Tong BME R & D Follow-on Award
Grip and Twist
Nathan Kleinhans and Sasha Cai Lesher-Pérez

Stroke is the number one cause of adult disability in the United States. Of the 700,000 people affected by stroke each year, a third of the survivors will have a severe, long-term disability. Currently there are no standardized forms of physical therapy and rehabilitation of paretic limbs and disabilities. Rehabilitation centers throughout the United States utilize systems with varying degrees of sophistication to regain bodily function following hemiplegia, paralysis on a lateral side of the body caused by stroke, which is the most common outcome of stroke. A stroke occurs when there is an interruption of blood supply to the brain. The current rehabilitation systems range from squeezing a ball, to a robotic arm system that mirrors the movements between hands. Our design group has been working with the Medical College of Wisconsin, after we took on the problem statement they proposed of designing a portable, universal device for acute rehabilitation of the paretic hand after stroke.

The goal for our device is to increase mobility within stroke victims by assisting the patient to regain supination and pronation of the wrist and flexion, extension of the hand as well as finger dexterity. We would like to make a device that fits in between the two extremes of practiced rehabilitation. By designing an intermediate device, a medium will allow for the benefits of having more autonomous exercises with a more economical solution. With a rehab method that focuses on these motions of the wrist, the number of long-term disabilities could be decreased by working muscle memory in the hand.

Prior to any explanation – of what has been or will be constructed, we would like to illustrate the final envisioned device:

We would like the patient of any size to be sitting up in their hospital bed or a wheelchair; the Grip and Twist will be placed in front of them either on a table or a wheel chair tray. The physical therapist will easily place their hand (left or right, whichever one needs rehab exercises) into the Grip and Twist with the patient's hand in the vertical direction. Adjusting the armrest, the patient will be comfortable and have proper support under their elbow. The physical therapist will then choose a setting, based on the exercises the patient can perform or should be attempting to perform. Once the Grip and Twist is on, the patient will receive audio/visual cues to supinate/pronate as well as extend and flex their hand and move their fingers. If the patient will not be able to fully complete all the specified exercises and when they are not able to complete the exercise the device will assist them.

This device will focus on rebuilding the neuromuscular network for those patients post stroke; flaccid patients will be able to regain motion by practicing motion and having active assistance in reaching the desired positions and motions. Patients with rigor will be able to receive stretching from this device, which increases vascular flow and elasticity of the muscles, as well as have assistance in overcoming the rigidity in their limbs.

By the end of the academic spring semester, our design consisted of three components: an adjustable arm rest; a motor powered wrist rotator; an inflatable bladder (Fig. 1).

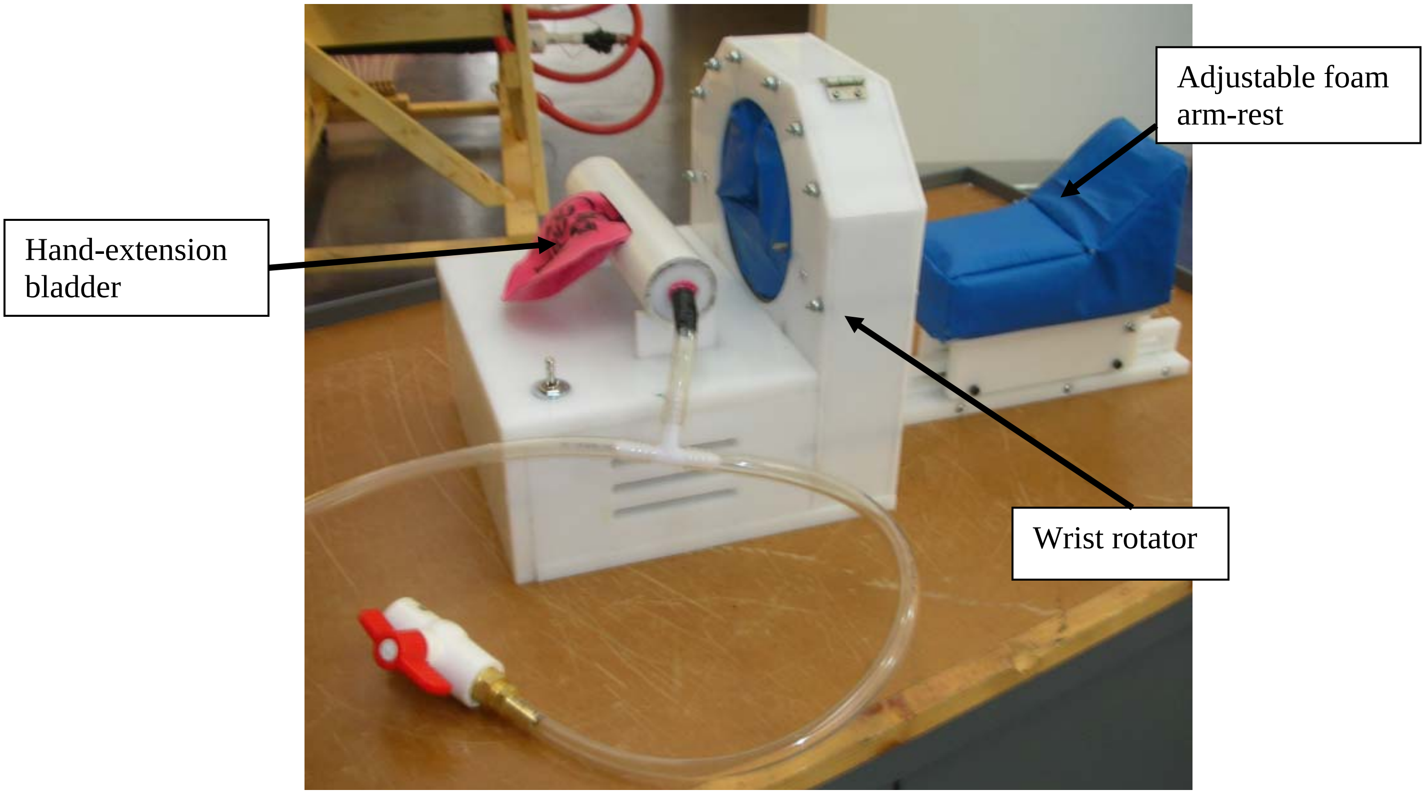

Figure 1. Picture of the prototype built by the end of the 2007 spring semester; The wrist rotator is powered by a 12VDC motor that is enclosed within the hdpe box underneath the inflatable hand-extension bladder. The motor is controlled by a dp/dt switch.

Current Design/Prototype

The wrist rotator consists of a horizontal cylinder that the patient can place their wrist into. The cylinder was made of 6” diameter PVC. The top will be notched to allow the patient to place their wrist into the device. The cylinder will have different sized padding inserts, small, medium and large, so that the device is compatible with various wrist sizes, these will also provide a comfortable support for the wrist. The padding will be covered with a material that can be easily cleaned between users. The cylinder is supported by an enclosed structure that contains bearings to allow for smooth rotation of the cylinder. The motor is housed in a box adjacent to the wrist rotator. A toothed gear runs along the outer surface of the wrist rotator cuff and is meshed with a compatible gear that is powered by a 12 V DC motor. This semester, the motor was connected to a manual DPDT switch to allow for the clockwise and counterclockwise rotation of the wrist rotator cuff.

The hand grasper is based on an air pump and bladder. A pneumatic actuator fills a rubber bladder that the patient grasps. As the bladder is inflated, the fingers are extended. The grasper is powered by an air pump and controlled by manual valves that regulate the air entering and exiting the bladder. The hand grasper at this moment is separate from supination/pronation of the wrist but we plan to incorporate these two motions in the future.

Finally to incorporate the largest amount of patients our prototype has an adjustable armrest, allowing for a distance, from the elbow to the wrist, of 5 – 12 inches from the wrist rotator. Through anthropomorphic data, we established that 98% of the demographics would fit in this category. The armrest is adjustable in half-inch increments allowing for a relatively large range of users to comfortably have their elbow support and add to the stability while using the grip and twist.

Future work

This device is still in the early stages of development. While our current prototype is a good demonstration of proof of concept, it still lacks the functionality to be applicable in a clinical setting. This award would allow us to reconstruct and refine our prototype to make it safer, more efficient, and better suited for clinical testing. After the construction of the current device, talking with faculty, consulting doctors and advisors, we have some changes that we know will be necessary to implement prior to any testing in the fall or spring of the next academic year. These changes are the following:

- reduce the weight and size of the system's components built thus far;
- incorporating a new mechanical design for finger dexterity rehabilitation;
- design a feedback system that will engage the motor control so that the patient will be able to do both assisted motion and independent motion;
- incorporating both the movements, wrist rotation and finger movement/flexion/extension, at the same time to more adequately rehabilitate the patients for daily activities and use of their impaired hand;
- incorporate embedded systems with variable settings into the design to allow a larger range of rehabilitation exercises to patients and also reach more patients with varying degrees of impairment and need of rehabilitation.

The Tong Biomedical Engineering Research and Development Follow-on award will assist us specifically, by sponsoring one student, Nathan Kleinhans, with a small stipend this summer to remanufacture the prototype in a smaller model, implement a system to engage the motor in our device to allow for both autonomous and assisted motions, and develop a new component for more specified finger rehabilitation. The tong award will also contribute by assisting a student, Sasha Cai Lesher-Pérez, over the fall semester with a small stipend to incorporate an embedded system controller which will have multiple programs to allow different exercises and rehabilitation regimes to be accessible by the physical therapist and also allow for a diverse amount of exercises to test in our pilot study in the clinical setting. Beyond the financial support to implement these various components, the award will assist in providing materials for further progress of our design.

Summer Research and Manufacturing Award Development

Below is the specific work that will be done with the assistance of the follow-on award.

We feel the modifications previously stated are important prior to clinical testing, rehabilitation implementation, and commercialization. Having a smaller, lightweight device will allow a larger accessibility to patients. By making a rehabilitation device that will allow for semi-autonomous or autonomous rehabilitation exercises, you can have patients practicing exercises prior to seeing the therapist and with the therapist they can focus on more specific exercises or other rehabilitation exercises the patients may need. Also having a portable device, patients will be able to have access to rehabilitation exercises while in bed or at a table prior to seeing the physical therapist. There will be efforts this summer to reduce the weight of our design, currently with our unfinished prototype our design weighs 17.3 lbs; our maximum desired weight is 25 lbs. We, however, have not fully incorporated all our components so this summer we would like to reduce the size and weight of the components already fabricated to allow us to reach our maximum weight and not surpass it.

Another modification is creating a feedback system, Another modification is creating a feedback system that will allow the motors, which power the device, to be engaged or disengaged; this will allow the patient to perform the motion on their own or with the help of the motor. When the patients are capable of doing the specified motions, we would like them to do it without active assistance from the device's motors. We will be creating a feedback system that will allow them 5-8 seconds to do the specified motion and if they have not completed it in the allotted time, the device will assist them in completing the motions. The motors will then become engaged and actively move the patient's hand/wrist in the specified motions. This aspect is especially critical for patients within the flaccid phase, most typically the first stage, the first three months, post stroke. These patients will have limited or no motion, so by assisting them with specified motions, the goal is to have the neuromuscular network be rebuilt. Once they have gotten an audio/visual cue for the movement, they are mentally attempting to move their muscles, however due to the disability; the motion isn't able to be completed. So our device will assist the muscles to complete the motions, this will allow the user to rebuild a series of networks to help them regain motion and eventually muscle development.

Finally, the new component will focus on rehabilitation of the hand, more specifically, finger dexterity: flexion and extension. The intended design is a more mechanical approach then currently used. We will be fabricating and testing a mechanical hand, which will be connected to the patient's paretic hand from underneath, see Figure 3. When the patient receives the audio/visual stimulation to practice a specific movement the hand will assist the patient, if they are unable to perform the motion autonomously. The patient will have each finger strapped onto one of the individual "fingers"; the mechanical fingers will move independently from each other allowing the patient to achieve refined motion when they are at that stage of rehabilitation. If the physical therapist would like the patient to focus on gross motion at the beginning stages of rehabilitation there will exist a program setting for the fingers to move in unison. The goals for this component are to increase mobility within the patients hand and assist in rehabilitating a larger range of specified movements, from gross motion to grasping specific object, as well as being able to provide resistance when they are at the stage of muscle building and toning.

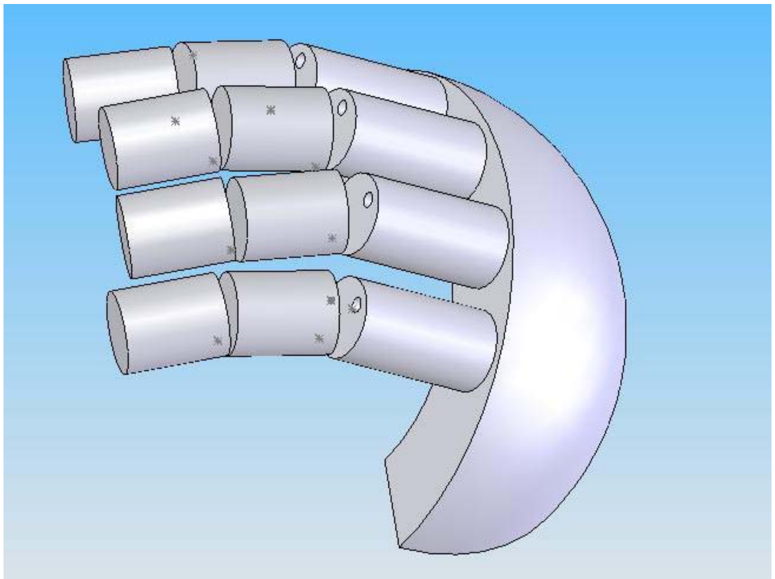

Figure 2. Solidworks design of the mechanical hand, in this design there lacks the motors that will be controlling each finger through a worm gear/spring system.

These three aspects will be taken on by Nathan over the summer while the rest of the team will focus on learning how to write IRB's, learning how to program microprocessors, and develop a way of incorporating the two motions (wrist rotation and grasping/finger movements), so that the patient can practice real world applications in our device.

Fall 2007 Research and Manufacturing Award Devolpment

There will be further design development in the fall, the follow-on award will assist by allowing Sasha Cai to focus his attention and time beyond the other aspects of the project to write a variety of programs while working with physical therapists to properly implement their desired exercises into our device's microprocessor (Brainstem Moto Motion Controller). The goal will be to have these variable programs so that during our clinical pilot study we will have a variety of patient's needs met. Thus, we will more accurately weigh our devices strengths and weaknesses before refining the physical hardware and software programming. Also by having multiple programs, we will be able to test our devices on a broader range of patients.

While Sasha Cai will be working on the software programming of our device to make it fully functional and automated through the microprocessor, the rest of the team will work on full incorporating the rotation of the wrist and the flexion/extension of the hand and finger movement as well as finishing the submission of an IRB with the MCoW personnel. We have already been guaranteed support in obtaining access to patients through the Medical College of Wisconsin rehabilitation clinics and will be working with doctors and physical therapists to maximize the functionality of our device.

Other Considerations

In the spring 2007 semester, our design team submitted an invention disclosure report to Wisconsin Alumni Research Foundation (WARF) and met with a representative to discuss our prototype as well as the future advancement of our design and our prospective market for stroke patient rehabilitation.

Besides gaining intellectual property and establishing a patent of our device, we would like to get this device into clinical settings so as to assist patients who have been afflicted by stroke resulting in hemiplegia. We feel that this design can be highly commercial due to the need for rehabilitation devices and the scarcity of those that do exist commercially and in clinics. By introducing a universal device for regaining two of the most difficult movements after stroke, we feel we could bridge this gap.

Budget Estimates for Development

For Mechanical Hand and Prototyping Refinements	
HDPE	$90.00
5 * miniature fan motors	$70.00
Steel Rope	$10.00
Aluminum 1/2” rod * 4’	$15.00
Torsion Springs	$25.00
Memory Foam	$30.00
Velcro straps	$10.00
Linear Actuator	$55.00
Worm/Spur Gears	$110.00
Hardware (screws, eyehooks, etc.)	$20.00
Vinyl/Non-porous covering	$15.00
For Automation	
Module, 2 Motion Controller BrainStem Moto 1.0	$80.00
Module, H-Bridge Motor Control 3A EMF H-Bride	$48.00
Dual H-Bridge, 1.1A	$27.00
LED Screen and Switches	$50.00
Total Prototyping Material Costs:	$655.00