Capabilities

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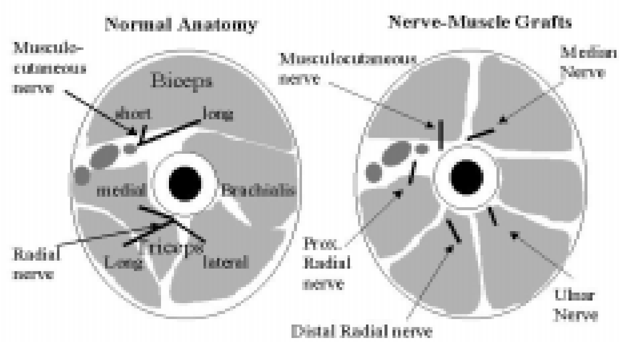
The Use of Nerve-Muscle Grafts to Improve Myoelectric Prosthesis Control

By Todd Kuiken MD, PhD, Nikolay Stoykov, PhD, Madeleine Lowery, PhD, and Allen Taflove, PhD

Figure 1. Nerve-muscle graft paradigm for transhumeral amputation



Introduction

Improving the control of artificial arms remains a considerable challenge, especially for high level amputations. Although the limb is lost with an amputation, the control signals to the limb remain in the residual peripheral nerves of the amputated limb. The potential exists to tap into these lost control signals using nerve-muscle grafts to greatly improve the control of powered artificial limbs. As first suggested by Hoffer and Loeb[1], it may be possible to denervate expendable regions of muscle in or near an amputated limb and graft the residual peripheral nerves to these muscles. After reinnervation of these muscles, the surface EMG signals from the nerve-muscle grafts might be used as additional myoelectric control signals for an externally powered prosthesis.

The main advantages of a nerve-muscle graft system are that more discrete myoelectric control signals are potentially available and that these signals are directly related to the original function of the limb. For the long transhumeral amputee, it is proposed that the medial head of the biceps and two heads of the triceps would be denervated. The median, ulnar and distal radial nerves would be grafted on to these heads, and allowed to reinnervate these regions of muscle (see Fig.1). These nerve-muscle grafts would produce five independent EMG control signals that could be used for simultaneous control of at least the terminal device and elbow, and possibly a third degree-of-freedom such as wrist rotation, or wrist flexion-extension. Furthermore, shoulder motion would still be available to control an additional degree-of-freedom. Now if the amputee thought 'close hand' the neural control signal would travel down the median nerve and cause the medial head of the biceps to contract. The surface EMG from the medial head of the biceps would then be used as a control signal to close the terminal device of the prosthesis. If the amputee thought 'bend elbow', the neural control signal would still travel down the musculocutaneous nerve and cause just the lateral head of the biceps to contract. The surface EMG from the lateral head of the biceps would then be used as a control signal to flex the prosthetic elbow. Thus the amputee would be controlling functions in the prosthesis with neural path-

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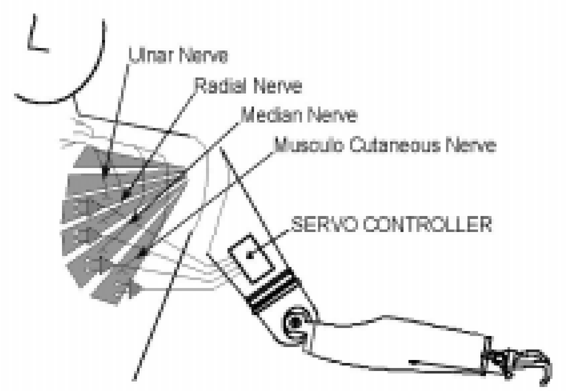
ways that are directly related to their normal anatomical function. This should reduce the conscious effort required by the amputee, making the prosthesis easier to use and more functional.

For the shoulder disarticulation patient, a broad surface muscle could be used, such as the pectoralis major or latissimus dorsi. The muscle would be denervated and each brachial plexus nerve would be grafted on to a separate region of muscle (see Fig. 2). Each region of muscle could then serve as an independent myoelectric control signal.

Figure 2. Nerve-muscle graft technique for shoulder disarticulation.



The use of nerve-muscle grafts to improve the control of artificial limbs has not been studied to date. However, the related concept of 'neuroelectric control' has received considerable attention. In neuroelectric control, electrodes are directly connected to the residual nerves of the amputee through nerve cuffs and the electroneurogram (ENG) of the nerve is used to control the artificial limb[1,2]. This method has the potential to create additional control signals that physiologically correlate to the natural arm function of the amputee. Technical problems have prevented practical clinical application of neuroelectric control[3]. The ENG is very small, difficult to record and difficult to separate from the EMG of surrounding muscle. Nerves are sensitive to mechanical stresses and it is difficult to maintain long-term ENG recordings. Finally, the ENG electrodes need to attach to the prosthesis through percutaneous wires that are prone to infection, or the ENG needs to be transmitted to receivers in the prosthesis that involves complicated implanted transmitter-receiver systems.

With the nerve-muscle graft system, muscles serve as biological amplifiers of the nerve signals and eliminate the need for any implanted hardware. Furthermore, existing myoelectric technologies could be applied with this technique. Powered elbows, wrists and terminal devices are commercially available. The circuitry allowing up to six input control signals and the control of up to four motors is available. A new prosthesis would not necessarily need to be developed.

It is also possible that the nerve-muscle grafting technique could be combined with EMG pattern recognition research[4,5,6,7] to further improve the control of artificial limbs. Providing control information about hand and wrist function with nerve-muscle grafts makes EMG pattern recognition paradigms more feasible for amputation levels at and above the elbow.

How do we test the feasibility of this intriguing idea and develop it into a practical clinical tool? There are two main areas of on-going research. First, we need to understand more about how the residual peripheral nerves would grow into spare muscles in or near the residual limb. We also need to know how EMG signals from these nerve-muscle grafts propagate through the arm.

The Hyper-Reinnervation of Muscle

The nerve-muscle grafting technique involves implanting large nerves containing many motoneurons on to a relatively small muscle mass, thus 'hyper-

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reinnervating' the muscle. Direct nerve implantation frequently has poor muscle recovery[8,9], which could be problematic in the implementation of this technique. We hypothesized that by grafting an excessive number of motoneurons onto a muscle we could improve muscle recovery, making the technique feasible. To test this hypothesis, rat medial gastrocnemius (MG) muscles were hyper-reinnervated by grafting additional nerves onto the MG muscle. Five different nerve graft combinations were used to implant up to 11.6 times the normal number of motoneurons onto the MG muscle. The rats were allowed to recover from the surgery for at least 16 weeks to insure that the reinnervation process was complete, then terminal experiments were performed. In the terminal experiment, a large number of parameters were quantified including motor unit size, motor unit number, maximum muscle force and muscle mass of both the experimental muscles as well as several control muscles.

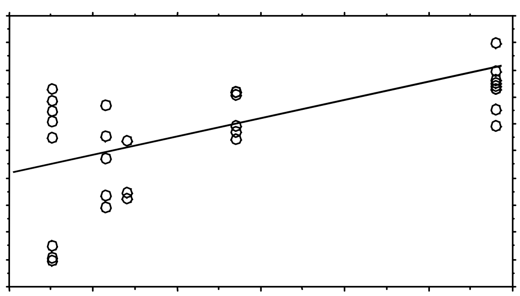

Figure 3: *Relative muscle recovery versus the relative number of motoneurons grafted onto the muscle.*

Hyper-reinnervation improved the recovery of the MG muscles. The relative muscle mass steadily increased as more motoneurons were grafted on the muscle (see Fig. 3). In the largest nerve grafts, the experimental muscle recovered to near normal levels with a relative muscle mass of $94.4 \pm 8.2\%$ (n=8). In these animals the experimental MG muscle mass was significantly greater than the recovery of self-reinnervated muscles ($P<0.005$) and was not statistically different from the contralateral un-operated muscles.

We conclude that hyper-reinnervation would allow nerve-grafts to fully reinnervate muscle and that the technique is feasible to use in amputees. Hyper-reinnervation may also be useful in treating plexus injuries in amputees. The recovery of denervated or partially denervated muscles may be improved by grafting residual nerves onto these compromised muscles.

Another question is what happens when multiple nerves are simultaneously implanted on different regions of muscle? Ideally, each nerve would only reinnervate the region of muscle on to which it was implanted. However, the reinnervation process is complex and it is unknown if the nerves would reinnervate separate regions of muscle or if they would intermingle. Research is ongoing to clarify this important issue.

Computer Models of EMG Signal Propagation

For the nerve-muscle graft technique to be successful, the myoelectric (EMG) signals from these grafts would need to be independent of each other and the surrounding muscles. If the cross-talk (unwanted signals detected from muscles other than the muscle of interest) between multiple surface recording sites were too high, it would be difficult for the amputee to isolate movements in the myoelectric prosthesis. Cross-talk has not been quantified between muscles of the arm, far less between these smaller nerve-muscle grafts. A tool is needed to study the factors affecting surface EMG signal independence and to enable the prediction of cross-talk from adjacent muscles.

To this end, 3-dimensional finite element models (FEM) are being developed of EMG signal propagation in an idealized limb. To test the accuracy of the FE modelling technique, computer simulation results were compared with experimental data recorded from sinusoidal sources embedded within an inert single-tissue physical limb model. There was a very high correlation between the FEM models and the experimental data ($R>0.99$). Absolute magnitudes of the calculated data were generally within 5-10% of the experimental mean.

A sensitivity analysis was performed to understand the factors affecting EMG signal propagation and cross-talk in this simple arm. Several interesting results have been found. The permittivity or capacitance of tissues can have a significant affect on EMG signal propagation is some circumstances. This is important because capacitance has traditionally been neglected in bioelectromagnetics modelling. Also the shape of the limb can affect how the EMG signal propagates. However, this affect is small and probably not of clinical significance.

To study more realistic representations of the human arm, static FE models that included skin, fat, muscle, bone and realistic transmembrane potential sources were developed (see Fig. 4). In a model comprised of 40 mm diameter muscle surrounded by a 1.3 mm thick layer of

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NUPRL&RERP Fatique Tester for Prosthetic Feet

Simulating the mechanical deterioration caused by walking from Chicago to Los Angeles — without leaving the laboratory

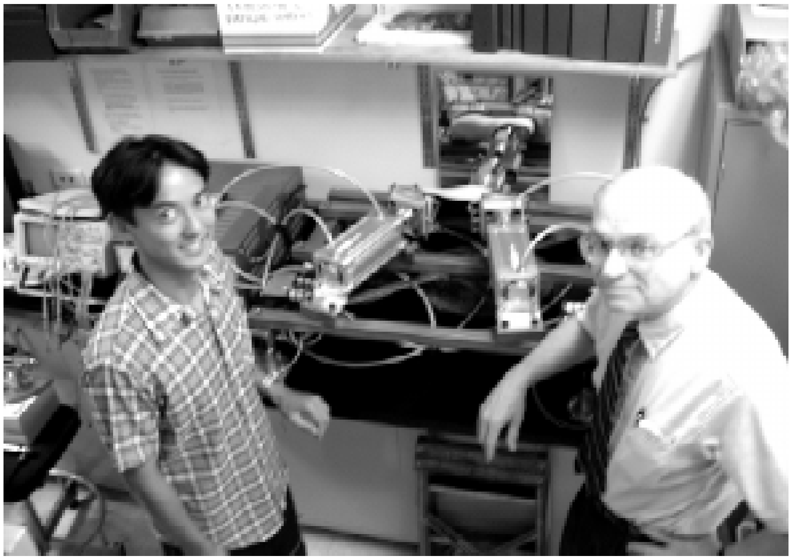
By Jan Little

Dudley Childress, PhD, Director of the Northwestern University PRL & RERP, smiled as he opened the door to the lab area from which issued a continuous pounding noise. "Michel Sam built this testing device for much, much less that we thought we would have to pay," he explained. "This foot has been tested for approximately 700,000 cycles and we're hoping for two million. The foot is somewhere in western Kansas on a walk the distance from here to California."

The machine simulates loads produced by walking

The foot mounted on the testing device doesn't resemble a human foot very much. It is a prototype built to test simulated actions of a human foot as a person walks. The testing device strikes the heel and toe area of the foot alternately, simulating the loads that would be placed on a prosthesis during walking. The two million cycles of testing sought by the Northwestern University researchers is equivalent to about 2000 miles of normal walking. The results of the testing will add important data to the ongoing exploration of prosthetic foot design.

Michel Sam, who developed this testing device, has chosen to enter medical school after completing this Northwestern University PRL & RERP foot prosthesis testing project. His work in developing the testing apparatus is an interim stop between his education in mechanical engineering and medical school. He came to Northwestern when his advisor from UCSD, Dr. Richard L. Lieber, suggested he contact Dr. Childress. Michel's education, combined with his interest in medicine, resulted in an advantageous match for both Michel and NUPRL & RERP.



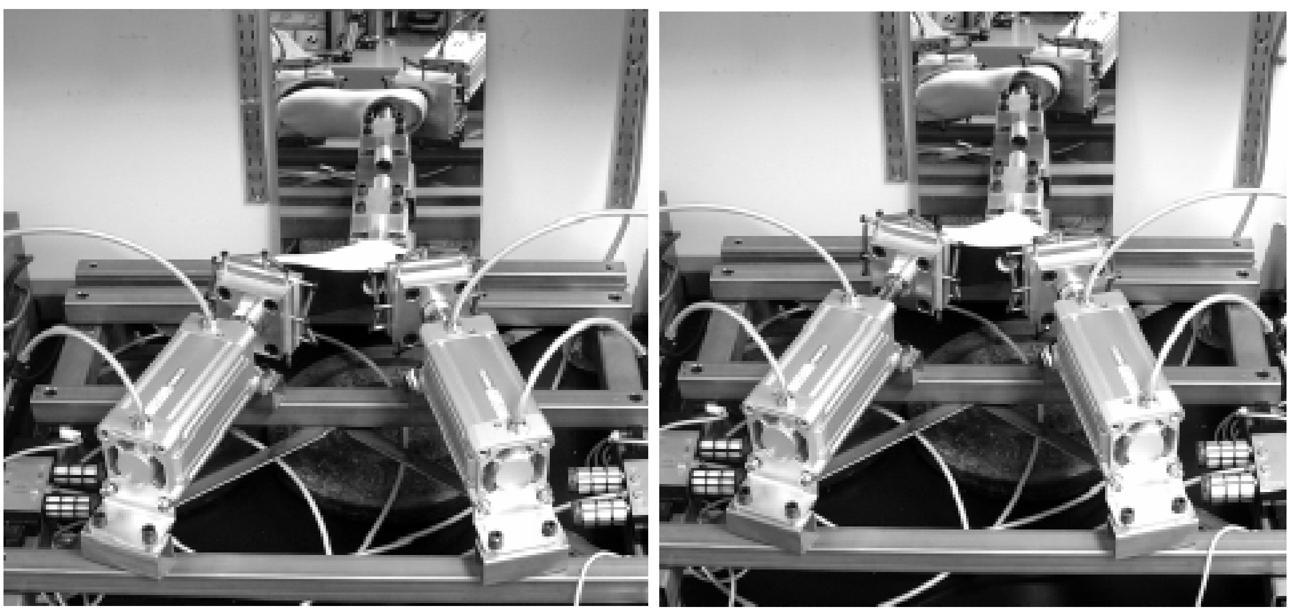
Michel Sam, left, and Dudley S. Childress, PhD, decided to build the testing apparatus, rather than purchase commercially available products. Michel concieved the design, specified the equipment and built the apparatus.

Michel, who was born in France after his parents moved there from Cambodia, finished his last two years of high school in Los Angeles. After earning his bachelor's degree in Mechanical Engineering from the University of California at Berkeley, he earned a master's degree in Mechanical Engineering from the University of California at San Diego. His research for his master's degree focused on biomechanics and muscle injury. He intends to specialize in orthopaedic medicine and feels that his time in the NUPRL & RERP laboratories will provide him with a unique opportunity to study human walking, prosthetics and orthotics.

NUPRL & RERP researchers have studied the role of feet in human walking for a number of years. Erick H. Knox conducted research comparing characteristics of 15 different models of "dynamic response" feet (*Capabilities*, July 1995, page 1) as part of his work to earn a doctoral degree in Biomedical Engineering from Northwestern University in 1996. Andrew H. Hansen investigated theories about the role of prosthetic foot alignment in human walking for his master's degree in Biomedical Engineering, awarded in 1999. He continues to investigate further aspects of this topic in his research involved in his doctoral studies. Some of his findings were published in *Capabilities*, July 2000.

In order to conduct further testing of durability of various configurations and materials used to fabricate prosthetic feet, the NUPRL & RERP laboratories needed to develop an apparatus that would simulate the forces applied to the heel and toe during walking over an extended period of time. The team decided to build a testing apparatus rather than try to locate a commercially available unit which met their specific needs. In addition to learning more about design and materials, such testing is necessary to meet International Standards Organization requirements.

The International Standards Organization has developed a set of standards to test lower-limb prosthetic components (ISO 10238). To satisfy these standards, a prosthetic foot has to undergo three tests: a static proof test, a static failure test, and a cyclic test. In the static proof test, a load is applied at the heel of the foot, maintained for 30 seconds, and then removed; the same procedure is then repeated for the toe region of the foot. The static failure test consists of applying a certain force to the heel of a prosthetic foot until the foot breaks, or until the force reaches a predetermined maximum value; the same procedure is repeated on a different sample but this time the toe is loaded instead of the heel. In cyclic



The machine simulates the loads of walking by loading the toe (at left), then the heel (right) with a force similar to the force exerted by a human wearing the prosthesis. The amount of loading and the loading angles have been determined by the International Standards Organization (ISO).

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Northwestern University

NEWS

PRL&RERP&NUPOC

NOTE: The Capabilities date designation has been changed from “January, April, July and October” to “Winter, Spring, Summer and Autumn” to more accurately reflect our quarterly nature. Volume and number designations remain the same.

New Grant from the Department of Veterans Affairs will Focus on Orthotics

NUPRL & RERP has been successful in securing a research grant to study lower-limb orthotics. As part of a Targeted Solicitation for Proposals in Selected Areas of Emphasis in Rehabilitation Science and Technology, the Veterans Administration Office of Research and Development will fund a project entitled An Investigation of Foot Alignment and Support in Ankle Foot Orthotics. The project will use quantitative gait analysis to investigate how ankle-foot alignment and foot-plate length in AFOs affect the gait of subjects with hemiplegia following Cerebral Vascular Accident (CVA). The grant is for three years with funding to begin July 1, 2001.

The project was developed by Bryan Malas (Director, Orthotics Education, NUPOC), Steve Gard, PhD, Stefania Fatone, PhD, and Dudley Childress, PhD, and will involve Rebecca Stine (Manager, VACMARL), Andrew Hansen (NUPRL grad student) and Dr Puangpeth Jantra from the VA Chicago Health Care System Lakeside Division. A goal for the results from this study is to provide a better understanding of the effect of ankle-foot alignment and foot support on hemiplegic gait, and may enable the research team to recommend more appropriate AFO designs.

NUPRL & RERP Staff Members Attend RESNA

Dudley Childress, Kerice Tucker and Michel Sam attended the annual meeting of RESNA, the professional society for the advancement of assistive technology, held June 22-26 at the John Ascuaga Nugget Hotel, Reno, Nevada. Northwestern University RERC was one of the 14 RERCs sponsored by the National Institute on Disability and Rehabilitation Research (NIDRR) to exhibit information about their research projects. Dr. Childress, a RESNA Pioneer, was influential in initiating the Annual RESNA Conference and chaired the first event managed solely by the fledgling organization in 1981.

Pinata Hungspreugs Receives Master’s Degree in Biomedical Engineering

Pinata Hungspreugs was awarded her Master’s Degree in Biomedical Engineering in November, 2000. Her thesis was titled: "A Computer Based Simulation Tool to Aid in Upper-Limb Prosthesis Design”. Ms. Hungspruegs, whose work was reported in the April 2000 issue of *Capabilities*, is continuing her research at Northwestern to earn her doctoral degree. Her doctoral research may focus on lower limb prosthetics modeling.

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NUPRL & RERP News

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Measuring Outcomes of Prosthetic & Orthotic Services Project Presented at ISPO

Allen Heinemann, PhD, and Director of the Rehabilitation Services Evaluation Unit at the Rehabilitation Institute of Chicago (RIC), joined other members of the Northwestern University prosthetic and orthotic research staff as a presenter at the 10th World Congress of the International Society for Prosthetics and Orthotics (ISPO). The meeting was held July 1—6, 2001 in Glasgow, Scotland. Dr. Heinemann reported progress to develop a database to describe the outcomes of prosthetic and orthotic services in terms that are uniform across service sites and useful across the continuum of care from acute to community reentry. The project has accomplished a literature search and two rounds of data collection. As a result, a set of measures for outcome has been developed including a 23-item measure of upper extremity function, a 21-item measure of lower extremity function, a 23-item measure of quality of life, an 11-item measure of equipment satisfaction and a 10-item measure of service satisfaction.

The measures have been used at nonprofit and for-profit clinical organizations in the USA and appear to be sensitive to change over time and to distinguish clients with different functional status, satisfaction and quality of life levels. *Capabilities* has published articles by Camille O'Reilly, Project Manager, in past issues and will publish further information about this project in the future.

Todd Farrell Receives Three-Year Scholarship for Graduate Study

Todd Farrell, who will conduct research for his Master's thesis in Biomedical Engineering at the NUPRL & RERP labs, was selected from 1,500 applicants to receive a 2001-2002 National Defense Science and Engineering Graduate (NDSEG) Fellowship. The award is sponsored by the Office of the Deputy Under Secretary of Defense for Science and Technology and Air Force Office of Scientific Research. Mr. Farrell received his Bachelor's Degree from Catholic University and is working toward his Master's Degree in Biomedical Engineering. He will continue at Northwestern to work toward his Doctoral Degree. His area of research is using electromyography to control a multiple degree of freedom prosthetic hand or wrist.

John Lyman: Pioneer in Prosthetics and Orthotics Dies

John Lyman, a futurist and visionary who pragmatically applied his pioneering the-future-is-now thinking to the creation of more comfortable and maneuverable artificial limbs for amputees, has died. He was 79. His obituary, published by the *Los Angeles Times*, May 9, 2001, noted that Dr. Lyman was currently Professor Emeritus at the University of California, Los Angeles. Dr. Lyman received his PhD in psychology in 1951. He became involved in prosthetics when he served as chief aide to Craig Taylor, head of the Biotechnology Laboratory at UCLA. In the opinion of Dudley S. Childress, PhD Craig Taylor was much responsible for providing the foundation for upper limb prosthetics in the USA. When Taylor died in 1958, Lyman took Taylor's position as head of the Biotechnology Laboratory.

Following Taylor's death, Lyman continued to work with Dr. Charles Bechtol, an orthopaedist, in work Bechtol had begun with Taylor. That work led to development of cineplasty techniques so that they could be used with new American prostheses. Lyman and Bechtol's challenge was how to provide greater control of an artificial limb. Childress noted, in a tribute he wrote to Lyman, that it is interesting that 40 years later, this problem has still not been solved and that the Northwestern research team is perhaps closest of any group in the field to the early control ideas of Bechtol. Childress also noted that Dr. Lyman in later years looked primarily to "computer-based" solutions to this problem. However, Childress pointed out, it was an unfortunate choice for controls in that Lyman was about 30 years ahead of the technology curve for practical application of computers in this area.

Childress said, "John Lyman was a futurist at heart and interdisciplinary by nature. He more or less defined himself as being in human engineering. Prosthetics provided a ready outlet for his sometimes far-out thinking. We have lost another person who was heavily involved with the development of P&O research and education in the USA during its formative years."

It should be noted that a Lyman publication is referenced in the lead article of this issue of *Capabilities*.

Advanced Training Course: Overview of Gait Analysis for Prosthetists and Orthotists

NUPOC, in conjunction with NUPRL & RERP and the American Academy of Orthotists and Prosthetists (AAOP), will offer the first advanced training in an overview of gait analysis for prosthetists and orthotists September 27-29, 2001. Training sessions will be held at NUPOC, located on the 17th floor of the Rehabilitation Institute of Chicago (RIC)

The overall course will be divided into three sections:

Fundamentals of Gait Analysis
Gait Analysis in Prosthetics
Gait Analysis in Orthotics

The first day's course will provide a basis for further work in gait analysis. Topics to be covered on the first day include:

- History of Gait Analysis
- Observational and Objective Gait Analysis
- Kinematics and Normal Gait
- Kinetics and Normal Gait
- EMG and Normal Gait

Following the formal presentations, course attendees will have the opportunity to see how the above areas work together in case examples. Reading assignments from *Gait Analysis*, by Jaqueline Perry, MD, will be made each day.

The second day of the course will cover topics including:

- Self Assessment Examination
- Unilateral Transtibial Gait
- Unilateral Transfemoral Gait
- Complex Prosthetic Gait

The sessions on the second day will also include work in the Veterans Administration Chicago Motion Analysis Laboratory (VACMARL) in the Northwestern prosthetic and orthotic research area on the 14th floor. Concurrent parallel sessions will include case study discussions and demonstration of simplified gait analysis equipment including the D.U.R.S. direct ultrasound ranging system.Those attending the course will also have the opportunity to work with multimedia self-education materials developed by NUPOC and other education facilities.

The last day of the course will include sessions focusing on gait analysis of anomolies resulting from stroke, Cerebral Palsy and Myelodysplasia and results from attempts at remediation with orthoses. A written examination following presentation of the course material is required of all attendees.

Faculty for the course will be staff members from both NUPOC and NUPRL&RERP and include:

- Dudley S. Childress, PhD
- Steven A. Gard, PhD
- Stefania Fatone, PhD, CPO [Australia]
- Margrit-Regula Meier, PhD, CPO [Switzerland]
- Rebecca Stine, MS
- Mark L. Edwards, MS, CP
- Bryan S. Malas, CO
- Luciano S. Dias, MD

Tuition for the course is $995 for members of AAOP and $1095 for nonmembers. A copy of Dr. Perry's text, *Gait Analysis*, breakfast and lunch is included in the fee.

Registration cut-off is August 28, 2001. Application for registration may be obtained from NUPOC (www.nupoc.northwestern.edu) or from the AAOP web page, located on the Orthotic and Prosthetic website, www.oandp.com. ■

Roundtable Reviews Topics For Future Prosthetics Research

A roundtable discussion group met at the NIH Neuroscience Center, Washington, DC on June 25, 2001 to identify immediate and anticipated future needs in prosthetics research. The meeting was sponsored by the National Institutes of Health's (NIH) National Center for Medical Rehabilitation Research (NCMRR) and the Department of Veterans Affairs Rehabilitation Research and Development Service (VARRDS).

The Roundtable was organized to review advances in areas including tissue engineering, MicroElectric Mechanical technology, biomaterials, nanotechnology, remote sensing and information technology. In addition, a new world paradigm has evolved as a result of use of landmines in warfare and civil terrorism campaigns. UNICEF estimates that over the last decade more than five million children were disabled by landmines. In the U.S., clinicians must respond to the shifting needs of a population of people with amputations who are aging and an increasing number of amputations resulting from diseases associated with aging.

Three broad categories were addressed: orthopaedics and amputation management; prosthetic refinement and service delivery; and trauma/tissue repair and regeneration. Areas addressed by "State of the art" presentations were tissue engineering, micromachine technology, microsensors, robotics, osseointegration, tunnel cineplasty, computerized componetry, materials, CAD-CAM: international systems, imaging system, and AdVAntage Arm: Upper Extremity Advances. Dudley Childress made short presentations on tunnel cineplasty and CAD/CAM at the roundtables.

The results from the Roundtable will be used in determining needs, research projects and goals for incorporating advanced technology in future prostheses and service delivery to people with amputations. ▯

Fatique Testing for Prosthetic Feet

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testing, the heel is loaded, then unloaded, then the toe is loaded and unloaded, and this sequence (which makes up one cycle) is repeated at a frequency of one to two Hertz, until two million cycles are reached or the prosthetic foot fails, whichever occurs first.

The force levels for all three tests vary depending on the weight and activity level of the person for which the prosthetic foot was designed. For example, if a foot is designed for a 80Kg person, the foot needs to sustain a force of 2065 N (460 lbs) for the static proof test, 4130 N (930 lbs) for the static failure test, and survive a cycling force of 1230 N (276 lbs) for the cyclic test. The testing apparatus was built to follow the parameters given by these ISO 10328 standards as much as possible while remaining inexpensive.

The first machine didn't last through the test. "We built the first machine out of parts from a mountain bike and the motor from a powered wheelchair," Michel said. "It wasn't strong enough. The prosthetic feet being tested lasted longer than the machine." This first machine also only allowed for a cyclic test of the toe region.

To build the second machine, Michel used pneumatic pistons. "After seeing the failures from the first machine, we decided to use parts that were designed to sustain heavy cycling loads for extended periods of time". The use of pneumatic pistons would allow not only reliable cyclic tests, but also static proof and static failure tests of prosthetic feet. One piston is used to load the heel, while another is used to load the toe. Both pistons are equipped with anti-friction plates which greatly reduce shear forces on the feet. The force and frequency of cycling applied by the pistons is controlled by monitoring the air pressure supplied to them. A pressure regulator is used to control the frequency of cycling, while pressure switches are used to control the force applied to the foot. The pneumatic pistons and valves are connected so that they can cycle in the correct order without the use of a computer or microprocessor.

The second effort to build the testing apparatus was extremely successful. Michel's machine works day and night, simulating a walk from Chicago to Los Angeles. ▯

The VA Presents

News from the Department of Veterans Affairs

Coordinated by Robert M. Baum
Prosthetic Network Manager, P&SAS SHG,
VA Headquarters, Washington D.C.

Improving Access to Care in the VA Health System: A Progress Report

By: Laura J. Miller, M.P.A.
Assistant Deputy Under Secretary for Health, Veterans Health Administration

"VA Health Services Research & Development"
Originally published in June, 2001, Forum.

With the implementation of Veterans Integrated Service Networks (VISNs) and the shift toward community-based primary care, VA has made tremendous strides in improving access to veterans' health care. We know, for example, that the number of veterans served by VA increased 30 percent from 1996 to 2000. In addition, more than 400 VA community-based outpatient clinics (CBOCs) currently provide care to veterans throughout the system. Moreover, 87 percent of the veterans who enroll for VA health care services are able to be seen by a VA provider within 30 miles of their home. These are substantial accomplishments!

Technology has helped reach more veterans

Technological advances are also helping VA improve access to care. Telephone triage and advice programs have been implemented at all VA medical centers, and health education is available to veterans on the internet. Last year, VA provided more than 350,000 consultations via telemedicine. Telemedicine and in-home teleconsultation programs have also been implemented for spinal cord patients. In 1998 and 1999, the Vet Center program implemented the Vet Center-Linked Primary Care Project, which uses telemedicine to make primary care more accessible for high-risk, under-served veterans.

In addition, the use of computers and electronic communication are cutting through barriers of care. One new software program, Web Top, allows VA physicians and nurses to view patient records from other sites. With "real time" information sharing, the medical decision-making process is expedited and patients receive the services they need faster.

VA has also made it easier for veterans to apply for VA health care by eliminating nearly three-quarters of the forms once required for application and enrollment. Veterans may now obtain applications for enrollment and medical care on the internet. In addition, they can send the forms electronically to the VA health care facilities of their choice, or they can print out the completed forms and mail them.

Now more than ever, VA is in the truest sense a health care system. With the VA's new focus on populations rather than facilities, we are doing a better job of bringing needed services to patients in a timely manner. We are also making more efficient use of our resources – increasing the benefits provided to patients. We will continue to be challenged by competing and conflicting forces of change, but addressing these challenges is part of our task in keeping the promise to America's veterans.

Please send us your articles, success stories, comments or suggestions for future issues in the VA Presents. E-mail: Robert.Baum@Mail.VA.Gov. Address: PSAS SHG (113), 810 Vermont Ave., NW, Washington, DC 20420. Phone (202) 273-8515. Fax: (202) 273-9110.

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skin, the root mean square (RMS) amplitude of the surface EMG signal from a source 10 mm below the surface was only 3.4% as large as for a 1.0 mm deep source. Values are given for bipolar electrodes, separated by a distance of 20 mm. Surface EMG amplitude fell to 10% of its peak value at 11.0 degrees from the source with a 1.0 mm deep source. While for a 10 mm deep source, the amplitude fell to 10% of its peak value at an angular displacement of 52 degrees. Clearly, most of the power in the surface EMG signal comes from the muscle fibers that lie a few millimeters below the skin, while most of the cross-talk originates in deeper muscle fibers.

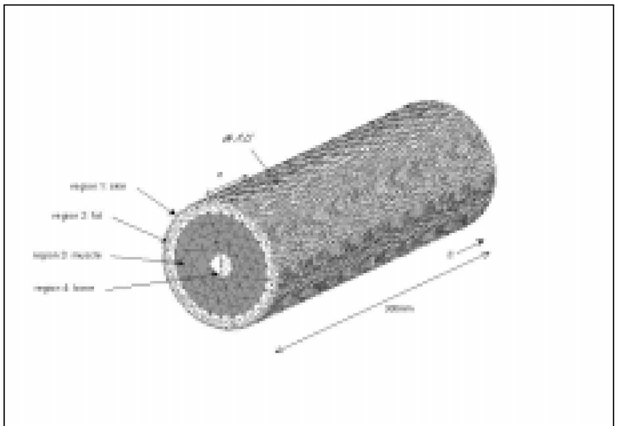

***Fig. 4**: Finite Element Model including skin, fat, muscle, bone and realistic transmembrane potential sources.*

When a 9 mm layer of subcutaneous fat was added to the model, the amplitude of the surface EMG signal decreased and the cross-talk around the limb increased. For a source 1.0 mm beneath the surface of the muscle, the amplitude decreased by 86% and the angle at which the surface EMG amplitude fell to 10% of its peak value increased to 27 degrees. Thus we see that subcutaneous fat significantly decreases surface EMG signal power and increases cross-talk.

Ongoing research is in progress to study the affect of diffuse muscle activation (a more physiological condition), quantify the affect of different thicknesses of subcutaneous fat and to see how small a nerve-muscle graft can be while maintaining an independent surface EMG signal. We also plan to study ways of increasing myoelectric signal independence with simple surgical manipulations. These may include liposuction of subcutaneous fat or placing insulating barriers (such as sheets of silicone) between nerve-muscle grafts. Our hope is to be able to apply some of these methods for improved control of myoelectric prostheses to human amputees within the next three years.■

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