# AN EVALUATION PROGRAM FOR POWERED WHEELCHAIR CONTROL SYSTEMS

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## INTRODUCTION

Despite our continuous and deep involvement at the VA Prosthetics Center in the evaluation of both conventional and powered wheelchairs, we have not previously devoted efforts to special control systems for powered wheelchairs. We have reported our experiences in evaluating a number of powered wheelchairs, including the E & J Power Drive, Model 840; the Motorette; and the Power Aid, among others. In fact, we have previously proposed standards for powered wheelchairs (BPR 10–11, p. 9). However, all of our experience to date has been focused on the utility of these devices for patients with some *useful degree of hand and/or arm function.* We have not had occasion in the past to consider the problems of those quadriplegics and other similarly afflicted patients who are incapable of operating the integral control systems of commercially available powered wheelchairs because they do not have the required hand and arm function. The Power Aid, a product of California Medical Aids, Inc., for example, requires at minimum a certain degree of useful shoulder motion and a significant amount of hand function. The Motorette can be operated with perhaps less residual function requiring only the use of the hand, and to some extent the wrist. Similarly, the E & J Power Drive is controlled by low force, low excursion joy stick motions. In the absence of adequate hand function, non-conventional controls; i.e., those operated by other than hand and arm motions, must be used.

A limited search for a device indicates that although several have been designed for non-manual control of powered wheelchairs, the E & J Chin Control is the only one sold commercially. Five or six other non-manual control systems for powered wheelchairs have been described in the literature; however, none of them has been extensively applied in VA

Spinal Cord Injury Centers. Upon analysis, the reasons are clear. Even simple devices such as the E & J and Engen chin controls cannot be used by large numbers of patients *without substantial modification or customization.* Others are far more complex and even at this writing, highly experimental. In the absence of engineering personnel and facilities, most would be difficult to install, and moreover, these systems are adequate for only a fraction of the patients who require non-manual control.

In the absence of comprehensive evaluation studies on these devices it is difficult for clinicians to prescribe the most effective control systems for their patients. This is particularly true in the Veterans Administration Spinal Cord Injury Centers. The Spinal Cord Injury Services at the Bronx and Castle Point VA Hospitals are attacking these problems by individually adapting the few available systems for use by their own patients. The VA Prosthetics Center is cooperating with both of these hospitals in a program to evaluate the utility of the available devices with a view toward improvement and further development, if necessary. The following is an outline of a program in progress to find suitable devices and improved means of adapting these devices to the individual needs of these disabled veterans.

## CLASSIFICATION OF PATIENTS

The first step was to conduct a survey and an analysis of the patient population requiring powered wheelchairs. Several classes of patients were defined. One group consisting of paraplegics and even certain partial quadriplegics was found to be capable of propelling conventional non-powered wheelchairs, in some cases by means of wheel pegs (Fig. 1). A second group, principally partial quadriplegics, was also capable of propelling conventional or modified powered wheelchairs but only for short periods of perhaps an hour during the day. A third class was identified consisting of those patients who were completely incapable of operating either conventional chairs or powered chairs with manual controls. The first phase of our program is concerned with the problems of the last two classes of patients.

Patients who can only operate conventional chairs for short periods of time are being furnished the Power Aid and the Motorette systems in an effort to determine the value of intermittent use of powered wheelchairs during the day. Use of the conventional chair will provide sufficient exercise to maintain muscular tone. The onset of fatigue will not mean they must remain immobile during the rest of the day. By switching to another chair equipped with a powered system or by attaching the powered system to his otherwise conventional chair, the patient will continue to be mobile.

Those patients who cannot possibly employ manual control systems of any type are the principal focus of the second phase of this program.

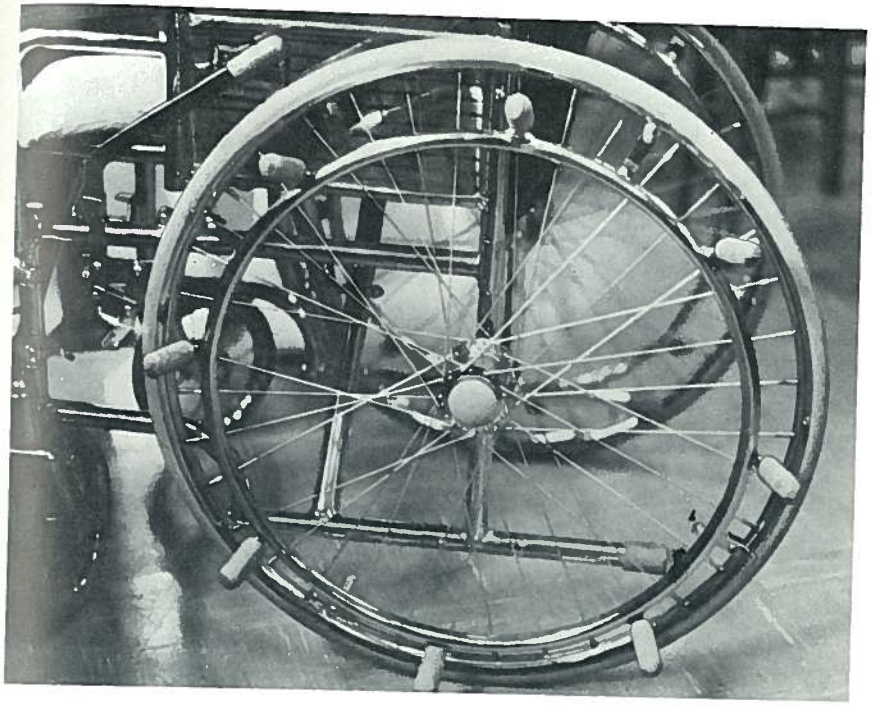

FIGURE 1.—Wheel pegs.

Our plan is to equip each of them with the E & J Power Drive, Model 840, wheelchair, *but with several different non-manual control systems.* Patients who can operate the E & J or the Engen chin controls will be furnished these devices modified in accordance with the residual capabilities of each patient. For those who are incapable of operating these devices we have taken steps to procure models of the Rancho Los Amigos Tongue Switch, the Sonic Control System of Professor Newell, and the Hayes Photodetector Sight Switch System. Another such device, available on special order, is a pneumatic control system procured through the National Institute for Rehabilitation Engineering, Pompton Lakes, New Jersey.

## DESCRIPTION OF CONTROL OPERATIONS

The E & J Chin Control (Fig. 2) and the Engen Chin Control (Fig. 3) are quite similar. Both are modifications of the standard E & J joy stick manual control for powered wheelchairs. Both have been modified by extending the joy stick and installing a chin cup. The Engen unit is packaged somewhat differently. In both units the control box is mounted on an extension bracket attached to the frame of the wheelchair. They

FIGURE 2.—E & J Chin Control.

are readily installed by an orthotist with some experience in the handling of electrical devices. Standard electrical wire connectors and terminals are used. In both cases, forward movement of the chin causes the chair to go forward, and a backward movement causes the chair to go in reverse. Motion of the chin to the right or left causes the chair to move in the corresponding direction.

The Rancho Los Amigos Tongue Switch Control (Fig. 4) is actuated by the tongue, lips, or teeth of the patient. A bank of three pairs of switches actuated by three levers controls the direction in which the chair is driven and the power input. One pair of switches controls the forward and reverse motions of the chair, a second controls the right

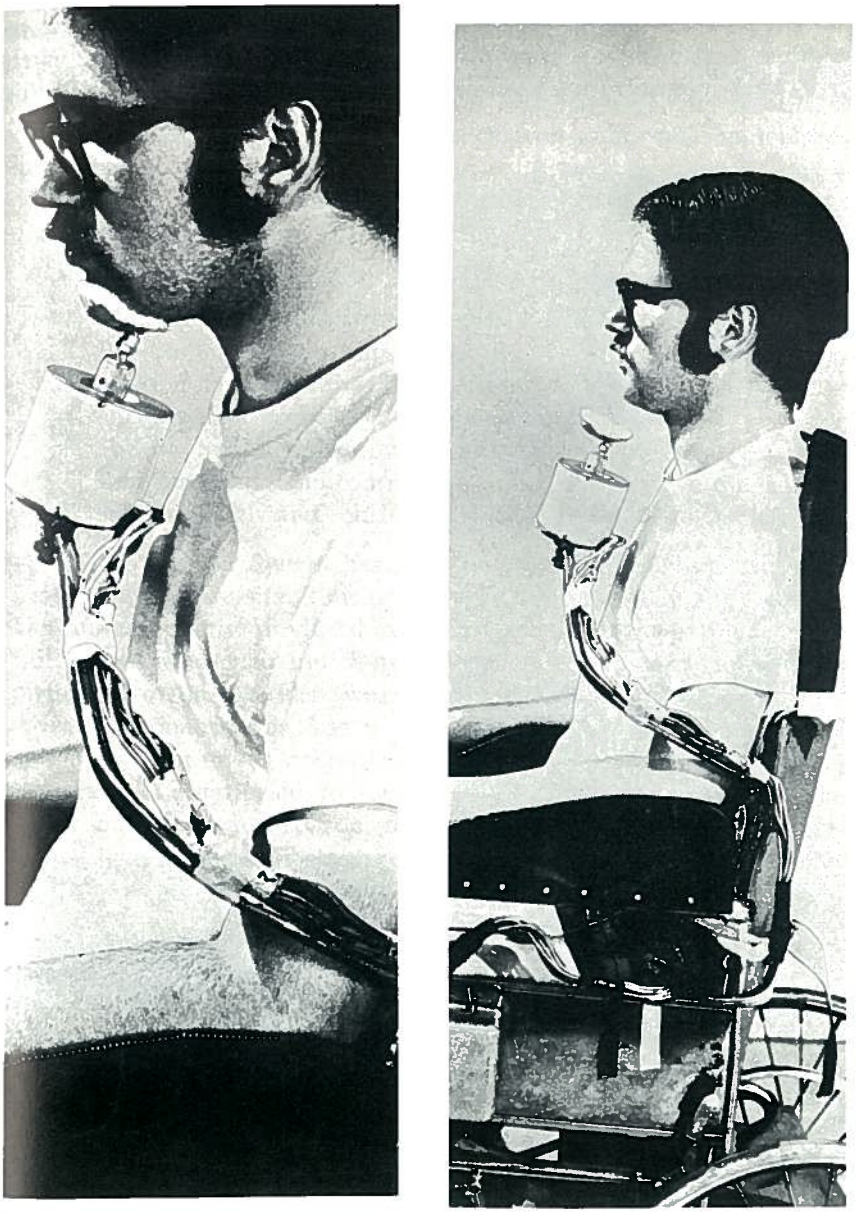

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FIGURE 3.—Engen Chin Control.

and left directions, and a third turns the power on or off. A novel feature of this device is another pair of switches positioned on one side of the head by means of a bracket attached to the rear of the wheelchair. This pair of switches, actuated by a lever, operates a small motor which swings

the entire bank of control switches to the side and away from their normal position in front of the patient's mouth. Pushing this lever to another position by an appropriate head movement swings the switch array back into operating position. The instructions furnished with this

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FIGURE 4.—Rancho Los Amigos Tongue Switch Control.

device are not completely clear and its installation is significantly more complex than either the Engen or E & J chin controls.

A pneumatic control system, the "Puff and Suck," is also available. When the wheelchair occupant puffs or sucks through an air tube, he controls the motion of a powered wheelchair. An electronic control box, mounted on the side of the wheelchair, is operated by the occupant by means of this air tube which is located between the control box and the occupant's mouth.

The following functions can be generated:

1. Blowing hard propels the wheelchair forward.
2. Blowing hard again stops the chair.
3. Sucking hard stops the chair suddenly.
4. Sucking hard propels the chair backward.
5. Sucking hard again stops the chair.
6. Blowing gently and continuously turns the chair to the right.
7. Sucking gently and continuously turns the chair to the left.

A Sonic Control System has been designed by Professor Newell of Texas A&M University. This device senses variations in the frequency of a humming noise produced by the patient. Different frequencies control various wheelchair functions. The system consists of a throat microphone, an on-off shoulder switch, frequency meter, audio amplifier, a series of resonant reeds, and various types of relays. According to the developer, continuous operation of the wheelchair is possible so long as a sound of appropriate frequency is produced by the patient. Motion of the chair in each direction (forward, reverse, right, and left) is controlled by a given sound frequency. The shoulder switch prevents inadvertent operation while talking and is essentially a power cutoff. The frequency meter indicates to the patient the frequency of the sound he is emitting and enables him to adjust it for the desired function.

A Sight Switch Control has been developed by Hayes International Corp. A photodetector is actuated by a predetermined level of light intensity radiated from light sources mounted in the frames of eyeglasses worn by the patient.

The light sources are mounted in a pair of standard eyeglass frames. Forward and reverse motions of the wheelchair are controlled by the left eye through a "forward-stop–Reverse-stop" sequence. The right eye is used to turn the chair through a "right turn-neutral–left turn-neutral" sequence. The switches are actuated by definite upward and outward, diagonal glances. If the operator looks ahead, to the left or right, or hard upward, the switches will not be actuated. In the event of a malfunction or the inability of the patient to effect control, a safety circuit stops the wheelchair. A special time interval circuit interrupts

power to the drive motors when the time between inputs from the sight switch exceeds a selected time interval from 5 to 20 seconds.

## PRELIMINARY RESULTS OF EVALUATION PROGRAM

To date in our program, only the E & J and Engen chin controls and the Rancho tongue switch control have been used by several patients. Both chin control systems have the advantage of utilizing natural body motion which are well correlated with the corresponding wheelchair functions. Both systems are quite reliable, having functioned adequately without maintenance for reasonable periods. In addition, both display the same shortcoming in that the chin cup must be custom contoured to match the chin of the patient.

The Rancho Tongue Switch, in contrast to the chin controls, has the advantage of permitting the patient to swing the device away from its position in front of his mouth by means of a head control switch. It is, however, highly over-designed for wheelchair control, as it was originally designed to operate both a wheelchair and a powered upper-extremity orthotic device. For wheelchair operation purposes alone, therefore, it is unnecessarily expensive and with extra components perhaps more subject to breakdown. In addition it requires a more complex installation procedure than do the simple chin controls.

To pursue this program a protocol has been established to furnish powered wheelchairs and various control systems to appropriate patients and to monitor their experiences systematically. The program at the Bronx VAH is under the supervision of Dr. Peter Hofstra, Chief, Spinal Cord Injury Service. Participating in this program at that Center are Mr. Kenneth LaBlanc, Acting Chief, Orthotics Laboratory and Mr. Wendell Browne, Supervisor, Corrective Therapy.

At the Castle Point VAH the program is under the supervision of Dr. Emilio Ejercito, Chief, Spinal Cord Injury Service (and Chief, PM&R Service), and Mr. Michael DiPompo, Acting Chief, Orthotics Laboratory, is participating. Mr. Ronald Lipskin, Staff Engineer, VA Prosthetics Center, is providing the bioengineering support for both of these programs. The immediate goal of the VA program is the procurement of electrically powered wheelchairs with an assortment of control devices to enable patients to become mobile. These experiences will provide sufficient data to guide us in evaluating and optimizing existing devices as well as developing design specifications for improved control systems.

The study is designed to shed light on the following questions:

1. *Optimum man-machine relationship.* What is the ideal patient-wheelchair interface? How can we achieve natural, rapid, and efficient response of wheelchairs to patient desires? Can the system be effectively

learned in a few hours or is an extended learning and practice period required?

2. *Installation.* How much service is required of the engineer, electronics technician, or orthotist? What is the most effective means to power a conventional wheelchair?

The following kinds of data are being collected:

1. Patient background.
2. Instructions, maintenance, repair.
3. Patient response and reaction.

Motion pictures are used to record the patient's complete range of motion, his use of the control system as originally received, and the control system with any modifications which improve his effectiveness in operating the wheelchair.