V. Functional Assessment

[*See also pgs. 9, 35, 132*]

Improved Methods of Quantification of Function/Performance

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Sponsor: National Institute of Handicapped Research

Purpose—The University of Texas at Arlington (UTA), the Dallas Rehabilitation Institute (DRI), the University of Texas Health Science Center at Dallas (UTHSCD), and the Dallas Rehabilitation Foundation (DRF) have formed a research consortium that established the Center for Advanced Rehabilitation Engineering (CARE). The primary research goal is to develop improved methods for quantification of sensory and motor function in handicapped individuals. Central to this effort is the computer-automated laboratory system for quantitative assessment developed in the joint UTA/UTHSCD Biomedical Engineering Program. The system includes measurements of mental alertness, vision, hearing, speech, steadiness, reactions, tactile sensations, manual dexterity, range of motion, speed and coordination, postural stability and control, selected activities of daily living, strength, resistance of passive motion, and fatigue. The laboratory is being expanded to include assessments of gait and proprioception as well as some of the above functions at new body sites. New instruments and software are being developed, and the system's reliability and utility for assessing the function of handicapped individuals are being evaluated.

Development of a Computer-Automated System for Functional Assessment

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Purpose—Researchers at UTA have developed a computer-automated system to quantitatively assess a broad selection of sensory and motor functions. The objectives of this project are to further develop and expand the basic system and to prepare two complete prototype systems for clinical evaluation and application studies at our clinical settings, the University of Texas Health Science Center at Dallas (UTHSCD) and the Dallas Rehabilitation Institute (DRI). In this battery of tests each function is assessed by having the test subject carry out very specific simple and short duration tasks that usually involve responding to computer-generated stimuli. Special purpose transducer modules have been designed to convert responses into voltages for digitization by computer. Signal processing algorithms compute single number results for most tests that quantitatively indicate the level of a specific function.

Progress—Clinical evaluation sites at UTHSCD and DRI have been established. Each is equipped with a basic version of the computer-automated sensory and motor function test battery. Patient and normal data are being collected routinely to meet the objectives of planned studies. An automated database management system with interactive test result inspection capabilities has been implemented. At present, the database contains more than 1500 records of sensory and motor function, of which approximately one-half represents patients with various handicaps. The other half represents normal data that are essential to interpret patient findings properly. It is possible, through a computerized process, to collect any or all of 150 measures of sensory and motor function, deposit results in the database, and examine an individual's results by comparison to a selected subset of the normal population. Results are expressed in terms of standard deviations from the selected comparison population. Cooperative research that allows replications of the system to be used and evaluated at external sites has been entered into with Chicago Shriner's Hospital and Cordis Corporation. Similar efforts at other sites are pending.

New devices and software have been completed recently for measurement of: 1) forearm pronation/supination speed, strength, and range of motion; 2) speech motor function; 3) resistance to passive motion (rigidity/spasticity) and isokinetic strength (separate devices for finger/wrist, knee/elbow, and ankle); 4) range of motion about most body joints; and 5) spinal curvatures.

Software for personal computers has been developed to allow interface to the database and display of individual results as well as test/retest comparisons in various easy to interpret forms, such as graphical profiles of anatomy and corresponding color-coded levels of relevant sensory and motor functions at each site. Expert systems are being developed to provide more refined information to individuals in various disciplines that may use the system such as neurologists, orthopedists, physical therapists, occupational therapists, and vocational experts.

Skill Evaluator and Trainer

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Sponsor: Channel 10 Children's Medical Research Foundation of S.A., Inc.

Purpose—A device has been developed that objectively evaluates a disabled person's skill in controlling switches, joysticks, and other interfaces to electrical devices and subsequently trains the disabled person to use the interface which is best suited to his capabilities. The need for such a device has been established, and its reliability and validity have been authenticated. Negotiations for its commercial production are in hand.

Quantitative Measures for Assessing Gait

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Purpose—The objective of this project is to develop an easy to use multi-dimensional parameter technique that can characterize significant abnormalities in gait. The parameters will be used to assess the effectiveness of various types of therapeutic interventions. Normals are currently being run to obtain a standard database.

Clinical Evaluation and Application of a Computer-Automated System for Functional Assessment—Part I

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Purpose — A prototype of the Center's computer-automated quantitative assessment system is being evaluated for test/retest repeatability, effects of age, gender, and handedness while gathering normal sensory and motor function data and short- and long-term stability of patient data. Other studies involving rehabilitation of knee injured patients, postoperative spinal pain patients, spasmodic dysphonia, and post-polio subjects are being carried out in cooperation with local investigators.

Progress — Significant progress has been made in evaluating carefully screened normal individuals to establish a sensory and motor function database. To date, norms for approximately 150 measures have been obtained. Test/retest data are being used in a large scale study of reliability and learning effects. Results obtained for eight tremor measures and 14 strength measures indicate good repeatability and little or no learning effects.

Patients with progressive neurologic diseases such as Parkinson disease, multiple sclerosis, myasthenia gravis, Huntington's disease, and chronic low back pain and those receiving neuroleptic medications also are being characterized. These studies are planned to continue and will be expanded as new tests move from development to clinical stages. The total number of measures that can be selected is expected to grow to 350. These tasks are facilitated by the automated nature of the system and database. The majority of these measures can be obtained in a two-hour test session. However, in routine use only selected subsets of available tests would be administered.

Clinical Evaluation and Application of a Computer-Automated System for Functional Assessment—Part II

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Purpose — A second prototype of the Center's computer-automated quantitative assessment system is being evaluated clinically and used to conduct studies at The Dallas Rehabilitation Institute (DRI). Work at this site has been underway to evaluate the sensory and motor function of patients with head injuries, spinal cord injuries and peripheral neuromuscular damage, cerebral palsy, amputated limbs, spinal pain, and arthritis. Data are being used to develop functional profiles and databases of these conditions, as well as to document effects of therapy and recovery trends. At this time, 152 patients have been evaluated in 218 test sessions.

Progress — DRI investigators have closely collaborated with those at UTA and UTHSCD to improve test devices. As experience with these patient groups increased, several modifications to test devices were found necessary. A project is in progress to compare data acquired at the UTHSCD clinical site to data on the same set of normal subjects evaluated at DRI. Results will be used to assess factors such as instrument calibration and effects of test administrator training.

Preliminary Results—In one preliminary study fifteen head-injured patients with similar prognoses and at various stages post-injury were evaluated over a broad set of functions. Results indicated that the test battery was effective in documenting function in this population. Results generally improved with time since injury. Short-term repeat testing indicated that stable data could be obtained for most functions, and long-term repeat testing quantitatively documented changes that agreed with other subjective clinical indicators. Short-term memory and upper and lower extremity strength were shown to be least impaired, while activities of daily living, manual dexterity, and upper and lower extremity reactions, speed, and coordination showed the greatest losses. The average function of the group across all measures ranged from one to four standard deviation units below that of norms of similar age and gender. An expanded study is underway.

Measurement of Muscle Strength, Endurance, and Range of Motion

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Purpose—The goal of this project is to develop a computerized isometric muscle strength, endurance, and range of motion measurement system. The unique aspect of the system is its ability to quickly and easily make measurements on the entire body from the neck down to the ankle. The system will use a special joint stabilizing chair and table with multiple load cells in order to make measurements from 24 muscle groups on each side of the body.

Progress—The data are collected using an Apple computer with an analog to digital converter. The delay time, rise time, and the decay of the force response are calculated. The EMG is measured and parameters relating to the timing of the EMG with respect to the force response are calculated along with frequency shift information related to fatigue.

The computer software has been completed and the first prototype chair is undergoing testing.

Quantification Mobility Performance for Functional Assessment, Diagnosis and Therapy of Neuromuscular, Skeletal, and Synovial Joint Dysfunctions

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Purpose—This comprehensive computer-based project, first described in the 1983 Veterans Administration Rehabilitation Research and Development Progress Reports, will provide the orthopaedic surgeon with a computer-assist similar to that which the engineer enjoys with Computer-Aided Design (CAD). With CAD the engineer may plan orthopaedic procedures on a computer display of the patient's anatomy and then view on an animated computer screen a simulation of the consequence of the procedure on the patient's posture and gait, with the opportunity to iterate and improve the procedure before undertaking actual surgery. Enhanced confidence in outcome, including the likelihood in some situations of the choice of non-intervention, and quantitative assessment of change are the expected utilities of Computer-Aided Surgical Simulation (CASS). The overall project is comprised of several components and is relevant to functional assessment in its own right.

Progress — Regarding gait analysis, our Selspot I/TRACK system at MIT has been augmented by our Selspot II/TRACK System with improvements in kinematic resolution and accuracy and greater flexibility. The necessary frequency or sampling requirements for adequate kinematic data in human gait have been reported. Graduates of our program have installed a 4-camera, 2-forceplate Selspot II/TRACK System at the Massachusetts General Hospital for orthopaedic/pediatric movement analysis.

With reference to dynamic joint force estimation, our NEWTON computer program automatically calculates joint forces and moments using TRACK kinematic data, forceplate input and body segment mass, and inertial properties. The latter constitutes the greatest uncertainty in dynamic calculations since all methods described in the literature are based on very small and non-representative cadaver samples. We have developed computer programs that automatically calculate the patient-specific inertial tensor using as input computer tomographic or magnetic reasonance imaging data. Physical experiments on cadaver limb segments to compare direct measurement of the inertial tensor with our tomography-based computer analyses are underway.

Preliminary Results — We now have a year of data from the first pressure instrumented femoral head hemiarthrosis. Local pressures correlate well with the high and non-uniform readings we have recorded *in vitro* on cadaver specimens. We are attempting to spatially integrate the multiple pressure readings to calculate the direct force vector across the hip joint. Such an internal measurement would augment the dynamic joint force estimation from kinematic and force plate measurements and permit evaluation of the role of muscle co-contraction.

TRACK data into NEWTON followed by optimization analyses predict the force versus time of each of the 36 mono- and bi-articular muscles of the pelvis, thigh, shank, and foot complex. To improve the knee representation of our leg model, we are generating an explicit mathematical description based on experimental measurements and using our ultrasound technique for the articular and menisci geometries and incorporating the passive restraints of the ligaments. Reduction and interpretation of data on knee kinematics for which TRACK arrays were mounted on bone-pins disproves the contemporary crossed four-bar linkage model of the knee function, and demonstrates four degrees of freedom. When inserted into our overall leg model, including the 15 muscles that span the knee, the new knee representation will have four degrees of freedom and will improve the accuracy of prediction of individual muscle activity.

The surgeon must be presented with a realistic, manipulable representation of the subject's anatomy as she/he undertakes simulated surgery. The same data used for segment inertial property determination serve also as input to the anatomical representation. Automatic feature detection delineating between hard and soft tissue has been demonstrated, as has a data compression approach, based on frequency domain analysis, which achieves an order of magnitude in computer memory requirements.

Computer vector graphics displays of patients movement preoperatively and subsequent to a simulated operation must also be as realistic as feasible. Current stick-figure representations do not include segment orientation data and cannot capture nuances of pathological and/or idiosyncratic movement. We have developed computer programs that represent the limb segments as articulated solid bodies, which when driven by TRACK kinematic data produce much more adequate displays of human movement.

Predictive Assessment in Prescription of Functional Aids for the Motor-Disabled

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Purpose — The goal of this project is to develop data and theory on which to base prediction of functional gain from technological intervention. It was proposed that this concept be applied to three handicapping conditions: 1) disabling tremor of the upper extremities; 2) "equinus" and other spastic gait abnormalities; and 3) loss of vocal communication due to impaired articulatory motor control.

Progress — Work in the area of computer-guided assessment for prescription of non-vocal communication devices has continued, demonstrating accurate prediction from objective assessment data of communication rate using non-vocal communication devices. Straightforward phenomenological models of the dependence of movement time on distance, angle, and target size account for a major part of the performance differences observed among assessment tasks. Models derived in this way will provide a sound basis for device-specific rate predictions as part of a clinical selection scheme.

The primary area of work in this REC project since the last Progress Report has been in the area of spastic gait. Advances have been made in two directions—continued technical development of the laboratory-based wearable orthosis simulator and ADL testing of a prototype practical damping orthosis. The simulator applies energy-absorbing loads by means of a magnetic particle brake. Resistive torque is controlled in real time by a DEC 11/60 computer on the basis of signals from angle and force sensors as well as sole switches. Final preparations are complete for synchronous data acquisition from the simulator and the Laboratory's Selspot-based TRACK system, and real-time brake control.

The ADL prototype orthosis based on a passive linear damper was used at home by a cerebral palsied child for six weeks. Anecdotal data gathered by his highly cooperative family demonstrated gradual improvement in the range of activities (walking, running, stair-climbing, and jumping) in which the subject felt comfortable wearing the brace. An apparent subject improvement in gait was observed by his family. This was corroborated in the laboratory by means of weekly TRACK measurements. Analysis of kinematic data revealed that wearing the brace caused statistically significant reduction of mid-stance plantar flexion and reduction in the angular velocity of ankle dorsiflexion normalized by gait velocity during roll-over. It also confirmed (for this subject) the hypothesis that the abnormal reflex plantar flexion is triggered by dorsiflexion velocities above a threshold value. Redesign of the ADL orthosis for improved cosmetic and fit is planned.