical trials, to directly determine the effect of EMS on skin status while sitting, are also planned for the near future. New SCI subjects will be recruited from the population of inpatients in the Interdepartmental Acute Spinal Cord Injury Program at the University

of Michigan Medical Center.

Publications Resulting from This Research

Dynamic Effects of Functional Electrical Stimulation on Seating Interface Pressure and Tissue Shape. Kett RL, Levine SP, Bowers LD, Brooks SV, Cederna PS, *Proceedings of the 9th Annual RESNA Conference*, 6:313-315, Minneapolis, MN, June 1986.

Functional Electrical Stimulation for the Prevention of Pressure Sores. Levine SP, Cederna PS, Brooks SV, Friedman RH, *Proceedings of the 7th Annual Conference—IEEE Engineering in Medicine and Biology Society*, pp. 707-710, 1985.

Ischial Blood Flow of Seated Individuals During Electrical Muscle Stimulation. Levine SP, Kett RL, Wilson BA, Cederna PS, Gross MD, Juni JE, *Proceedings of the 10th Annual RESNA Conference*, 7:642-644, San Jose, CA, June 1987.

Factors Influencing Joint Compliance and Reflex Mechanisms in Spinal Cord Injury

Charles J. Robinson, D.Sc.; Gyan C. Agarwal, Ph.D.; Gerald L. Gottlieb, Ph.D.

Veterans Administration Medical Center, Hines, IL 60141 and University of Illinois, Chicago, IL

Sponsor: VA Rehabilitation Research and Development Service (Project #XB446-R)

Purpose—The normal pattern of motor control is greatly altered by spinal cord injury (SCI), often in unpredictable fashion. Much of the characterization to date of reflex activity in individuals with spinal cord injury comes from studying electromyographic responses to peripheral nerve stimulation, not to passive or active limb movement where joint compliances can be measured. While controlled passive movements can be achieved with torque motors, active movements in some of these individuals can be initiated with surface electrical stimulation. Restrengthening of paralyzed muscles by such stimulation also might alter compliance and reflex activity.

The following questions will be addressed in this project. Can joint compliance and spinal cord and supraspinal reflex activity be reliably measured in individuals with SCI? How does this activity change over the time since injury? Do joint rotations yield a more complete and reliable characterization of the peripheral motor control loop than do measurements of H-reflex changes? Are the compliances and reflexes different when the muscles are being activated by electrical stimulation? Does electrical muscle reconditioning alter compliance and reflex activity?

The research will be based on the following hypotheses. 1) Any treatment or pathological course that alters a muscle's capability for volitional movement, response to electrical stimulation, or reflex

excitability will be reflected in appropriate measures of joint compliance and reflex activation that are obtained by measuring mechanical and electromyographic responses to mechanical perturbations of the joint. 2) In adult-onset spinal cord injury, joint compliances and reflexes will change in a characteristic fashion that depends on the level and completeness of the injury: a) during the evolution of spinal cord injury (i.e., during the first 6 months post-injury); b) following 1 week controlled removal of anti-spasmodic medications in individuals with chronic (1 year post) spinal cord injury; and, c) following a 4-week period of electrical muscle reconditioning. 3) The changes in joint compliance will correlate with changes in residual supraspinal influences since measurements of joint torque and angle should be more physiologically appropriate.

The following research techniques will be employed. We will measure the time pattern of joint compliance at elbow, ankle, and knee using step and sinusoidal mechanical perturbations of limb position; EMGs and stretch reflexes of appropriate muscles; and H-reflex at Soleus. We will set the limb position passively or by volitional effort (if possible) or electrical stimulation and compare results. We will check for supraspinal influences. The populations to be studied are: 1) neurologically intact; 2) motor impaired due to spinal cord injury;

3) motor paralyzed—tonic; and, 4) motor paralyzed—flaccid. Intervention: If less than 6 months post-injury, we will monitor changes in measures over time for groups 2 and 3 above and compare with sequelae. If greater than 6 months post-injury, we will measure and then attempt to restrengthen paralyzed muscles of groups 2 and 3 above, then remeasure. We will compare subject responses while receiving long-standing clinically prescribed anti-spasmodic medications to that obtained on drug holiday. We will use the neurologically-intact subjects and the flaccid-paralyzed subjects as controls.

The project will cover a 3-year period. During the first year we will concentrate on ankle joint; in recently injured SCI patients (4 to 6 “complete,” 4 to 6 “incomplete”), compare joint compliance, EMGs, mechanically and electrically (H-reflex) induced reflexes, supraspinal influences, and volitional and electrically stimulated muscle strength. We will trace changes in these comparisons as the rehabilitation of the individual progresses. Just before discharge, subjects will be put on 1-week drug holiday, then remeasured. In the second year, we will continue these activities, but will also include knee and elbow joints (compared cervical with thoracic lesions). In the third year, we will test the effect that a 4-week

program of electrically induced exercise has on these measures for patients who are more than 6 months post-injury.

Parallel measures of joint compliances, stretch reflexes, and H-reflexes, while correlated, are not redundant. They provide complementary information about various aspects of the peripheral motor control loop and phasic and tonic supraspinal influences on alpha, gamma, and intraneuron motor pools. But, for spinal cord injured individuals, these measures might differ in their sensitivity to time-post-injury, drug removal, supraspinal influences, and electrical muscle stimulation (both in the short- and long-term). Indeed, a comparison of their respective sensitivities is a purpose of our proposed research. For the SCI patient, a spastic limb can be socially embarrassing, can put the patient medically at risk of bone fracture, abrasions, decubiti and joint ossification, and can hinder functional rehabilitation. This present proposal seeks to characterize joint compliance changes during the evolution of spinal cord injury. If such a characterization tracks the evolution and is sensitive to drug holiday, then later efforts can be directed using it clinically to quantify spasticity.

A Pilot Project on Skin Blood Flow Response to Loading

A.H. Sacks, Ph.D., and Inder Perakash, M.D.

Rehabilitation Research and Development Center and Spinal Cord Injury Center, VA Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service (Pilot Proposal #B924-PA)

Purpose—During the past year and a half, we have been conducting skin blood flow studies using a noninvasive laser Doppler instrument to measure alterations in skin blood flow with the application of external pressure loading. The significance of such studies lies in their possible use for identifying those patients who may be particularly susceptible to developing pressure sores. As a result of those efforts, we have made two major observations, both of which have now been reported at meetings and published. First, by application of an engineering technique known as dimensional analysis, we have found that one need not measure applied pressure, but it is essential to measure both skin deformation

and bone depth. Second, the laser Doppler flowmeter, when used at high loadings, gives a signal which does not accurately measure blood flow.

This proposed pilot project would seek to accomplish two goals: 1) use a new experimental setup and apparatus with the laser Doppler which keeps measurements in the low loading range where the instrument is believed to be accurate; and, 2) conduct sufficient preliminary experiments to demonstrate whether or not the use of dimensional analysis does indeed result in a clearer separation of subject groups than could be achieved by more conventional measurements.

Activities of the Georgia Regional Spinal Cord Injury Center

David F. Apple, Jr., M.D. and Lesley M. Hudson, M.A.
Shepherd Spinal Center, Atlanta, GA 30309

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—The purpose of the model system concept is to develop a model system of care for the spinal cord injured population in various sites nationwide (13), and collaborate on research questions involving the data collection effort. The program has been in existence since 1971. The Georgia Regional Spinal Cord Injury Center is one of two such models in the Southeastern region of the United States.

Progress—The methodology of the project is to demonstrate the effectiveness of the model of care which seeks to positively affect each major stage of treatment following traumatic spinal cord injury: EMS Treatment and Transport; Emergency Room Treatment; Acute Care; Rehabilitation; and Follow-Up. Additionally, research projects, both single site and collaborative within the system are required of each model system, based on extensive data collection on all acute admissions, which become part of an 11,000 patient national database which is housed at the University of Alabama/Birmingham National SCI Statistical Center. Progress at the Georgia facility has occurred in the areas of employment, outreach clinic programs, prevention and peer support. Research is currently underway at that location on educational and learning patterns, high quadri-

plegia considerations, family intervention in the return to work, deep venous thrombosis incidence, and atelectatic treatment modalities.

Preliminary Results—Results of the demonstration portion of the project have shown a marked improvement in length-of-stay figures, post-discharge medical complications and overall cost under the system approach to care, with early referral to the system, versus non-system treatment. Employment efforts have resulted in an increase in the percentage of patients who are able to return to gainful employment following injury. Outreach clinics have delivered treatment in the field to patients who were noncompliant with the existing outpatient clinic facilities of the Shepherd Spinal Center. All research projects, both single site and collaborative, are underway and are expected to continue through 1990. Results will be published at the conclusion of these projects.

Future Plans/Implications—The current award will terminate in September of 1990. The scope of work is fixed until that time, and future plans beyond that are still in the preliminary stage.

On the Reduction of Energy Requirements for Crutch Ambulation by Paraplegics

Dudley S. Childress, Ph.D. and Robert L. Van Vorhis, M.S.
Rehabilitation Engineering Program, Northwestern University, Chicago, IL 60611

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—Crutch walking facilitates increased mobility for a person with paraplegia. Swing-through ambulation is a relatively fast crutch-assisted gait modality but has associated with it high levels of energy expenditure. The objective of this study is to establish what aspects of crutch-assisted swing-through gait by persons with paraplegia are energy intensive and to establish methods to reduce these energy expenditures. The hypothesis is that efficient

crutch ambulation is feasible for the paraplegic ambulator.

Progress—This study expands a preliminary investigation performed at this laboratory entitled, *Kinematic and Pendular Aspects of Swing-Through Paraplegic Crutch Ambulation* (Rovick, J.S., M.S. Thesis, Northwestern University, 1982). Rovick examined the kinematics of swing-through para-

plegic crutch gait and modeled the gait with mathematical models which were based on physical principles. His work indicates three main areas of energy expenditure. These are: 1) the energy required in stabilization of the joints (e.g., elbow and shoulder); 2) the energy lost in muscular effort for elevating the body to allow the feet to clear the ground; and, 3) the energy used to control the motion of the trunk. A major focus of this study is to try and eliminate the significant lifting of the trunk and legs to facilitate floor clearance during the swing-phase. It is anticipated that by eliminating or reducing the energy expenditure associated with the mechanical work of lifting, there may also be reduction in energy expenditure associated with control of the motion of the trunk.

Our plan is to utilize both crutch lengthening (via a rocker modification of the crutches) and leg shortening (via ankle control) as means of facilitating ground clearance without energy-intensive lifting. The models of Rovick will be modified and used as conceptual design tools. Walking trials will be performed. The mechanical work of subjects with paraplegia during normal and modified swing-through gait will be compared. Mechanical work is calculated from its basic definition (the product of joint moments and joint velocity). To obtain useful results, high-accuracy, high-sampling-rate positional data is required along with measurement of feet and crutches floor reactions. The major focus of our efforts has

been the development of a motion analysis facility. This system is based on the CODA-3 Movement Monitoring Instrument and includes two AMTI biomechanics platforms. The collection of data during clinical walking trials has been delayed during this development.

Results—Completion of the gait laboratory was scheduled for the Fall of 1987. The validity and sensitivity of the mechanical work calculations will be done in the Fall and Winter of 1987. Evaluation of strategies for energy reduction will then begin.

Implications—Establishing a technique for efficient swing-through crutch ambulation can provide the paraplegic ambulator with an additional option from which to choose a gait modality. We believe it will be some time before functional neuro-muscular stimulation (FNS) systems can adequately provide dynamic postural control (balance) during ambulation. Therefore, even with sophisticated bipedal stimulation systems, crutches will likely be used. The gait modality of efficient and fast swing-through crutch ambulation would complement a bipedal FNS system as well as provide an alternative to wheelchair ambulation. It is hoped that the feasibility of reducing the energy demand of swing-through crutch ambulation by persons with paraplegia can be established and a technique with clinical potential can be realized.

Retrospective Analysis of the National Spinal Cord Injury Care System Database

Michael J. DeVivo, Ph.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Systematic and comprehensive management of acute spinal cord injury (SCI) is directed towards reducing morbidity and mortality, increasing life function capacity, and minimizing costs of care associated with this catastrophic condition. Accordingly, it is desirable to establish a mechanism to evaluate performance of the organized management system addressing desired outcomes in such a way that the impact of the system, compared to other pre-system or parallel non-system activities,

is clearly defined.

Further, assessment of system performance over time is essential to establish patterns of behavior which may then serve as a basis for implementing practice, policy, or programmatic change(s), if necessary. This study is evaluating, retrospectively, the performance of the Model Regional Spinal Cord Injury Care System, emphasizing quantifiable outcome variables.

Progress—Overall system performance is being evaluated using appropriate statistical procedures. The evaluation methodology includes, but is not restricted to: 1) the relative proportion of all new SCIs brought into and managed by federally-sponsored Model Systems in a given year, i.e., national capture; 2) average time between injury and system admission, i.e., mean time into system; 3) post-admission death rate, i.e., mortality; 4) post-admission medical complication and surgical procedure rate [i.e., morbidity]; 5) level of postdischarge independence, place of postdischarge residence, vocational outcome, i.e., life function; 6) post-injury hospitalization experience, i.e., length-of-stay and re-admission

experience; and, 7) costs characterized on the basis of appropriate epidemiologic variables to facilitate comparisons between early admission and delayed admission patients.

Preliminary Results—As of June 1987, the national database contained information on 11,374 patients. Overall system performance is being evaluated using appropriate statistical procedures. Additional accomplishments include: the publication and distribution of a new book entitled *Spinal Cord Injury: The Facts and Figures*; presentations at 27 professional meetings; and publication of 25 manuscripts or abstracts in professional journals.

New England Regional Model Spinal Cord Injury System

Murray M. Freed, M.D.

New England Regional Spinal Cord Center, The University Hospital, Boston, MA 02118

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—This project involves the implementation and study of a system of care for the spinal cord injured person. It is based on a coordinated plan beginning at the site of injury, continuing through emergency care, acute medical care, rehabilitation, vocational counseling; and, following discharge—vocational training, housing arrangements, and lifetime medical follow-up. This is done through the organization of a continuum of care by coordinating the contributions of the several medical and co-professional disciplines involved, as well as pertinent state and municipal agencies. Other objectives of the system include the evaluation of the services and cost benefits of such a system of care; developing improved methods and techniques as well as equipment in the treatment of the spinal cord injured individual, and finally, demonstrating programs of community outreach and education for individuals with spinal cord injury in health care maintenance, follow-up, employment, schooling, and other life adjustment activities including recreation.

The project also involves community education for prevention of spinal cord injury as well as education to minimize architectural, social and attitudinal barriers facing the spinal cord injured individual. Programs of education will also be carried out for the benefit of health care groups, agencies, and institutions. The project also addresses itself to

research activities that will improve the life of the spinal cord injured.

Progress—The research activities, both collaborative and intra-institutional, have been organized in areas wherein the gathered information will make significant progress in the pathologic, physiologic psychosocial, and vocational aspects of the spinal cord injured. Intra-institutionally, four areas of investigation will be pursued. In addition, a number of model systems have embarked on an ambitious plan for collaborative research. The New England Center will be involved in six of these collaborative efforts.

Over a 5 year period, it is intended that each research effort will have an N ranging from 350 to 1500. Key investigators of each individual System Project will be the director of the spinal cord injury model system and his designated staff person. Each project has one Model System as the lead organization, with the remaining participants in the role of associate organizations. A cost-effective feature will be the utilization of the already existing facilities and services of the Model Systems and a significant database which is already collected by the National Spinal Cord Injury Data Center. The ultimate collection and data analysis for each project will be done in the lead organization center after input from all of the participating centers.

The collaborative research projects are: 1) Incidence of Respiratory Complications Following Spinal Cord Injury; 2) Long-term Survival and Cause of Death Following Spinal Cord Injury; 3) Recovery of Motor Strength in the Upper Extremities of Quadriplegic Patients after Spinal Cord Injury; 4) The Multi-System Gunshot Wound Study; 5) Spinal Cord Injury Patients with Pre-existing Ankylosing Spondylitis; and, 6) Implications of HMO Reimbursement.

This multicenter effort complements each institution's intramural research efforts for the special investigation, important to the understanding of the physiologic and pathologic impacts resulting from injury to the spinal cord.

Future Plans/Implications—It is anticipated that these efforts will yield new information regarding complications, prevention, early detection of potentially troubling problems and successful management. It is intended that model systems of follow-up, outreach and development of diagnostic techniques and sophisticated evaluation and adaptive equipment as well as collaborative research will further contribute to decrease in costs and improvement in quality of life. Provision of site visits for health agencies, touring groups and representatives of medical institutions seeking information about spinal cord injury

care and concrete methods of organization of spinal cord injury services contribute to the goal.

Publications Resulting from This Research

- Disabled Women's Unmet Needs.** Biener Bergman S, Fertitta L. *Disability Studies Quarterly*, 1986.
- Sexuality and Traumatic Disability.** Ducharme SH, *Handbook of Contemporary Rehabilitation Psychology*, B. Caplan (Ed.), Aspen Publications, Rockville, MD, 1987.
- Developing Training Programs in Sexuality and Disability: A Personal Perspective.** Ducharme SH, *Journal of Sex and Disability* (in press).
- Sexual Functioning in Principles and Practice of Rehabilitation Medicine.** Ducharme SH, Biener Bergman S, Fertitta L. J. DeLisa (Ed.), J.B. Lippincott, Philadelphia, PA (in press).
- Functional Independence in Quadriplegia: Critical Levels.** Welch RD, Lobley SJ, O'Sullivan SB, Freed MM, *Archives of Physical Medicine and Rehabilitation* 67:235-240, 1986.
- Anterior Decompression and Rigid Internal Fixation of Cervical Spine Injuries.** (Abs.) Yablon IG, Ordia J, Freed M, Spatz E, Mortara R, *Paraplegia* 24:49, 1986.
- Justification for the Prescription of Durable Medical Equipment for Spinal Cord Injured Persons.** Donovan WJ, Freed MM, Waters RL, *American Spinal Injury Association*, Chicago, 1986.
- Nutritional Assessment and Estimation of Energy Requirements in Traumatic Quadriplegia.** Lerman RH, Kerrigan MH, Shapiro EA, Jannace PW, Tiller SB, Freed MM, *Proceedings, 13th Scientific Meeting, American Spinal Injury Association*, pp. 304-311, March, 1987.
- The Ascending Cord Syndrome—The Effect of Decompression.** Yablon IG, Ordia J, Spatz E, Reed J, Mortara R, Freed MM, Curtis LA, Biener Bergman S, *Proceedings, 13th Scientific Meeting, American Spinal Injury Association*, pp. 248-253, March, 1987.

Effects of Nutritional Intervention During the Acute Phase of Spinal Cord Injury

C.T. Huang, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—While the nutritional requirements of the spinal cord injured patient are largely a matter of conjecture, it is reasonable to postulate, in the absence of contradictory data, that there are potential benefits to aggressive nutritional intervention during the early post-injury period. Logic dictates that from a management standpoint it is desirable to minimize negative nitrogen balance while attempting to maintain near-normal weight and other physiologic parameters following trauma. This study is examining the association(s) between an aggressive nutritional intervention program, the prevention of secondary complications, and the preservation of

optimal immune, motor, and psychological function.

Objectives of this study include: 1) conduct of a randomized trial of aggressive nutritional intervention (ANI) for 6 weeks in spinal cord injury (SCI) patients; 2) determination of the effect of ANI on body weight, skin-fold thickness, serum diet-dependent proteins, blood vitamin and zinc levels and hair epilation force; 3) determination of the effect of ANI on incidence of secondary complications; 4) determination of the effect of ANI on muscle function; and, 5) determination of the effect of ANI on T and B lymphocyte numbers, delayed cutaneous hypersensitivity, and serum immunoglobulins.

Progress—Forty-eight SCI patients with neurologically complete, sensory sparing only, or non-functional motor capability type lesions who are between 18 and 60 years of age and less than 60 days post-injury will constitute the study population. Half (24) will have sustained cervical injuries and the remaining patients will have thoracic injuries. Patients with concomitant brain injuries and/or multiple fractures will be excluded.

Patients will be randomly assigned to “treatment” and “control/no treatment” groups. Patients in the treatment group are given aggressive nutritional support for 4 consecutive weeks. During and after this time, comprehensive nutritional, medical complication, muscle mass and function, immune function, and psychological data are collected and analyzed. Appropriate data will be compared for possible identification of association(s) between physiological and psychological findings/responses and ANI.

Preliminary Results—As of November 1986, SCI patients meeting the study’s rigorous entry criteria had been enrolled in the project. Provisional data

Clinical Considerations Regarding the Penile Implant in Patients with Spinal Cord Dysfunction

L.K. Lloyd, M.D.

Research & Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Erectile dysfunction is prevalent in the spinal cord injury (SCI) population as well as in numerous other males with various forms of spinal cord dysfunction. For patients who do not find alternatives to penile-vaginal intercourse acceptable, the inability to achieve and maintain an erection may be devastating in terms of self-esteem and overall sexual relationship. While surgical and mechanical success rates for penile implants are relatively high, there have been few attempts to rigorously examine SCI patient/partner satisfaction and behavioral changes following implant surgery. Additional study is required to assess these parameters, since clinicians will continue to be confronted with the question of whether the costs and attendant risks (infection/erosion) of such surgery are warranted.

Objectives of this study include: 1) establishment

of objective criteria for inclusion/exclusion of patients as potentially successful implant candidates; 2) development of objective assessment protocols and procedures; 3) determination of the level of sexual satisfaction pre- and post-operatively in patients and their partners; 4) assessment of the sexual behavior pre- and post-operatively in patients and partners; and, 5) documentation of postoperative incidence of mechanical and/or medical complications.

Future Plans—During the upcoming year, the new methodology will continue with vitamin C or a placebo being administered daily for 6 weeks. As a result, the aggressive nutritional intervention being provided to each patient in the treatment group by the nutrition team was reviewed in great detail. Based on that review, it was concluded that interventions were not aggressive enough to produce a significant effect on outcome measures being studied (e.g., muscle function, medical complication rates, etc.). Therefore, the ANI methodology was revised to include a randomized, placebo controlled, double-blind study. Patients will be given either 300 mg/day of vitamin C or a placebo capsule. Although opinions differ regarding appropriate vitamin C dosage, 300 mg/day currently is five times the recommended daily allowance (RDA), and therefore is legitimately classified as “aggressive.”

Progress—SCI patients seeking treatment for sexual dysfunction will undergo a comprehensive psychological evaluation that will include administration of the Minnesota Multi-Phasic Personality Inventory (MMPI). Subsequently, they will be assigned randomly to a penile prosthesis or psychological counseling modality for study purposes. MMPI’s and

other appropriate psychological profiles will be acquired at 3-month intervals. Ultimately, patients assigned first to the psychological counseling modality will be permitted to proceed with a penile implant after 3 months follow-up.

Preliminary Results—The project is scheduled as a 5-year activity and has been in effect since June 1986. As of November 11, 1986, one patient and his partner have been entered into the project. Initial screening was completed, sexual behavior and satisfaction forms filled out, and the surgical implant

successfully completed. This patient and his partner will soon be eligible for post-surgical follow-up data collection.

A Sexual Health Clinic was initiated and is advertised through the RT Center's newsletter sent to all former patients with spinal cord injury. These announcements have resulted in a steady flow of referrals for sexual information and should continue to provide potential candidates for this project.

Future Plans—The protocol will continue as previously described.

Development of a Prospective Multi-Center Database for Head Injury Utilizing the Data Collection and Analysis Experience of the Model Regional Spinal Cord Injury Care Systems and the National Spinal Cord Injury Statistical Center

T.A. Novack, Ph.D., and C.S. Nepomuceno, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—From among the millions of head injuries that occur each year, thousands of individuals survive to face significant physical, cognitive, and emotional difficulties associated with recovery. Unlike physical problems, cognitive difficulties do not necessarily diminish with time. At present, it is unclear which head injured persons with residual cognitive deficits are most likely to benefit from extensive professionally-directed care, as there is no consensus as to what the "average" severely head injured person is able to do, given a specific time post-onset.

The development of an evaluation protocol for persons with head injury combines the elements of assessment at fixed intervals, for sufficient lengths of time to derive an adequate assessment of outcome, could produce a pool of information about head injury recovery that might be applied across a variety of rehabilitation settings. Though collaboration exists among several medical centers to develop such a protocol, present data collection procedures are imposing and therefore of questionable use to centers with limited resources. In general, existing data collection projects seem somewhat fragmented, with difficulties arising due to the imposing nature of the data set being used or a lack of similarity of goals across settings.

Objectives of the study are to: 1) survey international rehabilitation centers so as to determine features of their closed head injury data collection and rehabilitation programs, if any; 2) provide summarized instrumentation describing survey findings to rehabilitation centers participating in the survey; 3) develop a pilot data collection protocol based on the findings from the survey; 4) utilize and refine the pilot data collection protocol at this RT Center; 5) employ the refined pilot data collection protocol in other rehabilitation centers in other cities to assess transportability; and, 6) evaluate and assess transportability and utility of the UAB closed head injury data collection protocol.

Progress—Areas of the head injury recovery process to be surveyed will be identified. Data collection/survey instrument(s) will be developed and the addresses of various rehabilitation programs acquired. Survey instruments will be distributed, followed by the re-distribution of instruments to non-responding facilities. Survey responses will be analyzed, and a final summary survey report prepared. Subsequently, a data collection protocol will be developed and staff will be trained in appropriate data collection procedures. Following this, data will be collected at this RT Center. After a thorough

review of data collection activities, a potential expansion site will be selected and contacted. Following completion of all necessary arrangements, data collection will be initiated at other rehabilitation centers.

Preliminary Results—A comprehensive literature review has been completed and a substantial reprint library established. A facility survey instrument was completed and distributed to nearly 2,000 U.S.

hospitals known to have a head injury team unit or head injury rehabilitation unit.

Future Plans—Using this RT Center protocol, a more comprehensive proposal was prepared and submitted to the Centers for Disease Control (CDC) and was approved for funding. Thus, the objectives of the RT Center protocol will be pursued under the CDC grant.

Assessment of Tendon Transfer Surgery in the Tetraplegic Upper Extremity

P. Hunter Peckham, Ph.D.; Michael W. Keith, M.D.; Alvin A. Freehafer, M.D.; Laurel S. Mendelson, M.S.
Case Western Reserve University Rehabilitation Engineering Program, Veterans Administration Medical Center and Metropolitan General/Highland View Hospital, Cleveland, OH 44109

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—The purpose of this project is to evaluate the results of tendon transfer surgery in the upper extremity of the C6 level tetraplegic. Studies are designed to measure the voluntary forces produced in the thumb and fingers as a result of tendon transfer, and to identify the muscle firing patterns responsible for these results.

Progress—Voluntary control of lateral pinch and palmar grasp has been restored in the patient with spinal cord injury at the sixth cervical level by transfer of the tendons of voluntarily controlled muscles into the insertions of a paralyzed muscle. Two such procedures are commonly performed in this center: opposition transfers to provide thumb positioning and pinch strength, and finger flexion transfers to provide grasp and a firm surface in which to position the thumb. The two most common muscles transferred for thumb opposition are the extensor carpi radialis longus (ECRL) and pronator teres (PT); the preferred motor for finger flexion is the brachioradialis (BR).

Subjects were divided into two groups. The first group (GI) retained weak C6 function. In these subjects, the BR was transferred to the flexor digitorum profundus (FDP), the ECRL transferred to the abductor pollicis brevis using a graft of the flexor digitorum sublimis of the ring finger, and the posterior head of the deltoid was transferred to the triceps. The second group (GII) had strong C6

function remaining, with the PT transferred for thumb opposition and the BR for finger flexion; the triceps retained voluntary control. Three subjects in each group were evaluated at least one year after surgery. Thumb and finger forces were measured isometrically and muscle firing patterns were measured using electromyography.

Preliminary Results—All subjects were able to voluntarily activate the transferred muscles in order to produce both movement and force in the thumb and fingers. The transferred muscles produced firing patterns which showed adaptation to their new roles. Significant differences in thumb pinch and finger grasp strengths were found between the two subject populations. With the elbow 135 degrees extended and the wrist neutral, the average pinch strengths were 10.6 (s.d. = 2.9) N for GI subjects and 26.4 (s.d. = 7.4) N for the GII subjects. The average grasp strengths were 13.0 (s.d. = 2.1) N and 23.3 (s.d. = 10.3) N. In all positions of the forearm, the subjects with lower C6 function produced greater force than those with weaker C6 function. All subjects showed change in pinch and grasp forces when muscle length was changed by varying the wrist and elbow positions.

New phasic patterns of muscle activity were observed in the transferred muscles. All motors contracted actively to produce motion and force in the digits. Each subject co-contracted an antagonist to elbow flexion (triceps or posterior deltoid) during

activation of the brachioradialis. The weak GI subjects generally contracted all the voluntary muscles in the forearm during attempted grasp and pinch. The strong GII subjects had a greater ability to isolate the firing of a transferred motor from synergistic muscles and from other transferred muscles. In no case did a transferred muscle completely lose its original pattern of firing.

Future Plans/Implications—We are currently extending these evaluation techniques to subjects provided hand control by functional neuromuscular stimulation. These results demonstrate that tendon transfer is effective for restoration of hand function in subjects with high levels (C6) of spinal cord injury. Grasp strength is improved and the subjects are able to activate muscles voluntarily. These procedures may be applied successfully in individuals with higher levels of injury than have previously

been felt to benefit from surgical intervention.

Publications Resulting from This Research

- Postoperative Results of Opponensplasty and Flexor Tendon Transfer in Patients with Spinal Cord Injuries.** Kelly CM, Freehafer AA, Peckham PH, Stroh KP, *Journal of Hand Surgery* 10A(6)(I):891-894, November 1985.
- The Posterior Deltoid to Triceps Transfer: A Clinical and Biomechanical Assessment.** Lacey SH, Wilber RG, Peckham PH, Freehafer AA, *Journal of Hand Surgery* 11A(4):542-547, July 1986.
- The Influence of Muscle Properties in Tendon Transfer.** Peckham PH, Freehafer AA, Keith MW, in *Clinical Mechanics of the Hand*, Paul W. Brand (Ed.), C.V. Mosby Co., St. Louis, MO, 1985.
- Planning Tendon Transfers in Tetraplegia—Cleveland Technique.** Freehafer AA, Kelly CM, Peckham PH, in *Tendon Surgery in the Hand*, J.M. Hunter, L.H. Schneider, E.J. Makin (Eds.), C.V. Mosby Co., St. Louis, MO, 1987.
- The Brachioradialis: Anatomy, Properties, and Value for Tendon Transfer in the Tetraplegic.** Freehafer AA, Peckham PH, Keith MW, Mendelson LS. Accepted for publication, *Journal of Hand Surgery*, 1987.

Psycho-Social Adjustment of Persons with Combined SCI and Closed Head Injury: A Longitudinal Investigation

J.S. Richards, Ph.D.

Research & Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Spinal cord injury (SCI) is often the result of rapid deceleration (eg., a motor vehicle crash) and/or a direct impact to the head, neck, or trunk. Therefore, in some cases, an associated closed head injury (CHI) is sustained in addition to the spinal cord injury. While evidence of a concomitant closed head injury is at times quite apparent (coma, CT scan, etc.) at other times “softer” signs of a CHI may not be so apparent and/or may be overlooked.

For example, recent studies of persons who have sustained mild/moderate CHI's—less than 1 hour loss of consciousness (LOC) and/or negative neurologic work-up—have demonstrated that a substantial proportion of such individuals experience debilitating symptoms (memory loss, thinking disturbances, fatigue, irritability) for some period of time after injury, which in turn often leads to an inability to function effectively at work or in school.

In recent years, there has been increasing recognition of the need to closely examine persons with SCI for concomitant CHI. At this RT Center, a

recently completed project focused on determining the coincidence of SCI and CHI via neuropsychological assessment. Similar efforts are underway at several other SCI Centers. However, to our knowledge there have been no prospective studies published to date that have examined adjustment to the home environment, workplace, school, and/or society in general of patients with both CHI and SCI. This project is attempting to do so.

Objectives of the study are to determine: 1) whether persons with concomitant CHI in addition to SCI experience more marital/familial distress postdischarge than a matched group of patients with SCI only; 2) whether persons with concomitant CHI in addition to SCI achieve less progress educationally and/or vocationally postdischarge than a matched group of patients with SCI only; 3) whether persons with concomitant CHI in addition to SCI experience more psychological/behavioral distress postdischarge than a matched group of patients with SCI only; and, 4) whether persons with concomitant CHI

in addition to SCI experience more social maladjustment postdischarge than a matched group of patients with SCI only.

Progress—We will compare the social, vocational, psychological, and familial adjustment, over time, of a cohort of persons with SCI and concomitant CHI and a matched control group of persons with SCI only. The SCI/CHI cohort and the matched SCI controls are being identified. Given the relatively small sample, the variables to be matched are being prioritized. Included in the matching process are: length of time post-injury, neurologic level and extent of lesion, sex, race, and years of education.

A literature review was initiated and completed

for the purpose of identifying existing, well-validated instruments which assess adjustment along social, personal, and vocational dimensions. A mailed questionnaire will be sent to the homes of patients who are scattered across Alabama. The size of the experimental and control groups are expected to be approximately 20-30 persons each.

Future Plans—During the next grant period, the SCI/CHI experimental and the matched SCI control groups will be identified. The assessment instruments, data-collection instruments, and data-collection strategy will be finalized and data collection will begin. Data collection is scheduled to continue through November 1989.

Complications of Cognitive Dysfunction in Spinal Cord Injury

Gary Davidoff

Department of Physical Medicine and Rehabilitation, University of Michigan Hospitals, Ann Arbor, MI 48109

Sponsor: *National Institutes of Health*

Purpose—Previous studies of trauma related spinal cord injury patients (SCI) suggest that nearly 50 percent of these patients sustain a concomitant closed head injury (CHI). Early reports suggest that some of these patients demonstrate cognitive deficits within the first year after injury. However, these studies are hampered by several problems, including the lack of controls and the inability to administer screening tests requiring hand function to this population. This study will evaluate neuropsychological deficits in newly injured spinal cord injury patients and relate this to the incidence and severity of medical complications at one year after injury.

Prevalence Study. The incidence and duration of loss of consciousness and traumatic amnesia will be evaluated in newly injured spinal cord injury patients. These patients will undergo a standard battery of neuropsychological testing, which is predominantly motor free, to evaluate deficits in orientation, memory, abstract reasoning and problem solving.

A control group matched for age, sex, level of education, and geographic location will be utilized to develop mental performance ranges on these tests. Premorbid information regarding other factors which may be related to cognitive dysfunction will also be assessed. This study will test the hypothesis that the majority of patients with evidence of cognitive dysfunction have sustained a concurrent CHI.

Medical Morbidity. All patients will be reviewed at one year following discharge from initial rehabilitative care to determine the incidence and severity of medical morbidities associated with SCI. It is expected that patients with associated cognitive dysfunction are at greater risk for the development of medical complications during this 1-year period. Such findings might warrant modification of patient education or length of stay during initial hospitalization as well as the frequency and form of outpatient follow-up for these patients.

Evaluation of Shoulder Position as a Command Control Source

P. Hunter Peckham, Ph.D. and Mark W. Johnson, B.S.

Case Western Reserve University Rehabilitation Engineering Program, Veterans Administration Medical Center and Metropolitan General/Highland View Hospital, Cleveland, OH 44109

Sponsor: National Institutes of Health

Purpose—The purpose of this research is to evaluate the use of shoulder position as a command source for use with functional neuromuscular stimulation (FNS) prosthetic devices by quadriplegic individuals.

Progress—This study was designed to evaluate several of the important aspects of the shoulder movement that defines its performance as a command control source. Three quadriplegic subjects and nine normal subjects were studied. The protraction/retraction and elevation/depression of both shoulders was measured using two dual-axis transducers mounted on the sternum. The experimental procedure included the following areas of study: 1) the range of active shoulder motion; 2) the subject's ability to make incremental shoulder movements; 3) the properties of different types of slow and fast shoulder movements, so that distinguishing characteristics of the movements could be used to derive logical commands; 4) the subject's ability to maintain a desired shoulder position using only proprioceptive feedback; 5) the subject's ability to control horizontal shoulder movements independently from vertical shoulder movements; and 6) the contamination of the shoulder movement signals due to movement of the opposite extremity.

Results—The quadriplegic subjects studied were found to have a considerably poorer active range of shoulder motion than their normal counterparts. Their active protraction and depression were very poor, with their active retraction and elevation being larger, but still approximately half that of the normals. In addition to being weaker than normal, the shoulder elevation had a significant component in the retraction direction, and the retraction had a significant component in the elevation direction, showing a very skewed range that diminishes the separation of the elevation axis from the retraction axis.

These quadriplegic subjects produced a much

lower average number of incremental steps over the vertical range, than the normal subjects. On average, these quadriplegic subjects could produce approximately 11 steps over their vertical range, compared to 37 steps for the normals.

Several parameters were measured for a number of different types of movements, to derive logical command detection algorithms. These movements included quick upward movements, normal step-like movements, and slower ramp-like movements, with movement sizes ranging from small to large. Both rise time and velocity divided by step size were found to be good indicators of the type of movement that a subject was making, whereas velocity was not a good indicator.

The quadriplegic subjects were found to be able to maintain a constant shoulder position to within 1 percent to 5 percent of their shoulder range for trials up to 15 seconds, and within 2 percent to 6 percent for 30 second trials. Most normal subjects were capable of controlling horizontal shoulder movements independently from vertical shoulder movements. However, the quadriplegic subjects tested were found to have poor two-axis control. This is due primarily to the poor horizontal range of these subjects, and the large component of retraction when the subjects elevate their shoulders. The contamination of the shoulder movement signals due to movement of the opposite extremity was also studied. This movement was found to have a magnitude of up to 50 percent of the range of motion. The source of the interference is the mounting of the transducers on the compliant skin. However, the body mounting of transducers is necessary for clinical application.

Future Plans/Implications—We plan to incorporate the command control processing techniques into our patient-portable systems, and test the efficacy of the user's ability to perform without generation of inadvertent command errors.

A Center for Acute Spinal Cord Injury: Epidemiology and Economic Costs of Spinal Cord Trauma _____

Leon Robertson

Yale University Medical School, New Haven, CT 06510

Sponsor: National Institutes of Health

Purpose—We are continuing to develop a model for the evaluation of the contribution of collateral sprouting of the processes of dorsal root ganglion cells to altered function or recovery following lesions of the spinal cord. We now can manipulate sciatic and saphenous central axons in order to examine, at the light and electron microscopic (EM) levels, alterations in their central terminal fields that occur following lesions. We have concentrated this year on the ultrastructural changes in afferent terminals,

target dendrites and somata, and glia formations that occur in the dorsal horn following rhizotomy, sciatic nerve section, or specific degeneration of sciatic central terminals after injection of the sciatic nerve with pronase. We will now carry out experiments to examine the possible collateral sprouting of saphenous afferents into the sciatic territory following destruction of the sciatic afferents. Documentation of the changes will be carried out with both light and EM analysis.

Body Composition and Nutrition in Spinal Cord Injury _____

Paul R. Schloerb

University of Rochester Medical Center, Rochester, NY 14642

Sponsor: National Institutes of Health

Purpose—Knowledge of body composition changes and nutritional requirements in spinal cord trauma with paraplegia or quadriplegia is limited. We plan to measure lean body mass (LBM) and total body fat as functions of total body water (TBW) and total body potassium (TBK), under controlled dietary conditions. Total body water will be measured with deuterium oxide (heavy water) and bioimpedance and extracellular fluid will be determined with bromide. When stable, patients will be transported to the 40K Body Counter for measurement of TBK. Studies will be performed shortly after trauma with periodic longitudinal evaluation (40K counting) through rehabilitation. To measure changes in mus-

cle protein turnover and muscle wasting, urinary excretion of the amino acid, 3-Methyl histidine, and urine creatinine will be determined. The effect of spinal cord trauma on bone mineral and soft tissues below the neurologic level of injury will be studied by photon absorptimetry and CT scanning. All of these body composition measurement techniques will be complemented by metabolic balance study periods at intervals to evaluate further the quantitative aspects of losses and gains of soft tissues and bone in spinal cord trauma. From all of these data, optimum protein-calorie nutritional support will be defined.

Neurochemical Correlates of Autonomic Hyperreflexia in an Animal Model _____

Susan L. Stoddard, Ph.D. and Tony L. Yaksh, Ph.D.

Indiana University School of Medicine, Indianapolis, IN 46202 and Mayo Clinic, Rochester, MN 55905

Sponsor: Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal NBN-633)

Purpose—Autonomic hyperreflexia (AH), or dysreflexia, is a condition that affects approximately 80 percent of individuals with a high spinal cord tran-

section. This condition involves the mass, reflexive discharge of the sympathetic nervous system, which is isolated from the modulatory control of the central

nervous system when the spinal cord is damaged above approximately the sixth thoracic level. The sympathetic nervous system is part of the autonomic nervous system, which regulates cardiovascular and visceral activities (such as bowel and bladder function). Given these diverse functions, it is not surprising that mass activation of the sympathetic nervous system can give rise to a complex family of symptoms including anxiety, sweating, pounding headaches, nausea, and paroxysmal hypertension. What makes autonomic hyperreflexia puzzling is that in the spinal cord injured person this syndrome may be triggered by a variety of stimuli, including urinary and bowel obstruction or skin irritation. These normally benign stimuli thus can elicit various prominent clinical signs and symptoms. The concomitant hypertension noted above generated by such stimuli may be severe, resulting in seizures, cerebrovascular accidents (strokes) or hemorrhage. Since such consequences can be life-threatening, an understanding of the neurological mechanisms of AH is of importance in controlling and treating the condition. Although AH has been recognized as a clinical syndrome since 1917, and has been well described phenomenologically, the time course of development and the mechanisms underlying this condition have not been systematically investigated.

The aims of our project are to describe the time course of development of AH in an animal model, the spinally-transected cat, and to characterize the associated activity of the adrenal medulla. The adrenal medulla is of particular interest in this syndrome since, as part of the sympathetic nervous system, it is controlled directly by autonomic neurons that originate in the spinal cord. Thus, we believe this organ is involved when the diverse stimuli listed above cause a mass discharge of the sympathetic nervous system. The adrenal medulla synthesizes and secretes a variety of neurochemicals, including catecholamines (noradrenaline, adrenaline, and dopamine) and peptides (such as me-

thionine-enkephalin and neuropeptide Y). All of these neurochemicals have potent direct and indirect cardiovascular effects in addition to other widespread physiological and metabolic actions. We will directly measure the output of these neurochemicals from the adrenal medulla following both somatic and visceral stimuli, and characterize the changes in the stimulus-secretion relationship as a function of time after high spinal cord transection.

Preliminary Results—Preliminary studies initiated in anticipation of this work revealed that the high spinally-transected cat is in fact an excellent model for the study of AH. The chronically-transected animals coped well with hind limb paralysis, developed reflex bladder function, and gained weight. Further, both visceral and somatic stimuli were effective in eliciting AH (defined as an increase in mean arterial blood pressure of at least 30 mm Hg) following chronic, but not acute, transection. This is similar to the clinical situation, in which AH usually develops concurrently with the return of bladder tone. Although it is not possible to translate findings from animal experimentation directly to clinical application, we are optimistic that our experimental paradigm in the spinally-transected cat will lend new insights into the neurochemical bases of AH. In this regard, a major result of our preliminary studies was that AH in the cat is accompanied by a notable activation of the adrenal medulla. This observation is of particular interest since, for obvious reasons, it has not been possible to directly characterize such activity in man.

Future Plans—If these preliminary observations are substantiated by further investigation, our future plans will be to explore the mechanisms of spinal reorganization that permit development of this sympathetic hyperactivity in the spinal cord injured patient.

The Health and Functional Status of Aging SCI Persons: A Feasibility Study Using Cases from Stoke Mandeville Hospital

Gale G. Whiteneck, Ph.D. and Robert R. Menter, M.D.

Craig Hospital, Research and Follow-up Department, Englewood, CO 80110

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal NOA-650)*

Purpose—The success of modern treatment of persons with spinal cord injury (SCI) can be measured in long-term survival. Presently, the goal of near-normal life expectancy is being met by many survivors of World War II spinal cord injuries. Recent concerns have focused on the impact of aging in this population. The present project is a feasibility study designed to determine if a scientifically valid investigation of aging in persons with spinal cord injury is possible using the records of individuals treated at the National Spinal Injuries Centre (NSIC) in Stoke Mandeville Hospital in England. The NSIC has a 43-year history of providing comprehensive rehabilitation and follow-up to the spinal cord injured, and is an ideal facility at which to conduct this investigation. A variety of resources will be utilized to gather the data necessary for the project. An extensive review of the gerontology literature has provided information from which key study variables have been identified. The medical records of the NSIC will be reviewed and local general

practitioners and district health nurses will be contacted to determine if available information is comprehensive and adequate to investigate the long-term health and functional status of an aging spinal cord injured population.

Future Plans—If the record review provides comprehensive information regarding the health and functional status of spinal cord injured individuals over the years, specific research designs and a major SCI aging research project will be prepared. This will include detailed methodological plans for using the NSIC data for further analyses and developing a protocol for tracking the key health and functional characteristics at facilities like Craig Hospital over the next decade. In addition, it may be determined that personal interviews with persons injured more than 20 years will be necessary in order to obtain information not available from records and other resources.

A Computer Interface for the TIPE Seating Pressure Evaluator

Lincoln A. Jaros, B.S.; Ronald L. Kett, M.S.; Simon P. Levine, Ph.D.

Rehabilitation Engineering Program, Department of Physical Medicine and Rehabilitation, University of Michigan Medical Center, Ann Arbor, MI 48109

Sponsor: *Rehabilitation Engineering Program, Department of Physical Medicine and Rehabilitation, University of Michigan*

Purpose—Pressure sores are a major problem for individuals who are wheelchair dependent, particularly those with sensory losses. Many researchers have investigated the causes of these pressure sores and have sought methods of preventing them. A project at the University of Michigan is investigating the use of electrical muscle stimulation as a means of preventing pressure sores. Part of this research involves measuring and recording the dynamic forces exerted at the seating interface.

An outgrowth of this work was the development last year of a computer interface to allow an IBM-PC compatible computer to acquire data from a

commercially available pressure sensor pad. The pressure transducer system being used is the Texas Interface Pressure Evaluator (TIPE) pad. The pad consists of a 12 x 12 array of switches within an inflatable pad. Wherever the externally applied pressure exceeds the internal pad pressure the corresponding switch is activated (closed). The TIPE pad is normally connected to a separate display unit which produces a transient visual picture of the pad switch conditions. No provision for the permanent recording of observed data is provided. Clinical evaluations and other experimental protocols require information about pressure behavior to be

recorded over an extended period (e.g., to develop a pressure distribution map for wheelchair cushion evaluation). This recorded data must also be converted to a form which prepares it for computer analysis and hard copy report generation. The following report describes recent changes to the interface developed over the past year.

Progress—The original computer interface was a stand-alone device with its own microprocessor. It was designed to connect to any computer through a standard serial interface. In the interests of simplicity and cost effectiveness, the interface has been completely redesigned. The new version is a single printed circuit board designed to plug directly into the bus of an IBM-PC or PC-compatible. This removes the need for a separate microprocessor and serial communication electronics. The resulting interface is powered by the computer supply and is controlled directly by the main computer. These changes reduce the device chip count and increase the operating speed.

Preliminary Results—Previously developed software which allows sequential recording of the switch on/off configuration over programmable time periods has been modified for the new hardware configuration. In addition, new software has been written to allow the interface to produce a two-dimensional map of interface pressures which can be printed in report form. This is accomplished by slowly releasing air from the pad and recording the pressure at which each individual switch is activated. This test is now being offered clinically from the Rehabilitation Engineering Program for use in evaluating different types of wheelchair cushions. We have recently made this interface available commercially on a limited basis. A small number have been built for other institutions who have a need to study and map seating pressure for clinical or research applications.

Publication Resulting from This Research

A Computer Interface for a Seating Pressure Evaluator. Jaros LA, Kett RL, Levine SP, *Proceedings of the 9th Annual RESNA Conference*, 6:419-421, Minneapolis, MN, June 1986.

Chemical Dependence and Spinal Cord Injury Outcome

Allen W. Heinemann, Ph.D.

Rehabilitation Institute of Chicago, Chicago, IL 60611

Sponsor: *Rehabilitation Institute of Chicago; Spinal Cord Research Foundation; National Institute on Disability and Rehabilitation Research; and National Institute on Alcohol Abuse and Alcoholism*

Purpose—This report describes three currently funded projects. The common goal of these projects is to expand our knowledge about substance use by persons with spinal cord injuries (SCI). Some persons with spinal cord injuries may be at risk for substance abuse, dependence or addiction and, as a consequence, have their rehabilitation outcome profoundly influenced by substance abuse. Early identification of persons with spinal cord injuries who abuse or are addicted to substances, or who are at risk for abuse, should decrease the cost of rehabilitation and improve rehabilitation outcome. Since the annual medical costs for all persons with SCI is estimated at \$1.9 billion, timely and effective intervention for persons with cord injuries who abuse or are at risk for chemical abuse is both humane and cost effective.

Progress—To date, we are well on our way to achieving the objectives of this study. In brief we are seeking to: 1) describe the natural history of substance use among persons with spinal cord injury; 2) quantify the pre-injury prevalence of substance use in 20 categories; 3) validate self-report of substance use with laboratory analysis; 4) quantify the post-injury prevalence of substance use in 20 categories; 5) determine the relationship between pre-injury and post-injury substance use; 6) determine the relationships between personal, medical, social and behavioral characteristics of persons with spinal cord injury and their patterns of substance use both pre- and post-injury; 7) determine the relationship between pre- and post-injury substance use and rehabilitation outcome, including employment; and 8) assess the efficacy of chemical de-

pendence interventions both before and after spinal cord injury.

This prospective project will study the relationship between substance use and rehabilitation outcome in two samples of 100 persons, one sample of persons with recent injuries, and one sample of community residents whose injuries occurred more than one year ago.

A total of 103 Rehabilitation Institute of Chicago (RIC) inpatients who met the following admission criteria were recruited for the study: traumatic SCI within the last 12 months; between age 13 and 65, inclusive; no clinically significant head trauma, defined as no post-traumatic amnesia exceeding 24 hours; and informed consent to participate (parental consent when appropriate).

A total of 101 community residents have consented to participate who were recruited through the Northern Illinois Chapter of the National Spinal Cord Injury Association (NSCIA) and Access Living of Metropolitan Chicago (Access Living).

Our procedures for recruiting the inpatient sample included reviewing a record of daily admissions from the admitting department at RIC. This record contained patient names, admission dates, identification numbers, diagnoses, and attending physicians' names. The attending physician for each patient was contacted between the second and fourth week following admission to request permission to contact patients. Each patient was contacted only after permission was obtained. A meeting time was arranged to fully describe the purpose and procedures of the study. Ample time was provided for decision making because of initial hesitation in agreeing to participate. This procedure allowed us to recruit 67 percent of the eligible inpatients.

Preliminary Results—The initial evaluation included assessment of: biographic information, social status, depression, self-esteem, and activity patterns. The Substance Use Inventory was used to obtain data regarding all substances used prior to SCI, while the Substance Use Questionnaire was administered for all substances used during the six months prior to SCI. Some participants needed additional time and assistance to complete the interviews; shorter interviews were arranged as necessary to avoid fatigue and to maximize reliability. The interviewer provided physical assistance as required to complete the instruments. In some cases this included reading all items and recording responses. After each par-

ticipant was discharged from RIC, the medical record was reviewed for duration of stay, total charges, and prescribed medications administered and received.

Letters were sent to community members which explained the purpose of the project and solicited participation. A return-addressed, stamped postcard was enclosed so that individuals could contact the investigators requesting more information about the study or to volunteer. An interview was set via telephone and informed consent was obtained from persons agreeing to participate. The age, sex, race and injury level of all eligible persons who chose not to participate was recorded so that the representativeness of the sample can be assessed. Of the 237 persons contacted, 118, or 50 percent agreed to participate.

Future Plans/Implications—Initial, 6-, 18-, 30-, and 42-month post-injury evaluations are planned for the recent injury group; as planned, all of the initial and 6-month post-injury evaluations are complete. In addition, all community residents have been evaluated once; a one- and two-year follow-up is planned. All five instruments are administered at these re-evaluations. The information obtained at each assessment will be current for social status, depression, disability acceptance, and activity pattern. Substance use histories will cover the period of time since the last interview. Data analysis is underway to address the objectives listed above.

Publications Resulting from This Research

Alcohol Use and Activity Patterns Following Spinal Cord Injury. Heinemann A, Keen M, Schnoll S, Adair W, Paper presented at the *12th Annual Meeting of the American Spinal Injury Association*, 1986.

Alcohol Use and Activity Patterns Following Spinal Cord Injury. Heinemann A, Keen M, Adair W, Schnoll S, Paper presented at the *94th Annual Convention of the American Psychological Association*, Washington, DC, 1986.

Alcohol Use and Activity Patterns in Long-Term Spinal Cord Injury Outcome. Heinemann A, Keen M, Schnoll S, Paper presented at the *13th Annual Meeting of the American Spinal Injury Association*, Boston, MA, 1987.

Substance Use by Persons with Recent Spinal Cord Injuries. Heinemann A, Keen M, Mamott B, Schnoll S, Paper presented at the *95th Annual Convention of the American Psychological Association*, New York, NY, 1987.

Toxicology Screening in Acute Spinal Cord Injury. Heinemann A, Schnoll S, Brandt M, Maltz R, Keen M, Paper presented at the *95th Annual Convention of the American Psychological Association*, New York, NY, 1987.

Prevalence of Substance Use in Persons with Spinal Cord Injury. Heinemann A, Armstrong A, Asher M, Keen M, Paper presented at the *64th Annual Session of the American Congress of Rehabilitation Medicine*, Orlando, FL, 1987.

Outcome Studies Pertinent to the National Model Spinal Cord Injury System

M. Fuhrer, Ph.D.; R.E. Carter, M.D.; W.H. Donovan, M.D.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research

Purpose—This project encompasses three studies, two retrospective and one prospective, aimed at providing additional evidence about the effectiveness of the National Model Spinal Cord Injury System Project administered previously by RSA and currently by the National Institute on Disability and Rehabilitation Research.

The two retrospective studies capitalize upon existence of the common database established by the national systems. One study is an attempt to demonstrate that the highly advanced system of care practiced at the Royal Perth Hospital in Australia results in better patient outcomes than obtained in the less advanced care systems in the United States. The second study is concerned with documenting post-rehabilitation outcomes for quadriplegic patients who, at discharge from inpatient rehabilitation, require ventilatory assistance.

In the prospective study, the outcomes of two groups of patients are compared. One consists of patients whose acute and rehabilitation care was provided by the Texas South Central Regional Spinal Cord Injury (T/SCRSCI) System. It is comprised of four acute care hospitals in the Houston-Galveston area and The Institute for Rehabilitation and Research (TIRR) as the rehabilitation setting. The second group consists of patients who were discharged from the same four acute care hospitals but who did not receive rehabilitation services at TIRR.

Data for TIRR patients are being obtained in a companion project entitled, "Assessment, Development, and Clinical Application of Strategies to Coordinate Services for Spinal Cord Injured Clients After Discharge." Data for non-TIRR patients are being obtained during home interviews using an adapted form of the interview used in the companion project.

Progress—During the project's first year, the U.S.-Australian systems study directed by Dr. William

Donovan was completed, and an article was published in *Paraplegia*, 22:282-290, 1984. In that study, one data set reflected experience with 65 consecutively admitted patients whose care during 1979 and 1980 occurred in the spinal cord unit at the Royal Perth Rehabilitation Hospital in Perth, Western Australia. A second data set pertained to 1606 U.S. patients who had been cared for in one of the regional systems during the same year.

Preliminary Results—The results indicate that decubitus ulcers, atelectasis, pneumonia, pulmonary emboli, ulcers of the gastrointestinal tract, and heterotopic ossification all occurred more frequently in the U.S. group. The difference was particularly marked for decubitus ulcers and urinary tract infections. These outcomes demonstrate that the sooner spinal cord injured patients are referred to a center capable of meeting all their needs, the less likely it is that they will develop complications that slow rehabilitation progress.

Results describing post-rehabilitation outcomes for ventilatory dependent quadriplegics have been published in 1987 in the *Archives of Physical Medicine and Rehabilitation*. Compared with ventilator independent quadriplegics, ventilator dependent individuals had a longer duration of hospitalization, less self-care capability, more hours per week of hired attendant care, and more hours of actual physical assistance per day. The groups did not differ significantly in terms of duration of inpatient rehabilitation, duration of rehospitalization, and vocational or prevocational status at follow-up.

Future Plans/Implications—The prospective study comparing outcomes for system and non-system patients is continuing. Complete data are available currently for 150 system patients and 30 non-system ones.

An Implantable Sensor for Two-Degree-of-Freedom Position Transduction

P. Hunter Peckham, Ph.D.; Michael W. Keith, M.D.; Jorge Letechipia, M.Sc.

Case Western Reserve University Rehabilitation Engineering Program, Veterans Administration Medical Center and Metropolitan General/Highland View Hospital, Cleveland, OH 44109

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation*

Purpose—The purpose of this project is to develop a sensor for acquiring command control information of joint position. The sensor is to be surgically implantable, and be used to transduce position of two-degree-of-freedom joints, such as the sternoclavicular and the wrist.

Progress—Evaluation of different transduction techniques as design alternatives has been completed. Inductive displacement gauges, pressure sensors, bubble sensors, capacitive transducers, electromagnetic position transducers, inductive-type transducers, potentiometric devices, ultrasonic detection, tendon displacement, optic fibers and magnetic flux sensors (Hall Effect sensors) were evaluated, and their applicability and characteristics compared.

Preliminary Results—The results of these studies show that a Hall Effect device, properly positioned and aligned, could be used to meet the transduction requirements of a two-degree-of-freedom joint.

The design that we have chosen is composed of three separate elements: the sensors, their signal conditioning circuitry, and a permanent magnet. The magnet will be implanted in one side of the joint while the sensors and circuitry will be implanted in the other side of the selected joint. The transducer

we have designed consists of two pairs of sensors, located at 90 degrees with respect to each other and the magnet. Each pair of sensors (X and Y) is connected differentially. Thus two signals are generated, one indicating the angular displacement in X, while the other corresponding to the Y angular displacement of the magnet. A ball and socket mechanism was used to simulate the joint configuration. Preliminary results obtained earlier with a non-implantable transducer, built and operating under the same design principle, provided us with an adequate command control source to use with our clinical, upper extremity FES program.

Future Plans/Implications—Future plans include further characterization and packaging of the transducer elements. *In vitro* and *in vivo* experiments will be conducted by externally powering the device. At the completion of this project, we expect to have determined the viability of the Hall Effect transducer system as a source of joint position information. We believe that the availability of an easily obtainable, two-degree-of-freedom proportional command control source would be of interest and use to the rehabilitation community as an interface with neuroprostheses as well as a variety of orthotic/prosthetic aids and assistive devices in general.

B. Medical Treatment

Early Detection of Pressure Sores by Means of Biomedical Indicators

George Van B. Cochran, M.D.

Veterans Administration Medical Center, Castle Point, NY 12511 and Orthopaedic Engineering and Research Center, Helen Hayes Hospital, West Haverstraw, NY

Sponsor: *VA Rehabilitation Research and Development Service (Project #XB212-2RA)*

Purpose—Decubitus ulcers represent a severe problem for spinal cord injured patients. If a reliable and

practical clinical method of early detection of decubiti could be developed, it is probable that in

many cases, with suitable medical intervention, frank tissue breakdown could be reversed or at least limited in its severity. Various techniques for early detection of decubiti have been investigated to identify changes in mechanical, physical or physiological properties of compromised tissues. None to date have yielded a reliable and clinically practical means to detect early tissue damage.

We are currently conducting a study to investigate changes in the acoustic properties of tissues associated with pressure-induced damage. This proposal addresses a need for a parallel effort to develop a simple to use, inexpensive screening technique for early tissue damage. Patients whose tissue status is unsatisfactory would then be candidates for imaging techniques costing more to operate, and available at a central location under the supervision of skilled, specialist operators. In themselves, the imaging techniques are too complex for screening.

Current clinical practice for early detection of decubiti relies upon frequent inspection of skin color. Persistent red areas are often classified "stage I decubiti" and appropriate clinical measures taken. Several difficulties and limitations are, however, experienced with this highly subjective technique. Firstly, it is important for the clinician (or patient) to differentiate between persistent redness and the normal, healthy (short-term) redness of reactive hyperemia. Secondly, in the more advanced stages of decubitus formation, the area becomes ischemic and cyanotic with often only a margin of redness. Thirdly, all skin color changes associated with the early onset of decubiti are difficult to detect in nonwhite patients.

Sweat glands are richly endowed with a capillary blood supply which carries biochemicals whose concentrations may serve as indicators for decubitus formation. Associated with the inflammatory response, elevated levels of mediators such as histamine in the blood stream are well known. Limited evidence from basic research on the chemistry of sweat suggests that histamine may be transported

through the sweat gland membrane. In principal, it would therefore seem feasible to use sweat as a vehicle for monitoring localized histamine production and hence inflammation, non-invasively.

Using an appropriate technique, an area of local inflammation will be induced in a group of able-bodied subjects using a technique similar to the allergy "patch test" and sweat collected at that site. The concentration of histamine in the sweat sample will be measured and compared with sweat collected from a control site. Evidence to confirm that histamine readily diffuses into sweat from capillary blood and surrounding tissues will be sought. A clinical study will then be undertaken analyzing sweat from a group of spinal injured patients with clearly defined localized persistent redness of the skin. Sweating will be induced locally using iontophoresis of pilocarpine nitrate in the erythematous tissues and also from a control site of normal healthy appearance. The hypothesis for this study proposes that there will be marked elevation of histamine in sweat from the erythematous site compared with the control. If positive, this result would form the basis for establishing a routine test for tissue status that could be undertaken routinely by a hospital biochemistry laboratory.

An adjunct to local analysis of biochemical changes associated with tissue breakdown is the possible increase in biochemical factors in the systemic blood supply. A study by others of CPK levels in elderly people who have fallen and lain injured for prolonged periods also indicates that this test can be used to selectively screen for skeletal muscle damage. In preliminary work using a pig model we have found a significant and sustained increase in CPK associated with pressure damage to tissue. We propose to confirm that CPK can be used as a systemic indicator for early detection of decubiti through controlled experiments using our established porcine model. In addition, CPK may help establish improved tissue tolerance curves for sustained pressure.

A Feasibility Study on Detection of Impending Pressure Sores Using Ultrasound

George Van B. Cochran, M.D., M.Sc.D., and M.P. Kadaba, Ph.D.

Orthopaedic Engineering and Research Center, Helen Hayes Hospital, W. Haverstraw, NY 10993; and Surgical Research Service, Veterans Administration Medical Center, Castle Point, NY 12511

Sponsor: VA Rehabilitation Research and Development Service

Purpose—Pressure sores are a major complication for spinal cord injured and certain other disabled persons. Frequently, these areas of tissue breakdown begin deep in pressure-sensitive areas of muscle tissue and cannot be detected clinically until the process has become irreversible. The objective of our current study is to evaluate the feasibility of using ultrasonic techniques (measurements of attenuation and integrated backscatter) for assessing the state of deep muscle tissues with respect to early changes signaling the incipient development of muscle necrosis.

The proposed research will approach this problem by means of our established experimental model in pigs. Tissue damage in the animals is created by applying a constant force, over a period of hours, through specially shaped pneumatic indentors. This technique is being employed to create a known degree of tissue damage on which specific acoustic parameters can be measured for comparison to normal.

Progress—A three-dimensional precision scanning system, driven by stepper motors under the control of a computer, was developed for positioning the ultrasonic transducer over a tissue region of interest. Three groups of 4 Yorkshire pigs were indented for six hours at an indentation pressure of 700mm of Hg (13.9 psi), using 2cm diameter indentors. The indentation site chosen for these experiments was the tissue region over the mid-back region. The animals in the first group were sacrificed 7 days post-indentation, the second group 14 hours post-

indentation, and the third group 21 days post-indentation. Backscattered signals from tissue regions of interest were recorded, *in vivo*, before and after indentation and, *in vitro*, from excised tissue specimen. Data were recorded at 25 locations from each site of indentation and corresponding normal region. A focused 5 mHz, broad base ultrasonic transducer was used in all the measurements. To date, calculation of the slope of attenuation and integrated backscatter has been completed only on the *in vitro* data from the first group of animals.

Results—Preliminary results show that in the first group, the integrated backscatter was significantly increased in the damaged region ($-33.8 \pm 3.1\text{dB}$) compared to normal region ($-46.3 \pm 4\text{dB}$). However, the slope of the attenuation coefficient of damaged region (0.096 ± 0.023 nepers/cm/mHz) was not significantly different from that of normal tissue (0.099 ± 0.026 nepers/cm/mHz). Further, the standard deviation of attenuation measurement was large, confirming the earlier findings that the skeletal muscle tissue is highly inhomogeneous. Data analysis from the other two groups of animals is currently under way.

Future Plans/Implications—If this feasibility study is successful, it will lead to a clinically usable ultrasonic scanning test that can warn of impending pressure sores at the preclinical stage; in time to take corrective action to permit healing before tissue necrosis occurs.

A New Technique in the Assessment and Treatment of Autonomic Dysreflexia

Kenneth Lehmann, M.D.

Veterans Administration Medical Center, Long Beach, CA 90822

Sponsor: VA Rehabilitation Research and Development Service (Project #SCI-B468)

Purpose—Despite the marked improvement in survival over the past few decades, spinal cord injury

(SCI) remains a devastating disease. Understandably, most efforts in rehabilitation have been directed

at the profound motor disabilities accompanying spinal injury. However, the autonomic nervous system may be compromised as well. As the cardiovascular system is highly dependent upon autonomic influences, it is logical that SCI might interfere with the complex mechanisms involved in cardiovascular rehabilitation. In work recently completed by the principle investigator, severe acute injury to the cervical spinal cord in man has been shown to be regularly accompanied by alterations in cardiovascular function, including bradyarrhythmias, asystole, marked hypotension, supraventricular tachyarrhythmias, and atrioventricular block. In addition, these individuals also experienced a statistically significant increase in primary cardiac arrests that often proved fatal. These abnormalities were not found in patients with injuries of the thoracic or lumbar cord. Evidence is presented that implicates an acute autonomic imbalance imposed upon the heart and vasculature by a cervical cord injury as the mechanism responsible for these abnormalities.

Interestingly, these cardiovascular disturbances in all instances resolved spontaneously 2 to 6 weeks after injury. Though this adaptive response is obviously beneficial, the chronic stage of cervical SCI is marked by its own set of cardiovascular abnormalities. Chief among these is autonomic dysreflexia. This condition, common to most quadriplegics, is characterized by transient episodes of profound hypertension, diaphoresis, bradycardia and piloerection, along with flushing above and vasoconstriction below the level of injury. Autonomic dysreflexia has presented a major obstacle in the rehabilitative program of many SCI patients. To date, the mechanism of this apparent mass sympathetic reflex has not been established and no satisfactory treatment has been discovered.

It is the purpose of this study to develop a method of subjectively and objectively quantifying the frequency and severity of spontaneous autonomic dysreflexia in patients at risk, to institute procedures

designed to induce autonomic dysreflexia and orthostatic hypotension in patients in a controlled laboratory setting with quantitative assessment of the response, and to perform a randomized, double blind, placebo controlled crossover trial to evaluate the efficacy of transdermal clonidine for the treatment of these disorders.

The frequency and severity of autonomic dysreflexia during routine activity can be reliably and reproducibly ascertained through the use of ambulatory blood pressure monitoring. Symptoms of autonomic dysreflexia are regularly accompanied by transient elevations of systolic blood pressure, but many episodes of brief hypertension go clinically unrecognized. Autonomic dysreflexia and orthostatic hypotension can be safely induced in humans in the laboratory setting, with accurate quantitative assessment possible using noninvasive techniques. Transdermal clonidine is a useful prophylactic agent for the abatement of both clinical and subclinical episodes of autonomic dysreflexia without exacerbating pre-existent orthostatic hypotension. Specific objectives of this project:

1) To employ 24-hour ambulatory blood pressure monitoring in symptomatic patients with high-level spinal cord injury to ascertain short-term systolic pressure variability, and quantitate transient hypertensive episodes as an index of autonomic dysreflexia.

2) To execute a randomized, double-blind, placebo-controlled crossover trial investigating the utility of transdermal clonidine in the treatment of autonomic dysreflexia and orthostatic hypotension during routine ambulation.

3) To provoke dysreflexia and orthostasis in a controlled setting with noninvasive hemodynamic monitoring during randomized transdermal therapy with clonidine or placebo.

4) To study the neurohormonal response to dysreflexia and hypotension and the role of clonidine in the mediation of this response.

A Pilot Study on Alterations in Blood Rheology in Spinal Cord Injured Patients

A.H. Sacks, Ph.D.; Arundhati Perikash, M.D.; Inder Perikash, M.D.
Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service (Pilot Proposal #B937-PA)

Purpose—Rheology is the study of flow and deformation of materials. Blood is considered to be a

rheological material because it can exhibit both liquid and solid behavior, depending upon the nature

and magnitude of the applied forces. Because of the importance of red cell rigidity and the viscous behavior of blood in venous thrombosis and in the initiation of microcirculatory compromise, and the relationship of the latter to the initiation of pressure sores, it is proposed that a pilot project be undertaken to study blood rheology of spinal cord injured subjects in comparison with that of normal controls without spinal cord injury. The necessary space and most of the instrumentation are currently available at the Spinal Cord Injury Center and the Laboratory Service of the VA Medical Center, Palo Alto.

Pressure sores and deep vein thrombosis are major problems in patients with spinal cord injury. Since observations in patients with other diseases have

shown that increases in blood viscosity and red cell rigidity are associated with tissue necrosis and/or thrombosis, there is a possibility that these factors may be of significance in the causation of pressure sores and/or deep vein thrombosis in patients with spinal cord injury. Both increased blood viscosity and red cell rigidity can at present be treated by drugs. We propose to perform a pilot study to determine whether there is indeed an increase in blood viscosity and/or red cell rigidity in patients with spinal cord injury in comparison with normal subjects without spinal cord injury. If this pilot study shows encouraging results, then a subsequent full-scale investigation will be proposed as a Merit Review project.

Sacral Nerve Stimulation for Neurogenic Bladder Management in Spinal Dog

James S. Walter, Ph.D.; Charles J. Robinson, D.Sc.; John S. Wheeler, M.D.; Robert D. Wurster, Ph.D.;
Talat Khan, Ph.D.; J. Bolam; J. Stein; H. Doktycz; M. D'Astice

Hines VA Hospital, Rehabilitation Research and Development Center, Hines, IL and Loyola Medical Center,
Department of Urology and Physiology, Maywood, IL 60611

Sponsor: VA Rehabilitation Research and Development Service

Purpose—The spinal cord injured patient does not have control of bladder voiding. This results in many problems including urinary incontinence, urinary infection, and high bladder pressures which can result in urological problems. Renal pathology secondary to these bladder changes continues to be a cause of morbidity in the spinal cord injured patient.

Sacral stimulation has been effective in clinical trials using cuff electrodes on sacral nerve roots within the sacral canals (Brindley et al., *J Neurol Neurosurg and Psychiatry* 49:1104, 1986). However, invasive surgical implantation procedures, including laminectomy and opening the dura for implanting nerve cuff electrodes, have been required. Less invasive methods are needed. In preclinical trials, we are evaluating two less invasive methods of sacral stimulation for bladder management, both surface electrodes over sacral foramina and epidural electrodes in the sacral canal implanted via a modified percutaneous procedure. Criteria for an effective method include optimum electrode arrangements and stimulating parameters in terms of pressure and voiding volume, number of stimulations to employ the bladder and residual volume.

Less invasive methods of sacral stimulation can be used for bladder management. Sacral stimulation

with either surface or implanted needle electrodes can effectively stimulate bladder motor fibers, induce bladder contraction and voiding. Stimulation can be safely applied.

Progress—Previously, we managed the bladders of one chronic spinal male and female dog for over 2 years using similar procedures to those described here (Tang and Walter, *Neurol and Urodyn* 3:43-50, 1984). The current results concern using less invasive epidural needle electrodes (PISCES SIGMA and QUAD, Medtronic) and surface electrodes in spinal animals.

Four evaluations are being conducted to meet our goal of bladder management with sacral stimulation in the chronic spinal dog:

1) Establish a model: conduct T8-9 spinal transection and implantation of epidural sacral electrodes in male dogs. Instrument chronic spinal dogs for recording bladder pressure, colon pressure, pelvic floor electromyography and volume voided. Maintain animals in good health according to NIH and AAALAC guidelines.

2) Determine optimum electrode arrangements: A single monopolar electrode on the sacral midline is a good arrangement for implanted electrodes and

surface electrodes over the S2 sacral foramina appear to be optimal.

3) Determine optimum stimulating parameters: One to three seconds bursts of 10 pps stimulation at currents of 1 to 2.5 mA for implanted electrodes and 25 to 40 mA for surface electrodes is effective.

4) Determine urodynamic responses: After the first three weeks of stimulation when bladder re-

flexes had returned, voiding was effective with 10 to 100 ml following each stimulation, and residual volume after repeated stimulation was less than 50 ml.

Papers will be published documenting the above results and additional observations on urethral mechanisms in the chronic spinal dog.

Inhibition of the Hyperreflexic Bladder: Preclinical Trials

**James S. Walter, Ph.D.; Charles J. Robinson, D.Sc.; John S. Wheeler, M.D.; Robert D. Wurster, Ph.D.;
Talat Khan, Ph.D.**

Hines Veterans Administration Hospital, Rehabilitation Research and Development Center, Hines, IL and Loyola Medical Center, Department of Urology and Physiology, Maywood, IL 60611

Sponsor: VA Hospital, Rehabilitation R&D Center Core Funds

Purpose—Spastic bladder contractions in the spinal cord injured patient result in incontinence and high bladder pressure. The spinal cord injured patient needs to be able to prevent unwanted bladder contractions.

Sacral stimulation has been effective in clinical trials for inhibition of the bladder using cuff electrodes on sacral nerve roots within the sacral canals (Brindley et al., *J Neurol Neurosurg and Psychiatry* 49:1104, 1986). However, invasive surgical implantation procedures, including laminectomy and entry inside the dura for implanting nerve cuff electrodes, were required. Less invasive electrode implantation methods are needed. In preclinical trials, two methods of sacral stimulation are being evaluated: surface electrodes over sacral foramina and epidural electrodes in the sacral canal implanted via a modified percutaneous procedure. Optimum electrode arrangements and stimulating parameters will be determined in chronic spinal animals. The criteria for bladder inhibition will be prevention or reduction of bladder contractions induced by cystometry and rubbing the perineum.

Less invasive methods of sacral stimulation can be used for bladder inhibition. Sacral stimulation with either surface or implanted needle electrodes

can effectively stimulate bladder motor fibers, inhibit bladder contractions, and promote continence.

Progress—We have preliminary observations on inhibition of bladder contraction using two techniques of sacral stimulation, low frequency (2 to 20 pps), low current, and high frequency (200 to 4000 pps) high current, in chronic spinal dogs. We are switching to a spinal cat model because this animal has been shown to have urodynamic measures similar to the SCI patient (Galeano et al., *Neurol and Urodyn* 5:45-63, 1986).

Four evaluations are being conducted to show bladder inhibition with sacral stimulation in the spinal animal. These are as follows. 1) Establish a model: conduct T1-2 spinal transection and implantation of epidural sacral electrodes in male cats. Instrument chronic spinal cats with a suprapubic catheter, and record colon pressure, pelvic floor electromyography and volume voided. Maintain animals in good health according to NIH and AAALAC guide lines. 2) Determine optimum electrode arrangements and stimulating parameters for inhibition of induced bladder contractions. 3) Determine if hyperreflexic bladder problems are improved with chronic stimulation for bladder inhibition.

Effect of Intermittent Catheterization on Renal Stone Formation in Spinal Cord Injury Patients

J. R. Burns, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Because spinal cord injury (SCI) patients commonly experience alterations in calcium metabolism (hypercalciuria) which may persist for many months after injury, it is necessary to determine how, if at all, intermittent catheterization in the presence of hypercalciuria affects the risk of urinary tract stone formation. This study seeks to examine the effects of intermittent catheterization and determine the significance of hypercalciuria in SCI patients.

Progress—The study population consists of patients with neurologically complete spinal cord injuries who are identified and entered into the study within 1 week of injury. Twenty-four-hour urine specimens are collected at admission and twice weekly thereafter until the patient is discharged. Serum calcium is measured. Urine pH and species concentration measurements are obtained at regular intervals. Relative supersaturation of the urine with respect to calcium oxalate and calcium phosphate is determined. Activity product and the formation product ratio of brushite is determined for each specimen. All data are analyzed statistically. Nine patients were followed for at least 5 weeks.

Results—Serum calcium was measured in all patients at entry. Six patients had hypercalciuria on at least one occasion with increased calcium detected in the

first 24-hour urine sample. Urinary calcium excretion returned to normal within 8 weeks of injury. Urinary oxalate excretion values fluctuated greatly because many patients received large doses of intravenous vitamins during the first few weeks after injury.

It was postulated that urinary supersaturation of calcium oxalate and possibly brushite would increase significantly when SCI patients were started on ICP (intermittent catheterization program) because urine volume would decline while urinary calcium excretion remained elevated. Indeed, in this series, urinary volume did decline. The average urinary output was 1959 ml/24 hours before ICP and 1280 ml/24 hours after ICP. However, the pattern of urinary calcium excretion differed from our expectations. Calcium excretion returned to normal in all patients within 8 weeks of injury. Since oxalate excretion varies little in normal individuals, the same is probably true for SCI patients.

Future Plans/Implications—It appears worthwhile to measure urinary calcium excretion prior to starting an ICP. If urinary calcium excretion is markedly elevated, ICP should be postponed for several weeks. Since patients are generally normocalciuric within 8 weeks of injury, such postponements can be of reasonably short duration.

Incidence, Characteristics, and Clinical Significance of Anemia in Patients with Spinal Cord Dysfunction

C.T. Huang, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Anemia commonly develops within the first 6 months following spinal cord injury (SCI), even in the absence of detectable blood loss. Whether anemia is due to stress, inadequate nutrition, blood

loss, depressed red blood cell (RBC) production, or increased RBC destruction has not been determined. Anemia may be an important factor in the development of secondary complications. It may also

delay or prolong the rehabilitation program. Thus, finding the cause of anemia in this population is a requisite to its prevention.

This study seeks to: 1) determine those epidemiologic and/or demographic variables affecting the duration and/or severity of anemia; 2) determine the natural history of changes in the hematologic profile of SCI patients; 3) establish the natural history of RBC kinetics after SCI; and, 4) determine whether alterations in nutritional profile are associated with the incidence, duration, and/or severity of post-injury anemia.

Progress—A series of neurologically complete quadriplegics (who have not received blood transfusions following their SCI) constitutes the study population. Demographic characteristics and the hematologic correlates of the population are being documented, as are basic hematologic profiles. Ferrokinetic studies are being performed. Nutritional profiles and their hematologic correlates are established. Erythropoietin quantitative assays are being performed. All data will be analyzed utilizing appropriate statistical techniques.

Preliminary Results—The project was initiated in June 1984. As of November 1986, 23 patients had

been entered into the study population. All 23 patients were found to have mild normocytic and normochromic anemia, a profile that is characteristic of patients with chronic disorders. Anemia was found as much as 7 weeks post-injury. During the same period, red cell mass was almost always low ($x = 1592.6$ mls) and plasma volume was almost always high ($x = 3093.7$ mls); yet total blood volume remained constant.

Total body hematocrit count measured by the isotopic method was always lower than hematocrit values from peripheral blood measured by the regular clinical laboratory. Therefore, it is concluded the true hematocrit should be based on isotopic measurement.

Since both erythropoietin and reticulocyte count were within normal limits, it is unlikely the anemia was caused by either the red stem cell maturation process in the bone marrow or the release of mature red cells into the peripheral blood from the bone marrow. However, additional iron turnover and red cell survival data are needed before any firm conclusions can be drawn.

Future Plans—Patients will continue to be entered in the protocol until 48 subjects have been enrolled. Preliminary data analysis began in the fall of 1987.

Pain Secondary to Gunshot Wound During the Initial Rehabilitation Process in Spinal Cord Injury Patients

J. S. Richards, Ph.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Surgical management of gunshot-related spinal cord injury (SCI) is controversial. There is concern that routine decompression laminectomies (in which the bullet and/or bullet fragments are removed) may aggravate the patient's prognosis rather than improve it.

Removal of the bullet tends to be a standard practice whether or not its presence represents a life-threatening situation. It is widely accepted that removal reduces the intensity of associated pain later in life. However, there is virtually nothing in the literature supporting this contention. By contrast, other clinicians believe laminectomy may

contribute to general instability of the vertebral column in addition to being partially responsible for some reported pain. Finally, there is a clinical impression that pain occurring secondary to a gunshot wound may differ in character from that occurring secondary to SCI resulting from other causes. This study is intended to help clinicians understand intractable pain following SCI, and also to verify or refute the efficacy and desirability of decompression laminectomy and bullet removal after SCI.

Specifically, this study seeks to: 1) determine whether the incidence of pain reported in GSW/SCI patients is significantly different than the incidence

in patients whose SCIs result from other etiologies; 2) characterize the incidence of pain reported by GSW/SCI patients epidemiologically and demographically; 3) determine the relationship between incidence of pain in GSW/SCI patients and surgical removal of the bullet; and, 4) determine, prospectively, the incidence of pain in GSW/SCI patients with or without decompression laminectomy.

Progress—This is a two-phase, prospective study. In Phase 1, pain data are collected on all SCI admissions (except those excluded because of overlying psychosis or senility) on a weekly basis from time of admission to first definitive discharge, with pain behavior changes being assessed over time. Data are evaluated with regard to epidemiologic and demographic characteristics of the population. GSW/SCI patient data are studied to determine absence or presence/location of the bullet or bullet fragment(s). If surgically removed before this phase, the pre-surgical location is documented. Pain history is documented and analyzed statistically. Patient outcome will be evaluated.

Preliminary Results—As of November 1986, the

project had enrolled 15 SCI patients who had the bullet or bullet fragment removed from the spinal canal, 10 SCI patients in whom the bullet or bullet fragment remains in the canal, 9 SCI patients in whom the bullet or bullet fragment remains present elsewhere, and 4 SCI patients in whom the bullet or bullet fragment was removed from a site other than the spinal canal. Approximately 30 SCI patients without gunshot wounds have also been entered into the study.

It can be tentatively concluded that removing the bullet does not always prevent pain, and furthermore, leaving the bullet in the canal does not inevitably lead to subsequent pain. In fact, 4 of the 10 patients followed with the bullet still in the canal report no pain whatsoever.

Future Plans—During the coming year, subjects will continue to be enrolled in the study. Preliminary analyses of the McGill Inventory data will be conducted. The plan continues to include entering both GSW/SCI patients and matched, non-GSW/SCI patient controls through June 1989. Final data analyses will be completed at that time.

Didronel in the Prevention of Heterotopic Ossification Following Spinal Cord Injury: Determination of an Optimal Treatment Schedule

S. L. Stover, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—Heterotopic ossification (H.O.) following spinal cord injury (SCI) or other severe neurologic injuries and diseases can limit joint range of motion and exacerbate the disability, often impairing function and limiting ambulation or wheelchair independence to the extent the patient must remain bedfast. Recently, however, a drug, Didronel (etidronate disodium), has been shown effective in preventing H.O. when administered prophylactically after SCI.

This study seeks to: 1) determine the optimal time post-injury Didronel therapy should be initiated to achieve the maximal prophylactic effect; 2) determine the optimal duration of Didronel therapy for

maximal prophylactic effect; and, 3) establish dosage recommendations for Didronel that are capable of yielding maximal prophylactic effect.

Progress—The study population consists of patients admitted to the UAB Spinal Cord Injury Care System between 0 and 120 days post-injury; whose lesions are neurologically complete (or neurologically incomplete with residual function equal to a Frankel Classification of "sensory only") and who are at least 16 years of age and who are not pregnant. Patients in the series are subcategorized into Early and Late Treatment Groups and further divided into 3- and 6-month administration groups. X-ray films

of both hips are obtained 1 day prior to initiation of Didronel therapy, at the end of each treatment period, and at 1 year post-injury.

Preliminary Results—As of November 13, 1986, 169 patients/subjects had been entered into the study. Substantially more patients/subjects have been entered into the Early Treatment Groups (15-44 days post-injury) than into the Late Treatment Groups (45-120 days post-injury). The reason for this is that most SCI patients are admitted to this center well within 44 days of injury, since the UAB Spinal Cord Injury Care System emphasizes early admission. (It is imprudent to delay transfer-admissions solely for the purpose of being able to enter a prospective patient/subject into any clinical study.) In this case, it would be considered particularly imprudent since the agent, disodium etidronate, has been proved effective in the early prevention of H.O. formation. However, if patients are admitted to our center 45 or more days after injury, they are entered into one of the Late Treatment Groups routinely, if they

meet all other selection criteria.

Ten additional patients developed clinically significant H.O. requiring continued drug treatment for at least 1 year. Because of its proven efficacy, treatment cannot be withheld when patients develop clinically significant H.O. Data from these patients will be analyzed separately at the conclusion of the study.

Provisional results based on 87 patients/subjects with complete data show that, for patients who do not develop H.O. during drug treatment, treatment for 180 days appears to be no more advantageous than treatment for 90 days, regardless of when treatment begins. However, early treatment is superior to late treatment regardless of treatment duration. Data for patients developing H.O. during drug treatment are inconclusive.

Future Plans/Implications—Patients/subjects will continue to be entered into the project until the target of 100 patients/subjects with complete data is reached.

Natural History and Clinical Course of Urinary Tract Complications in Patients with Spinal Cord Dysfunction

S. L. Stover, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Appropriate clinical management of patients with neurogenic bladders resulting from spinal cord dysfunction requires 1) knowledge of the natural history or clinical course of urinary tract complications in this group and 2) data from which to determine whether urinary complications in this group are predictable from early post-injury urinary tract status and method of early bladder drainage management.

The objectives of this study include: 1) determining the effect of method of bladder drainage management on the incidence of orchitis and/or epididymitis, penoscrotal abscess, penoscrotal fistula, ureterectasis, pyelocaliectasis, and effective renal plasma flow (ERPF); 2) determining the effect of various urinary tract infecting organisms on orchitis/epididymitis, penoscrotal abscess, penoscrotal fistula, ureterectasis, pyelo-caliectasis, and ERPF; 3)

determining the effect of vesico-ureteral reflux on upper tract changes including ureterectasis, pyelocaliectasis, calculi, and ERPF; 4) determining the effect of pyelocaliectasis on cortical thickness and development of renal calculi; and, 5) determining the effect of bladder calculi on bladder configuration changes, vesico-ureteral reflux, ureterectasis, pyelocaliectasis, cortical thickness and renal calculi and the effect of renal calculi on pyelocaliectasis and cortical thickness.

Progress—Rigorous statistical analyses are being performed on a massive urologic database derived from a large series of SCI patients having a spectrum of neurologic levels and extents of injuries, and those neurogenic bladders are/were managed in a variety of ways.

Preliminary Results—As of November 1986, the medical records of 1360 patients have been reviewed, although not every patient has been entered into the database. Objectives 4 and 5 have been completed. The findings suggest patients with treated asymptomatic bacteriuria do not have significantly fewer urologic complications, episodes of chills and fever, or therapeutic urologic surgical procedures than similar patients whose asymptomatic bacteriuria is allowed to go untreated. Moreover, 37 percent of the patients treated with antibiotics developed strains of bacteria that were antibiotic-resistant.

Patients whose urine was sterile at the first of two consecutive annual follow-up examinations had fewer urologic complications, episodes of chills and fever, and therapeutic urologic surgical procedures than patients whose urine was infected at the first examination. This finding can be explained by the fact that patients with sterile urine had some degree of bladder sensation or control. In this series, patients with untreated asymptomatic bacteriuria were more likely to have therapeutic urologic surgery than

patients with treated asymptomatic bacteriuria. Data have also been collected on a series of patients with vesico-ureteral reflux.

Future Plans—A case-controlled study is now being conducted to identify and quantify risk factors for the development of vesico-ureteral reflux. Secondly, a suitable control series will be identified who have never developed vesico-ureteral reflux. The proportion of patients who developed vesico-ureteral reflux and who were classified correctly (sensitivity) and the proportion of those patients who were vesico-ureteral reflux-free and classified correctly (specificity) will be assessed using a model to classify all patients in the study and comparing predicted with actual results.

We will also conduct a nonconcurrent prospective study to determine the effect, if any, of vesico-ureteral reflux on effective renal plasma flow, development of renal stones, pyelocaliectasis, and ureterectasis 3 years after reflux diagnosis.

Pathologic Effects of Recurrent Bacteriuria in Patients with Spinal Cord Dysfunction

K. B. Waites, M.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—Urinary tract infections (UTIs) are a serious source of morbidity for spinal cord injury patients. Recurrent hospitalizations and outpatient services required for treatment of acute and chronic UTIs are extremely expensive and may impede both the overall rehabilitation process and vocational pursuits. In addition, UTIs may lead to grave urologic complications and, in some cases, eventual renal failure. There is a need to prevent these infections and their sequelae so as to improve the overall rehabilitation potential and quality of life for SCI patients.

Objectives of this study include: 1) determination of the incidence of clinically significant urinary tract complications coincident with the major bacterial species; 2) determination as to whether aggressive treatment of most pathogenic organisms results in fewer long-term secondary urinary tract complications; 3) determination as to whether patients with

certain human leucocyte antigen (HLA) combinations are at unusually high or low risk for developing long-term secondary urinary tract complications; 4) determination as to whether the phagocytic activity of human leucocytes correlates with the incidence of clinically significant urinary tract infections and long-term secondary complications; and, 5) determination as to whether the degree of bacterial adherence to the urothelium correlates with the incidence of clinically significant urinary tract infections and specific HLA combinations.

Progress—Data will be analyzed to determine the effect of chronic UTI with the major bacterial species on parameters such as parenchymal thickness, reflux, effective renal plasma flow (ERPF), etc. by selecting SCI patients who have been infected for 1 year or more and comparing their data with those of uninfected patients.

SCI patients with histories of multiple urinary tract complications will be studied to determine if: a) their bacteria show a high degree of adherence to the urothelium; b) there is a particular HLA combination; or, c) they have circulating leucocytes or monocytes of unusually low phagocytic activity when compared with SCI patients who rarely or never have UTIs and with persons without SCI who have normal urinary tracts.

SCI patients with recurrent UTIs will be treated rigorously with antibiotics and followed. The effectiveness of rigorous follow-up and treatment will be assessed via comprehensive renal scintigraphy procedures (CRSPs), excretory urograms (EXUs), and by carefully documenting reinfection rates.

Preliminary Results—Based on 1,461 routine annual SCI follow-up examinations, the incidence of chills and fever, specific urologic surgical procedures, and the mean effective renal plasma flows (by specific genera of bacteria) has been determined. These data indicate that patients whose urinary tracts were infected with *Serratia*, *Pseudomonas*, *Providencia*, and *Acinetobacter* were more likely to have urologic complications and episodes of chills and fever than

patients whose urinary tracts were infected with *Staphylococcus*, *Enterococcus*, and *Enterobacter*.

A series of experiments has been designed comparing bacterial adherence in the urinary tract, effectiveness of urine and serum opsonization, phagocytosis, and intracellular bacterial killing by neutrophils among three groups of patients: 1) those who have urologic complications; 2) those who do not have urologic complications; and, 3) non-SCI controls.

Future Plans—In the upcoming grant period, differences in phagocytic activity of neutrophils, opsonization capacity of serum and urine, intracellular bactericidal activity, and bacterial adherence in the urinary tract that exist among SCI patients with clinically significant urinary tract infections and urologic complications, SCI patients with either sterile urine or uncomplicated bacteriuria, and normal controls without SCI or history of urinary tract disease, will be determined. HLA typing will be initiated for the purpose of determining if specific HLA types correlate with either the incidence of urologic complications or the degree of bacterial adherence.

Drug Effects on Bladder Smooth Muscle Contractility

W. T. Woods, Ph.D., and J. K. Bubien, Ph.D.

Research and Training Center in Spinal Cord Dysfunction, University of Alabama at Birmingham, Birmingham, AL 35294

Sponsor: National Institute on Disability and Rehabilitation Research

Purpose—Debilitating spasticity is an extremely serious secondary complication in patients with spinal cord dysfunction. Skeletal muscle relaxants are commonly prescribed to counteract spasticity, but experience has shown widely varying degrees of success. The bulk of previous research with these drugs has addressed their effects on skeletal and to a lesser extent, cardiac muscle. Their effects on smooth muscle have been considered only rarely. This study examines the role of skeletal muscle relaxants on arterial and intestinal smooth muscle contractions in rats, and on bladder smooth muscle in humans.

Objectives of this project include: 1) determination of the effect of baclofen (lioresal) and diazepam (Valium) on *in vitro* human bladder smooth muscle

contractions induced by electrical pulses or acetylcholine; 2) determination of the effect of baclofen and diazepam on *in vitro* rat arterial and intestinal smooth muscle contractions induced by electrical pulses or acetylcholine; 3) determination as to whether diazepam or baclofen alter the responses of rat bladder, arterial, and intestinal smooth muscle induced to contract by bethanechol chloride; and, 4) determination as to whether diazepam or baclofen alter the length-tension relationship of rat bladder, arterial, and intestinal smooth muscle.

Progress—Smooth muscle tissue specimens will be obtained surgically in accordance with institutionally approved guidelines governing the involvement of human subjects in research projects. *In vitro* tension

measurements resulting from artificially induced contractions under control and experimental (with drug) conditions will be obtained. Inter-species drug

effects on different tissue specimens will be determined and compared. (The project began June 1, 1987.)

Surface Sacral Stimulation for Bladder Management of Patients with Spinal Cord Injury

John S. Wheeler, M.D.; James S. Walter, Ph.D.; Charles J. Robinson, D.Sc; D. Gerfen

Hines VA Hospital, Rehabilitation Research and Development Center, Hines, IL, and Loyola Medical Center, Department of Urology and Physiology, Maywood, IL

Sponsor: *Neuroscience and Aging Institute, Loyola University, Stritch School of Medicine*

Purpose—Control of bladder functions of continence and voiding are lost in many spinal cord injured (SCI) patients. Because of this many problems are faced including urinary incontinence, urinary infection and high bladder pressures which can result in urological pathology. There is a need for control of bladder contraction for voiding and control of bladder inhibition to prevent incontinence and high bladder pressures.

Sacral stimulation has been effective in clinical trials using cuff electrodes on sacral nerve roots within the sacral canals (Brindley et al., *J Neurol Neurosurg and Psychiatry* 49:1104, 1986). However, invasive surgical implantation procedures, including laminectomy and entry inside the dura for implanting nerve cuff electrodes, have been required. Less invasive electrode implantation methods are needed. In clinical trials, surface electrodes over sacral foramina are being evaluated. Optimum electrode arrangements and stimulating parameters are being determined. Criteria will be established for: 1) bladder contraction: effective voiding at low bladder pressures, less than 20 stimulations to empty the bladder with less than 100 cc residual urine; and, 2) inhibiting bladder contractions: reduce or eliminate bladder contractions induced by cystometry.

Less invasive methods of sacral stimulation can be used for bladder management. Sacral stimulation

with surface electrodes can effectively stimulate bladder motor fibers, induce bladder contraction and voiding, or inhibit unwanted bladder contractions.

Progress—Previously, we managed the bladders of one chronic spinal male and female dog for over 2 years using similar procedures to those described here (Tang and Walter, *Neurorol and Urodyn* 3:43-50, 1984). We are also completing studies comparing sacral implanted needle electrodes to sacral surface electrodes in chronic spinal male dogs. The current studies concern using surface sacral electrodes in the SCI patient.

Three evaluations are being conducted to meet our goal of bladder management with sacral stimulation in the SCI patient. 1) Determine optimum electrode arrangements: surface electrodes over the S2 sacral foramina appear to be optimal. 2) Determine optimum stimulating parameters: preliminary results in one patient indicate that five seconds bursts of 20 pps stimulation at currents of 35 to 40 mA are effective for inducing bladder contraction. However, in a second patient, our highest stimulating current of 60 mA was ineffective. 3) Determine urodynamic responses: effective voiding remains to be shown.

Neuroaugmentative Procedures for Modification of Abnormal Motor Control in Patients with Spinal Cord Injury

M.R. Dimitrijevic, M.D.; A.M. Sherwood, P.E., Ph.D.; R.J. Campos, M.D.; P.C. Sharkey, M.D.
Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: *Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research*

Purpose—Sixty patients with muscle hypertonia after spinal cord injury have undergone spinal cord stimulation (SCS). These patients had spinal cord injuries (SCI) ranging from C2 to T12. Electrodes were placed above, below, or above and below the lesion in the posterior epidural space for a period of at least three days during which time stimulation pulses, typically of 3 to 5 mA amplitude and of 0.2 msec duration at 30 Hz were applied. The effects of SCS were monitored by recording motor unit activity with surface electrodes over leg muscles during an examination of segmental and suprasegmental spinal cord activity, in addition to patient reports and neurological evaluations.

Progress—The results of SCS can be divided into four distinct categories. In Group I, consisting of 17 patients, or 28 percent of the entire group, the effect was characterized by marked suppression of muscle hypertonia and so-called spontaneous spasms. In Group II, the effect of SCS on muscle hypertonia was moderate, as evidenced by the suppression of the tonic but not phasic features of spasticity. This was observed in 20 patients, or 33 percent of the total. In Group III, neurological and neurophysiol-

ogical evaluations revealed only a marginal effect. The condition of this group of nine patients (15 percent) did not improve significantly. In group IV, consisting of 14 patients (23 percent), there was no effect.

Preliminary Results—SCS was markedly or moderately effective in reducing spasticity in 63 percent of the patients. We found that control of spasticity by SCS was not correlated with the severity of spasticity, the type of spasticity (flexor or extensor), or the ability to ambulate. However, stimulation in incomplete cervical lesion patients was 90 percent effective, compared to 14 percent effective in complete cervical lesions, and stimulation below the lesion was more effective than above. We concluded that SCS is effective when electrodes are properly positioned below the lesion over the posterior aspect of the spinal cord in patients with some residual spinal cord function. We hypothesize that SCS controls spasticity by modification of activity of the spinal-brainstem-spinal loop and by suppression of segmental excitation through antidromic activation of propriospinal pathways.

Effects of Spinal Cord Injury on Drug Metabolism

Lauro Halstead, M.D. and Stuart Feldman, M.D.

Baylor College of Medicine; The Institute for Rehabilitation and Research; Department of Pharmaceutics, University of Houston, Houston, TX 77030

Sponsor: *Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research; Paralyzed Veterans of America*

Purpose—The pharmacokinetics of medications administered to spinal cord injured (SCI) patients have not been widely investigated. There are numerous reports regarding alterations of normal physiological, neurological, and biochemical functions in the SCI population which raise the possibility that one or more aspects of drug distribution, metabolism, and excretion may be altered in this group. The

overall objective of this research is to investigate, in a systematic fashion, a number of representative drugs commonly used at various times throughout the life of SCI patients.

Progress—Eighteen subjects with SCI who were to receive tobramycin, either prophylactically prior to a urological procedure, or to treat infection, were

given an explanation of the research project and gave written informed consent. All subjects had normal renal function as evidenced by creatinine clearance measurements. Eighty milligrams of tobramycin were infused intravenously by a pump over a 60-minute period. Serum samples were collected before the infusion and at 30, 60, 75, 90, 120, 150, 180, 240, 360, and 480 minutes after the start of the infusion. Serum samples were assayed for tobramycin by the EMIT method of analysis. Data were analyzed by the model-independent pharmacokinetic methods. The mean age of our subjects was 31 years (range 18 to 54); the mean weight was 66 kg (range 45.5 to 82.7); and level of injury was from T4 to C3.

Results—Following the infusion peak, tobramycin in serum concentration averaged 3.4 ± 0.8 g/ml. At the end of the 8-hour dosing interval, trough levels averaged 0.3 ± 0.2 g/ml. In the 18 subjects studied, the mean half-life of tobramycin was 113 minutes. The serum clearance (Cl) averaged 147 ± 40 ml/min or 23.5 ± 7.3 liters or 0.36 ± 0.10 .

The data in the limited population studied strongly suggests that the disposition of tobramycin in per-

sons with SCI may be quite different than in people with intact spinal cords. Both the volume distribution (V_{ss}) and clearance appear to be higher in SCI. Data published for tobramycin in the intact spinal cord subject indicates average clearance values of approximately 1.87 ml/min/kg and a mean volume of distribution of 0.26 l/kg. The physiological basis for the differences are not known, but these data suggest that dosages of tobramycin in patients with SCI requiring aminoglycoside therapy may have to be increased to provide serum concentrations to adequately cover susceptible organisms. Trough serum tobramycin concentrations were < 0.30 μ g/ml. If one assumes that trough tobramycin serum levels should be approximately 1 μ g/ml, we found that in our study population the aminoglycoside concentration falls below this level at four hours post-dosing. Thus, a change in tobramycin dosage regimen in SCI patients would be appropriate.

Future Plans/Implications—Further studies will examine the absorption of tobramycin following intramuscular administration to spinal cord injured subjects to determine if spinal cord injury affects the absorption of drugs.

Collagen Dysfunction in Quadriplegia

Gladys Rodriguez, M.S. and Jacqueline Claus-Walker, Ph.D.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research; Spinal Cord Research Foundation of the Paralyzed Veterans of America

Purpose—This study seeks to elucidate the ways in which collagen metabolism is altered in spinal cord injury (SCI), and determine the causes and consequences of such alteration.

Project I: A method has been developed to measure hydroxylysine glycosides in an automated amino acid analyzer to establish the fact that increased concentration of a specific glycoside is an indication of the tissue origin of the collagen being degraded. It is hoped that physicians will be able to use this information to decide what preventive measures are of greatest importance for the individual patient and thus reduce the number of complications following SCI.

Project II: Density of adrenergic receptors in the insensitive skin of SCI patients is being measured by radioligand binding assays. The objective is to

show that altered sympathetic responses lead to altered nutritional status of the skin, thus increasing its susceptibility to pressure damage.

Project III: The activity of the enzyme lysyl hydroxylase and the concentration of some amino acids characteristic of collagen are being measured in skin biopsies from above and below the injury in SCI patients. The objective is to show that SCI leads to abnormal enzyme activity which in turn leads to defective collagen biosynthesis and decreased tensile strength of the skin. If the specific defects in the collagen metabolism of SCI can be identified, they may be amenable to pharmacological intervention.

Progress—Project I: Eighty-six patients have been followed. Results show that approximately one month

prior to any physical incidence of skin irritations, the urinary concentration of the diglycoside increases and remains elevated until the condition is corrected. Increased concentrations of monoglycoside are associated with the incidence of urolithiasis, heterotopic ossification, and osteoporosis, but the temporal relationship is not as clearly defined.

Project II: Data has been published in the *Archives of Physical Medicine and Rehabilitation*, 67:177-180, 1986.

Project III: Biopsies have been obtained from healthy, nonparalyzed volunteers. The number of patients is small, but data so far indicates that lysyl hydroxylase activity is highest in healthy controls, next highest in the skin above the level of injury in SCI patients, and lowest in skin below the level of injury of SCI patients. Also, amino acid content of skin below the level of injury is much lower than in the skin above the level of injury in the same patients.

C. Spinal Cord Regeneration

Electric Field Distribution in the Injured Spinal Cord

Talat Khan, Ph.D.; Joel B. Myklebust, Ph.D.; Thomas Swiontek, Ph.D.; Dennis Maiman, M.D., Ph.D.; Robert D. Wurster, Ph.D.

Veterans Administration Medical Center, Hines, IL 60141 and Zablocki Veterans Administration Medical Center, Milwaukee, WI 53295

Sponsor: VA Rehabilitation Research and Development Service

Purpose—Injury to the spinal cord causes paraplegia or tetraplegia. Currently, there is little hope for functional recovery after spinal cord trauma; victims are often confined to bed or wheelchair. Although rehabilitation and orthotic devices aid these patients in enriching the quality of their lives, the ideal solution to the problem is a regimen which would enhance the regrowth and reconnection of the traumatized nerve fibers, so that functional neural connections can be reestablished.

Externally applied electric field has been shown to produce beneficial effects on the regrowth of injured spinal cord axons and other peripheral and central nerve fibers. In any attempt to stimulate regeneration in the mammalian spinal cord, it is quite important to provide some assistance to guide the direction of nerve growth if the axons are to make specific functional connections with their normal target tissues. In tissue culture, externally applied electric fields not only stimulate the nerve fiber growth but also influence the direction of that growth. Fibers grow extensively towards the cathode. Although fiber growth *in vitro* can be guided by externally applied fields, the application of these methods *in vivo* is limited because of the lack of information regarding current pathway and electric field distribution. In contrast to the controlled en-

vironment of tissue culture media, the spine and spinal cord is a highly inhomogenous and anisotropic structure.

Properly configured, applied electric fields should aid in guiding regenerating spinal cord axons. If the effect of electric currents upon regeneration is to be properly evaluated, the distribution of electric current and potential in the tissue must be determined for electrode configurations and electrical parameters which are suggested to produce stimulating effects. Furthermore, because it has been reported that currents are produced endogenously in the vicinity of an injury to the spinal cord and that this "injury current" is related to the potential healing process, it is important to measure the effect of the applied electric current on these endogenous electric fields. Following the determination of current and potential distribution in the spinal cord, those configurations which produce the best results will be used in cats after contusion or transection injury.

Progress—Previously we have used electrical currents of small magnitude on the injured spinal cord of rats. Initial evidence of clinical assessment of neurological function indicated a favorable response to the extrinsically applied electric fields after spinal

cord injury. However, accurate dosimetry which is essential to the optimum response to treatment should be determined.

Four evaluations will be made during the course of this project: 1) measurement of the distribution of electric fields in the spinal cord of the cat before and after spinal cord injury by contusion and transection; 2) measurement of the electric fields in the spinal cord resulting from applied currents from implanted electrodes; 3) correlation of the degree of axonal regrowth due to neural stimulation with electric fields distribution; and 4) implementing a standard measure of comparison, that is, current density measurement, to evaluate neural stimulation techniques with different electrode configurations

and stimulation parameters.

The initial studies (first 3-4 months) will focus upon the determination of appropriate electrical parameters for the *in vivo* studies of axonal regrowth. Following this, the electrical and neurophysiological experiments will be conducted in parallel. At the end of the first year, the results of the histologic studies will be reviewed together with the electrical measurements to determine whether particular combinations of electrical parameters is more efficacious than others. If this is the case, the experimental protocols will be modified to concentrate upon those parameters. Otherwise, the studies will be continued to evaluate a wide spectrum of electrical parameters.

Recovery Following Incomplete Spinal Cord Injury: An Animal Model

James W. Little, M.D., Ph.D., and Roger M. Harris, Ph.D.
University of Washington, Seattle, WA 98105

Sponsor: VA Rehabilitation Research and Development Service; University of Washington

Purpose—Recovery of voluntary movement is characteristic of incomplete spinal cord injury (SCI). Such recovery is observed even though a majority of descending axons are sectioned and degenerate; they do not regenerate. The spared descending axons apparently take over some function for those lost. This research undertakes to develop a practical animal model for investigating the mechanisms that mediate recovery and any interventions which might enhance recovery.

Progress—Adult rats undergo mid-thoracic subtotal spinal cord section, sparing either one ventral or one lateral funiculus. Hindleg locomotor and postural recovery and spinal reflex changes are described over 4 to 6 weeks after the cord lesion. Some locomotor recovery is supported by fewer

than 25 percent of descending fibers, and neither the dorsal half of the lateral funiculus nor the medial half of the ventral funiculus is necessary to mediate that recovery. Anterograde labelling of lumbar commissural axons and terminals, crossing from the side of the cord with spared descending fibers to the side without spared fibers, has failed to demonstrate any morphologic increase in this projection to explain the motor recovery.

Future Plans/Implications—Future studies will look for morphologic changes, such as collateral sprouting and new synaptogenesis by other spared commissural projections, to explain the motor recovery. This animal model of incomplete spinal cord injury will be used in trials of various therapeutic interventions which may enhance recovery.

Lower Extremity Spasticity Following Spinal Cord Injury

James W. Little, M.D., Ph.D.
Veterans Administration Medical Center, Seattle, WA 98108

Sponsor: VA Rehabilitation Research and Development Service

Purpose—Spasticity represents hyperactive spinal reflexes. Such exaggerated reflexes commonly de-

velop in spinal segments caudal to a spinal cord injury (SCI). Such hyperreflexia can further com-

promise patient function. This study examines the lower extremity manifestations of SCI spasticity and will describe the time-course for the appearance of the hyperreflexia over the first year post-SCI.

Progress—To date, serial spinal reflex studies have been initiated in 11 acute and 11 chronic SCI subjects with complete injuries. Tibial and femoral H reflex excitabilities, measured as H/M amplitude ratios, tend to increase during the first three months post-injury. Tendon reflex excitability also increases over time, in many but not all subjects, and is most excitable in chronic SCI subjects. Flexor withdrawal reflexes, recorded in the biceps femoris and tibialis anterior muscles, tend to be larger amplitude and lower threshold in chronic as compared to acute SCI subjects. Reflex excitabilities are measured as fractions of the compound muscle action potential amplitude, since this amplitude falls markedly with

disuse atrophy in the lower extremity muscles.

Results—A survey of lower extremity spasticity manifestations in SCI subjects has revealed that hyperactive tendon reflexes, clonus and extensor spasms commonly appear together. Spontaneous flexor spasms and triple flexion response with plantar stimulation of the foot are regularly seen together. Those with incomplete spinal cord injuries note more functional limitations due to their spasticity than do those with complete cord injuries. Quadriplegics and those with complete cord injuries report more functional use from their spasticity than do paraplegics and incompletes.

Future Plans/Implications—Future studies will examine reflex changes in incomplete SCI subjects and the effect of motor recovery on those changes.

The Neurite-Promoting Activity of the Basement Membrane Protein Laminin

Eva Engvall, Ph.D. and Matia Bar-Ner, Ph.D.

LaJolla Cancer Research Foundation, Cancer Research Center, LaJolla, CA 92037

Sponsor: National Cancer Institute

Progress/Methodology—Laminin promotes neurite outgrowth from cultured neuronal cells and promotes the adhesion and motility of glioblastoma cells *in vitro*. Laminin-containing acellular fetal membranes also show activity in nerve regeneration *in vivo*.

We have located the neurite-promoting site in human laminin to the end of the long arm using monoclonal antibodies to laminin and proteolytic fragments. We have evidence suggesting that glioblastoma cells interact with the same site and that the receptors on neuronal cells and glioblastoma cells are related. We propose to identify and characterize the neurite-promoting/cell adhesion site of laminin by isolating smaller active proteolytic fragments of laminin and analyzing these fragments by rotary shadowing-electron microscopy, electrophoresis, NH₂-terminal sequencing of peptide subunits, and antibody reactivity. Complete structural infor-

mation on the neurite-promoting site will be obtained from cloning and sequencing of cDNA coding for sequences around the site.

We will reconstruct the neurite-promoting site using peptide synthesis and/or synthesis in bacteria and test the constructs for *in vitro* and *in vivo* activity. The human cell surface receptor interacting with the neurite-promoting site in laminin will be identified, characterized, and isolated from glioblastoma cells using monoclonal antibodies and affinity-chromatography on natural or synthetic neurite-promoting/cell binding sites of laminin. The relationship of the glioblastoma cell laminin receptor to other laminin receptors on other cell types and to other extracellular matrix receptors will be established. The activity of the laminin receptor will be evaluated in various *in vitro* assays using specific peptides with neurite-promoting activity and using antibodies specific for this receptor.

Central Nervous System Regeneration in Adult Mammals: A Study of Inappropriate Terminal Axonal Contacts

Albert J. Aguayo and Garth M. Bray

Neurosciences Unit, The Montreal General Hospital Research Institute and McGill University, Montreal, Quebec H3G 1A4, Canada

Sponsor: Paralyzed Veterans of America, Spinal Cord Research Foundation (NBR-657)

Purpose—Experiments in this laboratory which utilized new techniques for the examination of neural tissues, established that several different classes of nerve cells in the brain and spinal cord of adult rats have the capacity to regrow lengthy axons if their environment is appropriately manipulated. Furthermore, we subsequently demonstrated that some of these regrown axons can form differentiated contacts (synapses) when they are guided to target regions of the brain. This anatomical reconnection of widely separated central nervous system (CNS) neurons was made possible by the interposition of long segments of peripheral nerve between the damaged fibers and their targets. In addition to determining if such experimental re-connectivity is functional or appropriate, it is also important to assess the extent to which unusual and inappropriate synapses can form between cells that do not normally connect with each other. If such aberrant contacts are a common feature of this type of regeneration, the experimental development of functional re-connectivity may well require the applica-

tion of strategies to prevent or eliminate such undesirable connections.

As an initial step in this direction of investigation, we will use peripheral nerve grafts to produce aberrant connections between selected groups of CNS neurons and also with skeletal muscle. Such studies are essential to the understanding of the freedoms and constraints that the injured adult CNS may impose on the connectivity of different groups of nerve cells when multi-functional fiber systems are stimulated to regrow.

Implications—The recovery of a predictably beneficial function after CNS injury will depend largely on the possibility that cellular mechanisms can be manipulated so that the formation of appropriate synapses can be stimulated and enforced while avoiding and eliminating incorrect contacts. With the development of the proposed system of clearly inappropriate synapses, it may then be feasible to use experimental manipulations to minimize the formation of such undesirable connections.

Immunocytochemical Analysis of Localized Extracellular Proteolysis During Neuronal Development

M.J. Anderson, Ph.D.

The University of Calgary, Department of Pharmacology and Therapeutics, Calgary, Alberta T2N 4N1, Canada

Sponsor: Paralyzed Veterans of America, Spinal Cord Research Foundation (NBR-665)

Purpose—Spinal cord injuries are more devastating than others because the central nervous system (CNS), unlike most parts of the body, fails to heal itself. This does not happen because there are no physiological repair processes in the nervous system; rather it is a result of a breakdown of these healing mechanisms in the CNS. In fact, the inability to repair injuries to the CNS is a hereditary problem we share with all mammals, but not with other "lower" animals. The CNS may ultimately be helped to repair itself, therefore, providing we can deter-

mine how the healing process has gone awry. However, this leads us to a more immediate problem: we still do not understand how nerve regeneration is controlled, and thus cannot determine what is wrong when it fails.

Our approach involves removing nerve cells from an embryo to place them in miniature aquaria, where we can observe their growth through a microscope. For these experiments we use embryonic cells from frogs and salamanders, because they develop much faster than those from humans. However, like hu-

man nerve cells, they also grow to their appropriate targets and interact with them to form synapses, the specialized cell contacts that allow electrical signals to flow within the nervous system. This kind of experimental system allows us to study the unknown signalling mechanisms which control nerve growth and development, and are likely to be similarly involved in human CNS regeneration.

Progress—In our current research we are studying the interesting possibility that growing nerve cells may chemically digest minute amounts of their surrounding environment, and then use the products of this digestion both to determine where they are, and to exchange signals with the cells they touch. This local digestion, occurring where growing nerves contact other structures or cells, may also release hormone-like substances that affect nearby cells,

causing them to regenerate the structures that were lost following injury. This kind of process could allow injured neurons to find their way back to their target cells, and then to rebuild their lost synapses, reestablishing the situation that existed before they were damaged.

Implications—If this hypothesis turns out to be correct, we may eventually be able to identify inappropriate chemical agents in the injured CNS that misdirect regenerating human nerves, and find ways to remove them. Alternatively, we may find that important chemical road-signs are missing in the injured human CNS, and be able to replace them. In either situation, it could become possible to assist the body's repair process, leading eventually to functional neuronal regeneration, the only really adequate treatment for spinal cord injury.

Regeneration of Spinal Projection Neurons in a Peripheral Nerve Environment

Mary Blair Clark, Ph.D.

University of Maryland School of Medicine, Department of Anatomy, Baltimore, MD 21201

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal 645)*

Purpose—This project addresses the problem of regeneration of the central nervous system's corticospinal neurons. Corticospinal neurons extend long axons from the cerebral cortex to the spinal cord. These neurons carry information from the brain to motor neurons in the spinal cord and thereby direct much of the motor activity of the body. It is not known if corticospinal neurons which extend axons from the cerebral cortex to the spinal cord are able to regenerate under any circumstances. This is critical information in attempting to experimentally influence repair after spinal cord injury. We will determine if components of the peripheral nerve which are known to promote survival and growth of some types of central neurons also support corticospinal neurons. We will use brain cell cultures to evaluate the trophic and neurite promoting contributions by cellular and extracellular matrix components of peripheral nerve. The specific objectives

are: 1) to obtain cultures of corticospinal neurons identified by retrograde labeling *in vivo*; 2) to compare the survival and neurite outgrowth requirements of corticospinal neurons to those for cerebral cortical interneurons; and 3) to determine the relative contributions by specific cellular components of peripheral nerve to such support.

Future Plans/Implications—After we have identified the cellular source(s) of trophic and neurite promoting factors for corticospinal neurons, the isolation and characterization of the factor(s) will be pursued in collaboration with Dr. T.L. Wallace, Baylor Center for Biotechnology, Baylor School of Medicine and transplantation studies will be done in collaboration with Dr. B. Bregman to evaluate the effectiveness of the cellular sources of the factor in promoting regeneration in spinal lesioned animals.

Rapid Neuronal and Glial Changes in the Spinal Cord Following Injury

Harry G. Goshgarian, Ph.D.

Wayne State University, School of Medicine, Detroit, MI 48201

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal #NFR-625)*

Purpose—The ultimate goal of all spinal cord injury research is to achieve functional restitution. Spinal cord regeneration research is directed toward establishing functional restitution by the growth of new axon pathways through the damaged regions of the spinal cord. Another approach to functional recovery after spinal cord injury would be to activate already existing, functionally latent axon pathways which survive spinal cord injury and are found in the non-damaged regions of the spinal cord. Recently, several examples of functionally latent pathways have been demonstrated, not only in the spinal cord, but in many other regions of the central nervous system as well. The pathways are latent because the synapses which connect them to neurons in the CNS initially are functionally ineffective in firing the postsynaptic cell. Within hours after injury, however, the functionally ineffective synapses are converted to ones which become capable of activating the postsynaptic target neuron. In many instances, the functional capabilities of the animal are markedly improved after synaptic conversion. Although the functional unmasking of ineffective synapses has been demonstrated physiologically in many regions of the CNS, the morphological basis for the synaptic conversion has not been discovered.

For years, the P.I. has associated functionally ineffective synapses with the expression of a respiratory reflex in spinal cord injured rats. In this model, the conversion of the ineffective synapses to effective ones results in the functional recovery of a portion of the animal's diaphragm which had been paralyzed by spinal cord injury. Through an extensive electron microscopic analysis of the phrenic nucleus (the location of neurons in the spinal cord which are responsible for diaphragm contraction) in normal and spinal cord injured rats, the P.I. has

discovered specific morphological alterations of the normal phrenic nucleus ultrastructure occurring within hours after injury which he hypothesizes are related to the conversion of functionally ineffective synapses. Such alterations have never before been shown to occur so rapidly after spinal cord injury. Current laboratory experiments are designed to substantiate the relationship of morphological findings to the physiological conversion of functionally ineffective synapses. This is being accomplished by using computer-aided morphometric analysis techniques to quantitate the observed morphological alterations and then comparing these data with earlier physiological results.

The goals of the research proposed are: 1) to begin to more clearly focus on the specific physiological conditions which induce the observed morphological alterations in the phrenic nucleus within hours after spinal cord injury in rats; and, 2) to determine if these morphological changes may not also be detected in other motor nuclei of the injured spinal cord. Horseradish peroxidase (HRP) will be used to label phrenic motor neurons or neurons innervating the hindlimb musculature at electron microscopic levels. A digitizing tablet will be used to feed several specific morphological characteristics of these labeled cells into a computer. The computer will demonstrate any significant differences in morphology among these cells after manipulation of the animals in the experimental groups.

Implications—When this work is complete it will provide important new information pertaining to the rapid changes that can occur in the spinal cord after injury and how these changes may be related to the functional recovery of paralyzed muscle.

The Effect of a GABA Agonist and a GABA Antagonist on Motor Recovery Following Subtotal Spinal Cord Lesions

Roger M. Harris, Ph.D. and James W. Little, M.D., Ph.D.

University of Washington, Department of Biological Structure, Seattle, WA 98195

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal 635)*

Purpose—Traumatic spinal cord injury in humans is often followed by some recovery of voluntary movement below the injury. In some individuals, the recovery allows return of motor function; in others, the recovery is minimal and movements are non-functional. Recent observations suggest that the inhibitory neurotransmitter gamma-aminobutyric acid (GABA) may either enhance or limit motor recovery within the spinal cord. This study will examine the effect of a GABA agonist and a GABA antagonist on motor recovery in an animal model of spinal cord injury.

Adult rats will undergo midthoracic three-quarter lesions of the spinal cord, sparing the left ventral funiculus. These rats will be assigned to one of three groups, each of which will receive a daily intraperitoneal injection for one month. Group 1 will receive Baclofen, a GABA agonist; Group 2 will receive Bicuculline, a GABA antagonist; and Group 3 will receive saline, as a control. The temporal course and final level of motor recovery will be observed over a 3-month period and will be used to detect

any improvements in motor recovery as a result of the drug injections.

After 3 months, these rats will be injected with horseradish peroxidase (HRP) within the left lumbar gray matter or thoracic ventral funiculus, in order to detect anatomical evidence for axonal sprouting as a mechanism for motor recovery. After 24 hours, the injected animals will be sacrificed and spinal cord sections processed histologically to visualize the anterograde transport of HRP into lumbar commissural axons and axon terminals. Comparison of this anterograde labeling with labeling from similar injections in nonlesioned rats will show whether axonal sprouting has occurred in the lesioned animals.

Implications—This study may lead to new treatment strategies which can promote recovery of motor function after spinal cord injury, as well as investigating the underlying mechanisms responsible for motor recovery.

Spinal Cord Synaptogenesis in Response to Deafferentation and Alterations in Nerve Growth Factor

Claire Elizabeth Hulsebosch, Ph.D.

University of Texas Medical Branch, Galveston, TX 77550

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation*

Purpose—Several types of spinal neural elements are damaged after spinal cord injury and this often results in a devastating loss of function. Thus, for appropriate return of function, several populations of nerve cells and fibers require reorganization. One important task toward gaining insight into procedures that results in spinal cord restitution is to understand precisely the capacity of axons to sprout in the spinal cord after denervation. Specific denervation procedures will be used, followed by quantitative analysis at the light and ultrastructural level to assess the sprouting response of synapses of primary afferents in the dorsal horn.

Another important task toward spinal cord restitution is to manipulate the sprouting response by factors which may be beneficial clinically. Nerve Growth Factor (NGF) is known to affect the growth and development of sensory and sympathetic neurons. Previous work in this laboratory demonstrates that sprouting of primary sensory neurons can be dramatically increased by manipulations of the levels of endogenous NGF. However, it is not known if these new sprouts make synaptic contacts in the neuropile of the dorsal horn. Specific projects will give insight into the amount of synaptic sprouting in two experimental situations: 1) surgically induced

denervation; and, 2) manipulation of endogenous levels of NGF. The procedures will be to quantitate the distribution of a stain specific for presynaptic terminals of unmyelinated primary afferent fibers (fluoride resistant acid phosphatase or FRAP) at the light and ultrastructural level.

Future Plans/Implications—These projects will pro-

vide a base for future studies which will combine stereologic techniques coupled with immunohistochemistry to assess not only the degree of presynaptic terminal distribution but the class of preterminal constituents (i.e., substance P, somatostatin, methionine-enkephalin, etc.) which responds to the paradigms.

A Study to Determine if Localized Extracellular Proteolysis is a Requirement for Successful Regeneration of Nervous Tissue _____

Nurit Kalderon

The Rockefeller University, New York, NY 10021

Sponsor: Paralyzed Veterans of America, Spinal Cord Research Foundation

Purpose—The working hypothesis of this project is that proteolytic activity is an essential process in achieving successful repair in a damaged nervous system. However, proteolytic activity, rather than general or random, must be a localized one. Namely, general injection of these enzymes can lead to an uncontrolled tissue destruction, whereas localized proteolysis, e.g., the plasmin-generating system, which is expressed by certain cells in a highly controlled manner, will remove only the unwanted tissue in the path of the growing regenerating axons.

Progress—The experimental design of this proposal was set to assess the validity of this hypothesis. Assuming that localized proteolysis is essential for regeneration, any treatment which will inhibit this activity, i.e., drugs or cells which produce protease inhibitors, should intervene and prevent the regenerating process. On the other hand, any other cell type which is known to produce this specific proteolytic activity, i.e., the immature astrocyte, Schwann cell, or tumor cell lines, should support neuronal regeneration when implanted in the injured tissue. In the same line of logic, removal of cellular components which presumably produce protease inhibitors, e.g., the glial scar, should facilitate the repair process. Two model systems of regenerating nervous tissues are being utilized: peripheral, i.e.,

sciatic nerve, and central, i.e., olfactory bulb with regeneration induced by various grafts into it.

Preliminary Results—Studies performed in the first year of the project followed the experimental strategy mentioned above, and two objectives were accomplished: it was shown that astrocytes which are deficient in extracellular proteolytic activity impair the regeneration process, and some experimental conditions were identified for the prevention of glial scar formation at the site of injury. This selective cell elimination was achieved by the cancer therapeutic procedure of irradiation of the injured tissue.

Future Plans/Implications—Future studies are focused on identifying the conditions under which, on the one hand, glial scar formation will be prevented and, on the other hand, the damaged tissue will regain functional activity. If the goal of this project is obtained and the working hypothesis is verified, novel avenues will be opened for research into possible therapeutic procedures to induce repair/recovery in any injured nervous system. One of these could be the development of a device which will apply these proteolytic enzymes of the plasmin-generating system in a localized manner at the locus of injury.

Modulation of Protein Phosphorylation in a Regenerating Central Nervous System (CNS) Tract

Denis C. Larrivee, Ph.D. and Bernice Grafstein, Ph.D.

Department of Physiology, Cornell University Medical College, New York, NY 10021

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation*

Purpose—The axon is the branch of a nerve cell that enables it to communicate with other nerve cells. When the axon is injured, the part that is separated from the cell body degenerates and the nerve cell can no longer communicate with its neighbors. To reestablish communication, the axon must be reconstituted and the former target cells recontacted. In the mammalian central nervous system, injury to the axon fails to elicit a regenerative response, whereas axons in the central nervous system of lower vertebrates are successfully reconstituted and their target cells appropriately selected. Many of the cellular changes associated with reconstitution of the axon and its terminal connections have been well characterized in a number of such regenerating systems, but the manner in which the cell regulates the production of materials required for reconstitution of the axons and their terminal connections is poorly understood at the molecular level. It would be of great interest, therefore, to determine the salient features pertaining to molecular regulation of the regenerative process in these cells, so as to have a firm basis on which therapeutic measures could be explored in non-regenerating mammalian neurons.

One of the primary mechanisms for regulation of metabolic changes in neurons is protein phosphorylation (Browning et al., 1985; Nestler et al., 1984). When a protein kinase transfers the terminal phosphate from ATP to a substrate protein, the change in conformation induced in the protein results in a change in its function. This mechanism is important, for example, in the operation of known second messengers such as cAMP or calcium through the

activation of specific protein kinases.

Progress—In the previous grant period, we identified a number of phosphoproteins in the optic nerve of the goldfish, which undergoes particularly vigorous regeneration after injury. Many of these proteins were shown to be axonal proteins and to change their level of phosphorylation during regeneration. The changes in phosphorylation were largely independent of protein synthesis and were associated with particular stages of regeneration. These phosphoproteins may therefore be important targets of post-synthetic regulatory mechanisms that become operative during particular phases of optic nerve regeneration. In the proposed experiments we intend to continue our examination of these proteins to define more clearly their role in regeneration. Our particular purpose will be to determine the molecular mechanisms which contribute to changes in the phosphorylation of these proteins since this will enable us to understand how the cell can regulate their phosphorylation and presumably their function.

Future Plans/Implications—In the long term we hope to be able to find ways in which phosphorylation of these proteins can be modulated selectively. By doing so, it may become possible to promote one or another stage in the regenerative process. Should similar mechanisms exist in mammalian neurons, we hope to be able to manipulate such mechanisms in these cells and so promote regeneration in the injured mammalian central nervous system.

Dorsal Root Axonal Regeneration in Adult Glial Deficient Mammalian Spinal Cord

Francis J. Liuzzi, Ph.D.

Bio-Architectonics Center, School of Medicine, Case Western Reserve University, Cleveland, OH 44106

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal NFR-654)*

Purpose—The dorsal roots of the spinal cord are the routes by which information from the skin, muscles,

joints, and viscera reach the central nervous system. This information is essential for spinal reflexes,

somatic and visceral, as well as for the conscious perception of the world around us. The avulsion of dorsal roots, either by injury to the roots themselves, or in concert with spinal cord injury, has grave consequences to the victim. Injury to the dorsal roots that supply the brachial plexus can render the arm a useless appendage devoid of any sensations including touch, pain, and position awareness. More seriously, damage to the dorsal roots of the sacral cord can disrupt vital visceral reflexes that are particularly important in bladder and bowel, as well as sexual function.

For the past 4 years, the P.I. has been studying dorsal root axonal regeneration in the adult frog and in the adult rat spinal cords using horseradish peroxidase (HRP) to specifically label regenerating axons for light and electron microscopic analysis. The regenerative capacity of dorsal root axons had already been well documented in the early part of this century. This work, and that of others, has shown that when the dorsal root is injured, cut or crushed, in either the amphibian or the mammal, the degenerative and regenerative responses in the peripheral portion of the root are exactly the same as those of any peripheral nerve.

However, at the dorsal root transitional zone, the region in which the peripheral nerve environment of the root is contiguous with the central nervous system environment of the spinal cord, there is a dramatic difference between amphibian and mammalian dorsal root axonal regeneration. In the frog, a large percentage of regenerating dorsal root axons

penetrate this region, grow into the cord and restore, in part, the segmental innervation of the gray matter. By contrast, in the mammal, the majority of regenerating dorsal root axons either stop or turn to grow back out into the root. It appears that, in the mammal, astrocytes in this region act in some way to prevent the penetration of regenerating axons into the spinal cord. Although there have been many reasonable hypotheses advanced to explain this enigma, the exact mechanisms by which these astrocytes prohibit dorsal root axonal reinnervation of the spinal cord remains unknown.

Implications—A number of laboratories, including our own, are examining the role of the transitional zone astrocytes in abortive dorsal root axonal regeneration. This work is of the utmost importance in the field of regeneration because it is directed at basic questions about the role of astrocytes in preventing axonal regeneration in the adult nervous system. The impediment of axonal regeneration by the astrocytes of the dorsal root transitional zone are, however, only one aspect of the broader question of axonal regeneration in the adult mammalian spinal cord. Of equal importance are the questions of whether, if the axons were able to gain access to the cord, the environment of the adult mammalian spinal cord is capable of supporting dorsal root axonal regeneration, and, if so, whether the regenerating axons are able to recognize and appropriately reinnervate their targets in the spinal gray matter.

Action and Metabolism of TRH in the Spinal Cord (TBR-463)

Chandan Prasad, Ph.D.

Louisiana State University Medical Center, Section of Endocrinology, Department of Medicine, New Orleans, LA 70112

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation*

Purpose—TRH ameliorates neurologic consequences of spinal cord injury in cats, suggesting its potential application in man. However, rapid *in vivo* inactivation of exogenous TRH presents a serious obstacle in its effective clinical use. Over the past few years, our laboratory has been actively seeking ways to overcome the above problem. Results of our recent studies, funded by PVA-SCRF, have shown that certain TRH analogues can raise the level of endogenous TRH presumably by inhibiting

its metabolism. We propose to extend the above observation to explore the conditions under which maximal elevation in TRH content can be achieved. In addition, the nature and extent of chemical changes in the spinal cord following TRH elevation will be determined. The chemical parameter selected for investigation will be those that are associated, directly or indirectly, with the process of tissue damage and recovery.

Future Plans—The ultimate goal of our study is to investigate recovery from acute experimental spinal

cord injury using TRH and its analogues that elevate the levels of endogenous TRH in the spinal cord.

International Symposium on Neural Regeneration

Fredrick J. Seil, M.D.

Office of Regeneration Research Programs, Veterans Administration Medical Center, Portland, OR 97201

Sponsor: *Paralyzed Veterans of America, Spinal Cord Research Foundation (Proposal NCR-666)*

Purpose—The purpose of this symposium is to: 1) present current information on research in neural regeneration by some of the world's leading investigators in specific research areas; 2) foster interchange among scientists about research information in an informal as well as a formal setting; 3) provide an opportunity for students and postdoctoral fellows to exchange ideas with senior scientists; and 4) disseminate the information provided by the symposium in the form of a publication of the proceedings. This will be accomplished by holding the symposium at the Asilomar Conference Center, a beachside conference facility run by the State of California, inviting leading researchers to present their work and supporting their travel and per diem expenses, organizing the conference with sufficient free time between formal sessions to allow relaxed interchange, and requiring most of the speakers to write a chapter for the proceedings book as part of their agreement to accept the invitation to partici-

pate. There will also be free communications from registrants at large in the form of posters.

The problem being addressed is the exchange of current information among neural regeneration research scientists and the dissemination of that information to the larger scientific community. The goal is to gather leading neural regeneration research investigators from around the world into one pleasant, quiet place and promote the exchange of information and cross-fertilization of ideas in both formal (scheduled presentations) and informal (free time) formats, and to convey the enthusiasm for this kind of research to students and postdoctoral fellows in attendance. This enthusiasm can be conveyed to a larger audience, both professional and nonprofessional, in the form of a proceedings publication and in lay summaries of the sessions that can be included in the *VA Regeneration Research Newsletter* and *PVA Paraplegia News*.

D. Rehabilitation

Hybrid Upper Extremity Orthoses for C5-7 SCI Patients

Nisim Benjuya, Ph.D., and Steven B. Kenney, BSME

Clinical Bioengineering Lab, Veterans Administration Medical Center, West Roxbury, MA 02132

Sponsor: *VA Rehabilitation Research and Development Service*

Purpose—To enable the upper extremity to function independently in spinal cord injury (SCI) patients at the C5-7 levels. The secondary goal is to restore range-of-motion including index-thumb opposition for the purpose of rehabilitation of patients with intrinsic and extrinsic motor dysfunction in the hand. The functions of the orthoses under development will offer pinch grip, lower arm supination/pronation, elbow flexion/extension and shoulder abduc-

tion/adduction. The engineering efforts are concentrated on simplicity, lightness and cosmesis of the device. Electromyography (EMG) from existing muscles, mixed with movements of accessible limbs are used as driving signal sources for our hybrid orthoses.

Progress—For the past year an ongoing effort has been made in developing an "ideal" orthosis system

for the hand. The orthosis contains a hand shell and finger guide, both made of light and rigid material. The unit consists of a 6-volt DC gearmotor located in the palm with a gear train assembly transferring the motor torque to the finger guide. The control system consists of a pair of dry EMG surface electrodes operating as on/off switches and current feedback controlled four channel push/pull driver. The driver sets the hold position to the motor at pre-selected grip forces varying between 1-3 lbs. The whole system is powered by a re-chargeable 6V battery encapsulated in a durable case. The case and circuitry are attached to the body of the user. We are at the stage where the hand orthosis is

undergoing clinical evaluation and testing.

Future Plans/Implications—In the coming year we will develop the elbow and shoulder system. These orthoses should enable the user to function in various daily living activities such as eating, shaving, etc. with minimum effort. The hand system will use a motor controlled by a 3-state proportional EMG detection and a strain gauge-based electrocutaneous pinch force feedback delivered to the patient via a surface electrode. Some other foreseen benefits of the hand orthosis are augmentation of upper extremity strength and coordination through a vigorous post-operative therapy regimen.

Treatment of Physiological Impotence

Inder Perakash, M.D.

Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service (Project #XB299-2RA)

Purpose—This is an interdisciplinary effort directed primarily at assisting several aspects of the sexual rehabilitation of paraplegic patients, and as such involves experts in urology, physiology, biomedical engineering, and rehabilitation medicine. Our research with 46 patients (96 studies) has further sophisticated the technique of rectal probe electrostimulation (RPE) to induce semen collection.

The technique of rectal probe electrostimulation (RPE) has been brought from a stage of trial development of instrumentation to clinical use as a miniaturized, fail-safe device operable by trained health professionals. This unit utilized an isolation transformer with 140 decibels of common-mode rejection, new semi-conductor technology to allow constant current stimulation, and plug-in modular construction. A battery-operated device is also being made available. The equipment is now ready for both clinical evaluation (of erections and emissions, depending upon existing patient sensorium and testicular function), and subsequent treatment or therapy (for physiological impotence or ejaculatory incom-

petence). A comprehensive evaluation, including sexual history, semen gonadotropin (FSH, LH, PRL) and steroid (estradiol, testosterone) hormones, microscopic (TEM, LM) evaluation of testicular biopsy (when applicable), and uroneurologic evaluation will accompany RPE in patient assessment. Equipment modifications and further animal experimentation will be done at Emory.

Goals for year 3 include: 1) identification of 10 additional paraplegic patients as candidates for home-based RPE; 2) clinical evaluation of these patients with initial education in the use of RPE in the home setting; 3) evaluation of success of year 3 paraplegic patients with RPE to produce erections and emissions in the hospital-based "home setting;" 4) introduction of year 3 paraplegic patients to RPE in their home setting; 5) extension of RPE to 5 additional quadriplegic patients, with management of autonomic dysreflexia based upon information obtained by work with year 3 patients; and, 6) continued Foley catheter modifications and semen treatment to improve motility.

Interactive Videodisk Training for Self-Care Skills

John Trimble, Ph.D.; Bernard Nemchausky, M.D.; Mark Ozer, M.D.

Spinal Cord Injury Service, Veterans Administration Medical Center, Hines, IL 60141 and Spinal Cord Injury Service, Veterans Administration Medical Center, Richmond, VA 23249

Sponsor: *VA Rehabilitation Research and Development Service*

Purpose—Rehabilitation training is frequently ineffective. The reasons for this are complex and range from people's unwillingness to learn more about their disability to health care professionals who do not have enough time to devote to teaching. The result of ineffective rehabilitation training is rehospitalization which is not only costly but also has a profound effect on the disabled person's quality of life.

There are ways to make rehabilitation training programs more effective. However, these are either marginally successful or costly. Some institutions have tried using videotapes, publications or pamphlets, but there is no evidence that these improve the quality of the training program. Other institutions have attempted to increase the number of personnel involved in rehabilitation training. However, this requires hiring additional personnel or relieving health care staff from their regular duties to give them more time to adequately train patients. As yet, there is no generally acceptable way of improving the quality of rehabilitation education.

We hypothesize that interactive videodisk training, used as an adjunct to traditional methods of rehabilitation education, will enhance the quality and effectiveness of the program. Interactive videodisk training has been used for several years in industry. Although the effectiveness of these applications has not been quantitatively determined, it is agreed that they have increased the effectiveness of training programs.

The few studies done on these applications suggest that the increased effectiveness is directly related to the medium. Like computer-assisted instructional programs, interactive videodisk training gives stu-

dents the opportunity to learn at their own pace. However, unlike computer-assisted instructional programs, interactive videodisk training lets students view highly complex visual material. This feature is especially important when learning skills that are predominantly visual or best learned through visualization. This advantage leads us to study the potential of interactive videodisk training as an adjunct to traditional rehabilitation education programs.

Progress—We have created an interactive videodisk training program on skin care using a videotape developed by the Spinal Cord Injury Service of the Richmond VA Medical Center. We have also developed a stand-alone interactive videodisk training system using commercially available components. Additionally, we have developed software that allows educators with little knowledge of computers to easily develop interactive videodisk training programs. We are presently examining patients' reactions to the new system, and determining the ease with which educators can develop their own interactive videodisk training programs.

Future Plans/Implications—Once we have evaluated the system on a small scale, we will create additional systems and evaluate them on a larger scale with a diverse subject population. We will also develop additional materials for training in wheelchair transfers, genito-urinary care, and bladder and bowel care. We also intend to develop software to analyze the tasks involved in these skills to produce an "expert system" for creating the outlines for interactive videodisk training programs.

Interactive Videodisk Training for Self-Care Skills (Project Extension)

John Trimble, Ph.D., and Bernard Nemchausky, M.D.

Veterans Administration Medical Center, Hines, IL 60141 and Loyola University Stritch School of Medicine, Chicago, IL 60626

Sponsor: VA Rehabilitation Research and Development Service (Project #XB451-R)

Purpose—Instruction in self-care skills is an essential component of the rehabilitation of persons with spinal cord injuries. The importance of this component is evidenced by the fact that between one-third and one-half of spinal cord injured persons are rehospitalized in any given follow-up year. The average annual cost for each rehospitalization can range from \$6,700, if surgery is not required, to \$20,000, if surgery is required. Self-care skills can reduce the incidence of rehospitalization due to preventable complications, hasten progress toward adaptation to the disability, and provide for greater personal independence.

Traditional methods of health-care education such as personalized instruction by a health-care professional, self-instruction from written or audiovisual materials, participation in learning groups, or interaction with other disabled persons are often ineffective. Factors such as the person's psychosocial, economic or educational status; the extent of involvement by health-care professionals; and, the instructional material or methods can all influence an educational program's outcome. Although some of these factors can be controlled and improved, others can not. Accordingly, health-care institutions are faced with the difficult problem of teaching valuable skills to people with diverse socioeconomic backgrounds, attitudes and skills, using staff who may have little time to teach them.

We believe that this problem may be resolved by augmenting traditional education programs with interactive learning technology. Technologies such as computer-assisted instruction (CAI) or interactive-videodisk instruction (IVI) have several advantages as adjuncts to traditional educational methods. People with diverse socioeconomic and educational backgrounds can learn at their own pace. The

novelty of interacting with a computer may provide motivation for learning. CAI or IVI may also be more effective than personalized instruction for teaching difficult or emotion-laden subjects, since they are impersonal and nonthreatening. Interactive learning technologies also free staff to give personalized instruction to people who need it.

Our project will examine the effectiveness of interactive videodisk instruction as a supplement to two traditional rehabilitation education programs. We will develop interactive videodisk material for instructing spinal cord injury persons on self-care techniques for skin care, genitourinary care, wheelchair transfers, and assertiveness. We will also develop and test instruments for evaluating the effectiveness of interactive education in terms of instruction (extent and recency of instruction), cognition (aggregate knowledge of self-care skills), and performance (current practice of self-care skills). We will determine the usefulness of interactive videodisk instruction by comparing the index scores of people who have received traditional instruction and people who have received a combination of traditional and interactive videodisk instruction. We will also develop authoring software that represents a considerable improvement over existing software so that the results of our study may be widely disseminated. The software will allow users to easily develop interactive learning sequences that incorporate motion video, overlay graphics, and questions.

We believe that our study could help spinal cord injured persons achieve greater independence by improving the instruction that they receive to learn the knowledge and skills that they need to lead productive and independent lives.

Man-Machine Interface for Upper Limb Neural Prostheses

William K. Durfee, Ph.D.

Massachusetts Institute of Technology, Department of Mechanical Engineering, Cambridge, MA 02139

Sponsor: *National Institute on Disability and Rehabilitation Research*

Purpose—The goal of this project is to improve the functional capability of quadriplegics outfitted with neural prosthesis to return grasp. To achieve this goal we are developing an experimental model to study the man/machine interface between a quadriplegic and an upper limb neural prosthesis. Our plan is to instrument able-bodied and spinal cord injured (SCI) human subjects who will perform simulated tasks by manipulating animated limbs appearing on a graphics display. This will enable us to isolate the command input system of a neural prosthesis from all other extraneous factors such as electrode shift and stimulated muscle fatigue. Using this experimental model, we hope to quantify the ability of subjects to manipulate specific command channels to drive neural prostheses, and identify command channels for particular subjects.

Progress—We have developed a set of graphics routines for an Amiga personal computer which display an animated hand that can translate, rotate,

and open and close under control of external signals. Our first tests will investigate shoulder motion as an input command channel while subjects perform simulated tasks of grasping, moving, and coordinated motion, between two hands. Most C5 and C6 quadriplegics still retain some shoulder motion and several research groups developing neural prostheses for return of grasp use shoulder motion for an input channel. There is a need, however, to quantify the information content in shoulder motion, particularly when both left and right upper limbs are involved as would be the case for bilateral neural prostheses.

Publications Resulting from This Research

Command Channels for Upper Limb Neural Prostheses. Durfee WK, Mariano T, *Proceedings of the 10th Annual Conference on Rehabilitation Technology*, RESNA, San Jose, CA, June 1987.

Determining the Range of Motion and Principal Directions of the Shoulder for Studying Static Shoulder Control with Hand Tracking. Rodriguez SD, *MIT BSME Thesis*, June, 1987.

Artificial Sensory Transducers

M.R. Neuman, Ph.D., M.D.; H. Chizeck, Sc.D.; P.E. Crago, Ph.D.; P.H. Peckham, Ph.D.; R. Riso, Ph.D.
Cleveland Metropolitan General Hospital and Case Western Reserve University, Cleveland, OH 44109

Sponsor: *Neural Prosthesis Program of the National Institute of Neurological and Communicative Disorders and Stroke*

Purpose—Sensors for measuring forces at the thumb or finger pads are being developed and evaluated along with sensors for determining thumb or finger positions through measurement of joint angles.

Progress—Prototype sixty-four element variable capacitance force sensor arrays have been constructed using thin and thick film technology. Each 2 mm square element is separated from its neighbor by 0.5 mm in the 8 x 8 array. Thin film chrome-gold capacitor plates are deposited upon 75 micron thick polyimide substrates. A specially developed silicone elastomer dielectric film is deposited between the plates using thick film screen printing techniques. A hybrid microelectronic circuit to provide isolation

and active shielding has been developed but not yet assembled on the sensor itself. Multiplexors within this circuit allow elements of the array to be addressed individually.

The sensor is operated under the control of a microcomputer that scans the array, linearizes the hyperbolic characteristic of each element and provides an array and graphic representation of the output from each element. Software to minimize cross talk between adjacent elements and to perform elementary edge and shape recognition is under development.

Joint position sensors based upon thin gold film strain gauges on a flexible substrate are also under development. Preliminary film structures measuring

9 x 30 mm or 4 x 20 mm on 75 micron thick polyimide substrates have been fabricated and are being evaluated. Fabric straps allow the smaller gauges to be placed on the dorsal side of a finger. The gauge is affixed to one strap on the proximal side of an interphalangeal joint. The strain gauge structure is able to slide within the second clamp on the distal side of the joint as the joint is flexed. This structure has been designed to give a change in resistance that is dependent only upon the joint angle.

Results—The output voltage as a function of applied force has been studied for each element of the force sensor. Typical sensor characteristics are: element capacitance, 6 ± 1 pF; mean sensitivity, at 0 N is 287 mV/N and at 4 N is 91 mV/N; mean cross talk, 5.13 percent; and refresh time, 0.64 s. The sensors were found to have high temperature coefficients due to the silicone elastomer dielectric. Joint position sensors were studied over angles of 0-100 degrees. Radii of curvature were varied from 5 to

15 mm. Nominal resistance for the gauges was 100 ohms and the characteristics were found to be linear. Mean sensitivities were found to be 1.31 percent/degrees at a radius of curvature of 15 mm and 1.54 percent/degrees at a radius of curvature of 5 mm. Single strain gauges had a high temperature coefficient but this could be compensated using gold film patterns in adjacent arms of the bridge circuit.

Future Plans—Both the force and position sensors are early in their development. Further *in vitro* studies are necessary before the devices can be used on human subjects. The force sensor needs to be temperature-compensated and packaged. The electronic circuitry needs to be placed on the sensor itself and incorporated into the package, and software needs to be refined for obtaining total force and its distribution. The work on developing joint angle sensor structures for placement on human fingers needs to be completed and evaluated *in vitro* and *in vivo*.

Vocational Evaluation for Quadriplegics with a High School Education or Less

W. Alfred, M.A.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research

Purpose—The project objective is to develop a vocational evaluation process that will expand the vocational options for spinal cord injured persons who are quadriplegic, who have a high school education or less, and who have either a limited work record or a job history incompatible with current functional limitations. Methodology involves: 1) identifying and documenting jobs that can be performed by the described population group; 2) conducting a comprehensive review of existing vocational assessment tools and determining relevance of the tools to assess the potential of quadriplegics; 3) selecting and organizing a meaningful process; 4) incorporating the model vocational process into the Vocational Department's service delivery program; and, 5) evaluating the effectiveness of the model evaluation process.

The expected outcome of this project is the establishment of a more effective and realistic vocational evaluation process that can be used to

assess the job potential of quadriplegics. The project may also have implications for other disability groups with severe physical impairments.

Progress—The developmental phase of the project has been completed. Of 12,278 jobs listed in the Directory of Occupational Titles, 497 were judged by the project staff to be options for quadriplegics with a high school education or less. Labor market surveys were conducted to identify the occupational outlook among these jobs. Findings indicated that jobs in clerical and sales occupations were the largest in demand. The outlook for jobs in machine trades and benchwork occupations was discouraging.

A total of 334 vocational assessment tools were reviewed, and 105 of these tools were determined by the project staff to be within the physical capabilities to be performed by persons with quadriplegia.

Results—The project staff has matched those assessment tools that appear to measure the duties of those jobs that have the best occupational outlook for the future. This has resulted in a vocational evaluation process that includes psychometric testing, work sample testing, simple work modifications, training in compensatory techniques, and limited situational assessment.

Development of a Reconditioning Exercise Program for Patients with Paraplegia

David Cardus, M.D.; W.G. McTaggart, B.S.; F. Ribas-Cardus, M.S.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research

Purpose—The overall purpose of this project is to develop a testing methodology and to evaluate an exercise training program for the physical reconditioning of the patient with paraplegia. The expected outcome is the formulation of guidelines for the prescription of exercise and the documentation of the effects of physical conditioning programs for the patient with paraplegia. Male paraplegics between 18 and 50 years of age, free from disorders which contraindicate relatively high levels of exercise, and who have reached a suitable status in their rehabilitation process, will be selected for participation in the project.

Each participant will be initially administered an exercise stress test consisting of interviews, blood sample for biochemical analyses, resting ECG, physical exam, and a graded arm ergometry test using an interrupted steady-state protocol. Expired gas will be collected during the last minute of each exercise phase. The training program modalities will consist of prescribed unsupervised exercise at home or exercises in a gamefield especially designed for wheelchair patients. Other patients will perform prescribed exercise under supervision in the laboratory or gamefield. Initially, the exercise period is for 5 to 10 minutes, increasing to 20 to 25 minutes with training. Training will be three to five days per

Future Plans/Implications—Currently, 20 subjects with quadriplegia are being sought to participate in the vocational evaluation process in order to gauge its effectiveness. In addition, a panel of rehabilitation professionals is assessing the usefulness of the results obtained from vocational evaluation.

week for 10 to 12 weeks. After training, the patient will be subjected to a post-training study in which the testing of the first study will be repeated.

Progress—Four arm exercise training ergometers have now been purchased and are being presently utilized in prescribed home training programs. One patient has procured his own trainer and is following a prescribed exercise program at home.

The assessment of the cardiovascular tolerance to physical work with arm exercise has been extended to 33 untrained paraplegic males, some more than one time for a total of 47 tests. In addition, 16 healthy males have been tested in the same manner, a total of 31 tests, for obtaining comparative data. Nine of the paraplegic males and eleven of the healthy males have been tested in the gamefield for evaluation of energy requirements for specific athletic events. To date, eight paraplegic males have been placed on prescribed training at home. Three patients on home programs initially had exercise training in this laboratory with extension of the program at home. Healthy subjects have been tested in the laboratory using leg and arm exercise protocols for comparing the mechanical efficiency of different muscle groups.

Longitudinal Assessment of the Utilization of Upper Extremity Assistive Devices Prescribed for the Spinal Cord Injured Quadriplegic

Susan Garber, M.A., O.T.R. and Theresa Gregorio, O.T.R.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research

Purpose—Upper extremity assistive devices are frequently prescribed during the rehabilitation of spinal cord injured (SCI) quadriplegics. However, though these devices are used daily during hospitalization, they may be discarded once the individual leaves the hospital environment. The primary objectives of this study are to: 1) identify functional categories of assistive devices prescribed for quadriplegics; 2) determine utilization and satisfaction with those devices one year and two years following rehabilitation; and 3) determine factors responsible for discarding devices.

This is a longitudinal prospective investigation in two parts. Phase I of this study is a review of 102 quadriplegics to determine functional categories and frequency of prescription of upper extremity assistive devices. Phase II employs an oral questionnaire of 75 patients to ascertain utilization of, and satisfaction with, devices prescribed during a first rehabilitation experience. This questionnaire is administered one and two years following discharge.

Satisfaction is determined using a Likert scale. It addresses the device characteristics of fit, cosmesis, mechanical, and functional performance. Factors that result in discarding a device include improved physical function, mechanical failure, alternative solutions, modification of living arrangements, non-compliance, and device outgrown or unattractive.

Progress—To establish the functional categories and frequency of prescription of upper extremity assistive devices, 102 charts of quadriplegic patients were reviewed. Feeding devices were prescribed to 49 percent of patients, splints and slings to 87 percent, dressings to 30 percent, hygiene/grooming to 22 percent, and communication devices to 20 percent. An oral questionnaire developed to determine device utilization and level of satisfaction was administered to 77 former patients one year following their first rehabilitation experience. For these patients, 262 devices had been prescribed. Sixty-seven devices were for feeding. One hundred and

sixteen patients received splints and slings; 18 received dressings; 19, hygiene/grooming; 17, communication; and 8, miscellaneous. At the end of one year, 151 devices (58 percent) were still in use (36, feeding; 75, splints and slings; 7, dressings; 8, hygiene/grooming devices; 17, communication devices; and 8, miscellaneous). On a scale of 1-5 (5 being the most satisfactory), those devices still in use were rated an average of 4.24. The most frequently cited reasons for discarding devices were improved physical function and alternative solutions found. Discarded devices represented a cost of \$5400 or 35 percent of the total expenditure for all devices.

Of the original population, 55 were queried two years post-rehabilitation. Of the devices prescribed during their first rehabilitation experience, 69 percent were still in use two years later, with an overall level of satisfaction of 4.35 with retained devices. Of the remaining 22 subjects from the original population, 20 could not be reached by mail or telephone, one was too disoriented to respond, and one had expired.

The overall costs of devices prescribed for subjects during their hospitalization were \$17,831. The costs of devices discarded during the first year following rehabilitation were \$5,860 or 32 percent of the total expenditure. The costs of devices discarded during the second year were \$2,877 or 31 percent of the total cost of devices in use.

Preliminary Results—The results of this study already have influenced some of the prescription practices within the occupational therapy department. Therapists consider less expensive short-term devices rather than ordering the most expensive models of the same item. Furthermore, the Occupational Therapy staff is relying more on department-owned equipment from which patients may be weaned prior to discharge. Data on specific devices are being scrutinized to establish practical guidelines for their continued prescription.

Future Plans/Implications—An addendum to the original proposal has been written, the purpose of which is to collect data on a device only recently introduced to the population of persons with quadriplegia. This device is a passive stabilizer of assistive devices as opposed to the reciprocal orthosis (wrist-driven flexor hinge) which requires active wrist extension to achieve fine prehension. This

study will have both financial and professional implications. These include relative costs of the two devices and custom versus ready-made fabrication. The investigators will address the issues of utilization and satisfaction with the newer device using the same methodology employed in the original project.

Longitudinal Assessment of Physical Therapy Factors in the Rehabilitation Process That Affect the Quality of Life of Persons with Spinal Cord Injury

L. Don Lehmkuhl, Ph.D.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research

Purpose—The primary objectives of this study are to: 1) determine the importance of the patient's compliance in performing weight-shifts in a wheelchair to prevent breakdown of skin in weight-bearing areas of the body; 2) improve the criteria and procedures for selecting which spinal cord injured patients should be braced and trained to become functional ambulators; and 3) determine the incidence, characteristics, and outcome of pain complaints in patients with severe spinal cord injury.

Progress—Reduction in the original level of funding necessitated reduction in the scope of the project being undertaken. Considering the resources and expertise available, we elected to defer action on objective 1 and concentrate on objectives 2 and 3. As we complete work on objectives 2 and 3, we will redirect staff effort to pursue objective 1. Patients being studied are individuals who have received severe injuries to their spinal cord resulting in paraplegia or quadriplegia.

A total of 70 patients between the ages of 20 and 58 years with paraplegia have been studied in pursuing objective 2. A list of patient attributes and equipment and services associated with the gait training program was compiled for each patient. Follow-up evaluations, six months to several years after bracing, are being made to assess brace utilization. We expect the results to improve the criteria for selection of those who will remain users of braces.

A total of 135 patients between the ages of 11 and

80 years (74 with quadriplegia and 61 with paraplegia) are being studied in pursuing objective 3. Information on pain status, method of treatment, and reported success of treatment is gathered on a weekly basis until time of discharge. We expect the results to illustrate trends in etiology and resolution of pain complaints. An additional 35 patients are participating in a prospective study of the effectiveness of specific therapeutic interventions in relieving specific types of pain complaints.

Preliminary Results—Thus far we have: 1) analyzed the results of brace utilization by 70 patients who received bilateral knee-ankle-foot orthotic devices and drafted a report of the findings; 2) begun pilot studies with an orthotist to devise a simplified, modular lightweight orthotic device for early bracing and gait training; 3) gathered and categorized data concerning the pain complaints made by 135 patients with spinal cord injury during their initial hospitalization for comprehensive rehabilitation; 4) examined correlations between population variables, etiology of injury, level and neurological completeness of injury, and location and suspected etiology of pain complaint; 5) documented the status of each pain complaint at the time of discharge; 6) identified therapeutic procedures that patients reported as most effective in alleviating individual pain states; and 7) initiated a prospective study (N presently = 35) designed to test the relative effectiveness of specific therapeutic interventions in alleviating particular types of pain.

Future Plans/Implications—We are preparing final reports of the results obtained from pursuing objectives 2 and 3. Articles describing our findings are

being prepared for submission to *Physical Therapy* and the *Journal of the American Physical Therapy Association*.

Documenting and Utilizing Programs Which Provide Community Adjustment and Independent Living Services for Persons with Spinal Cord Injury _____

Margaret A. Nosek, Ph.D

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: *Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research*

Purpose—The purpose of this project is to collect and maintain information about independent living and community adjustment programs that serve spinal cord injured people, to provide an effective means of communicating new ideas and experiences between individuals operating these programs, and to provide access to a dependable source of technical assistance related to these programs.

Progress—Nonexperimental survey methodology is being used. The data from earlier administrations of this survey were summarized in frequencies according to specified categories of interest, and some correlational studies were done to determine trends in independent living program development. Data from project surveys was used to assess the types of services being provided for persons with spinal cord injury, and the source and amount of funds being utilized. The survey instrument has been revised, expanded, and pilot-tested. It will be readministered to all identified independent living programs. Data will be analyzed using univariate and multivariate techniques and will be compared to earlier findings.

In order to facilitate use of the information which is developed, the project maintains a computerized bulletin board, a telephone communication network with all the extant independent living programs, and a mailing list of approximately 2000 additional individuals and organizations. Knowledge transfer strategies depend on the specific topic or sets of information, but they usually involve extensive reviews of existing literature, interviews with independent living program administrators, staff members, consumers, and supplementary reviews by additional experts both in and out of the independent living field.

Preliminary Results—The 1986 administration of the survey yielded a 70 percent response rate (166 programs) with 51 percent (54 programs) providing complete data. All data have been entered into the ILRU National DataBase on Independent Living Programs. Extensive analysis is being conducted to examine a broad array of variables related to the delivery of independent living services to persons with spinal cord injury. Preliminary results indicate that persons with spinal cord injury are served by 80 percent of independent living programs, an increase of one percent from 1984. Of programs meeting the criteria for independent living centers, 95 percent report serving this population. Further investigation into the significance of the "center" model is being conducted.

Future Plans/Implications—In addition to data runs and reports in response to specific inquiries, there have been many products from this study to date. Two major presentations and two poster sessions on the preliminary results have been given at four national conferences to date. The Directory of Independent Living Programs has been updated and reissued five times in the past year. The new Registry of Independent Living Programs is near completion, and will go to press in early July. By the end of the year, a third major publication will be completed, analyzing the longitudinal database in relation to services to persons with spinal cord injuries and discussing policy implications of the findings.

The ILRU project is continuing its training, networking, and information dissemination activities in the area of independent living and maintains an ongoing effort to update its databases.

Assessment, Development and Clinical Applications of Strategies to Coordinate Services for Spinal Cord Injured Clients After Discharge

D. Rintala, Ph.D.; J. Alexander, Ph.D.; E. Willems, Ph.D.

Baylor College of Medicine and The Institute for Rehabilitation and Research, Houston, TX 77030

Sponsor: *Rehabilitation Research and Training Center on Spinal Cord Dysfunction; National Institute on Disability and Rehabilitation Research*

Purpose—There are three major project objectives: 1) assess current strategies employed after discharge, to achieve psychosocial adjustment and productive lives for spinal cord injured (SCI) persons; 2) develop and test new strategies or refine current strategies to enhance outcomes postdischarge; and 3) facilitate the integration of new and tested strategies into the service delivery system at The Institute for Rehabilitation and Research (TIRR) and disseminate the strategies to other appropriate sites. Methods include interviewing rehabilitation professionals and spinal cord injured clients to assess needs and resources, collaborating with service providers to develop and test improved strategies to address unmet needs, and assisting integration of the improved strategies into the service delivery system. Approximately 150 spinal cord injured persons over 14 years of age who were admitted to TIRR for comprehensive rehabilitation from 1979 to the present will be interviewed. Rehabilitation professionals from a variety of disciplines will be interviewed and/or serve as an advisory committee.

The benefits expected from this project include meeting needs early to avoid compounding problems, utilizing resources efficiently by tailoring programs to meet the actual needs of clients, and improving rehabilitation outcomes by providing appropriate services.

Progress—A protocol was developed for interviewing rehabilitation professionals. Eight professionals from six rehabilitation disciplines were asked to describe the needs of SCI clients following discharge, the resources available to meet those needs, and the systems for linking the clients with the appropriate resources. Eight broad categories emerged: Health, Activities of Daily Living, Living Arrangements, Vocational, Psychosocial, Transportation, Financial, and Societal Issues and Policies.

The list of needs described by the professionals was used to develop an interview protocol for use with clients to determine needs, utilization of formal and informal resources, links, resources, satisfaction with resources, and special difficulties encountered in meeting their needs.

Preliminary Results—One hundred and fifty interviews have been completed from a pool of approximately 600 eligible clients. In the first of two sets of preliminary analyses, needs that were identified included: a) further efforts aimed at preventing urinary tract infections and pressure sores; b) professional attendant care services and the resources to pay for them; c) postdischarge psychosocial services for clients and their families; and d) efforts to overcome the additional handicaps experienced by females, blacks and Hispanics as compared to males and whites.

Findings from the second set of analyses included: a) psychosocial services need to be individualized and they need to be offered to both parental and marital family members as well as to the spinal cord injured client; b) gender and marital status must be carefully considered when planning and implementing services and when formulating expectations regarding appropriate outcomes; and c) available resources have not been utilized as often as they might be and client satisfaction with those that are used leaves room for improvement.

Future Plans/Implications—We are working collaboratively with the National Spinal Cord Database and the RTC project on Outcome Studies Pertinent to the National Model Spinal Cord Injury System. Requested preliminary data has been shared with the Medical Director, outpatient clinic, and vocational department.