NEW HEAD CONTROL FOR QUADRIPLEGIC PATIENTS

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INTRODUCTION

Our main objective in carrying out this project was to provide the quadriplegic patient, who cannot use his arms, with means of control over his direct environment. Residual head motion was considered to be adequate, first, to control an electric wheelchair and, second, to extend that same control to an orthotic device which may include an active elbow and a prehension orthosis. The latter is still an ongoing project.

In our latest developed myoelectric proportional pulse control system, provisions were included in the design to accommodate either myoelectric control signal or displacement tranducers with the ultimate goal to control prostheses and orthoses and, with some adaptations, an electric wheelchair (1). In the meantime, private firms have included in their commercial items electronic proportional controlled wheelchairs. Due to this factor and also at the urgent request of our clinical staff, it was decided to use the Everest & Jennings model 33 hand-controlled electric wheelchair, with our incorporating the necessary modifications for the integration of our projected head control unit.

HEAD CONTROL UNIT DESIGN CRITERIA AND CONSTRUCTION

Although various head controls have been designed by other groups (2, 3), in addition to chin controls designed by Everest & Jennings and by Engen, it was thought that a new approach utilizing a single head lever control moving in one plane was feasible. The advantage of this approach would be to minimize the head movments and to obtain a faster and smoother control of an electronically controlled wheelchair.

The shape and the physical location (Fig. 1) of the control unit relative to the head were dictated by the following factors:

a. The cosmetic appearance.

b. The safety factor which should obviate any possible trauma to the patient.

c. Minimum interference with the remaining activities, such as talking, eating, etc.

d. Maximum control stability over an uneven road or pavement. This last statement was confirmed by the clinical evaluation which indicated that the above-mentioned configuration helped and improved the lateral stability of the patient's body since he has to maintain a certain pressure against the head unit.

FIGURE 1.—Closeup of the head unit using a single axis lever for the speed and steering of an electric wheelchair.

Single plane movements of the head were the only ones retained for the steering and the speed control of the chair, and the use of a standard potentiometric joystick was decided upon, although this requires transformation of 180 deg. solid angle revolution to 90 deg. solid angle and then 90 deg. to single plane movements. This transformation was accomplished by using the mechanism, shown in Figure 1, with the result that only one-half of the joystick hemispheric range is now used. Consequently, inversion of the electronic control has to be initiated every time that motion reversal is required. This inversion is done through a brief elevation of one shoulder against a push button located above it. Finally, the single plane movement of the head amounts to a linear backward motion of approximately 1 in. and an angular rotation of ±15 deg. from center position. This angular rotation appears optimal since further reduction of the angular rotation may affect the steering stability.

Because a wheelchair is a public vehicle, special attention was given to the safety and reliability of the control mechanism, which has been designed using low friction bearing on the moving parts. Low friction is essential since it prevents the jamming risk and reduces the force required for a smooth and comfortable operation. To further insure safety, two extra features were incorporated in the electronic control (Fig. 2): The first was an emergency cut-off switch which could be operated by the unused shoulder, and the second was an electronic circuit, whose function is to prevent motion reversal of the wheelchair when the speed exceeds a certain predetermined limit. Motion reversal above this limit may cause the chair to overturn or throw the occupant out of the seat.

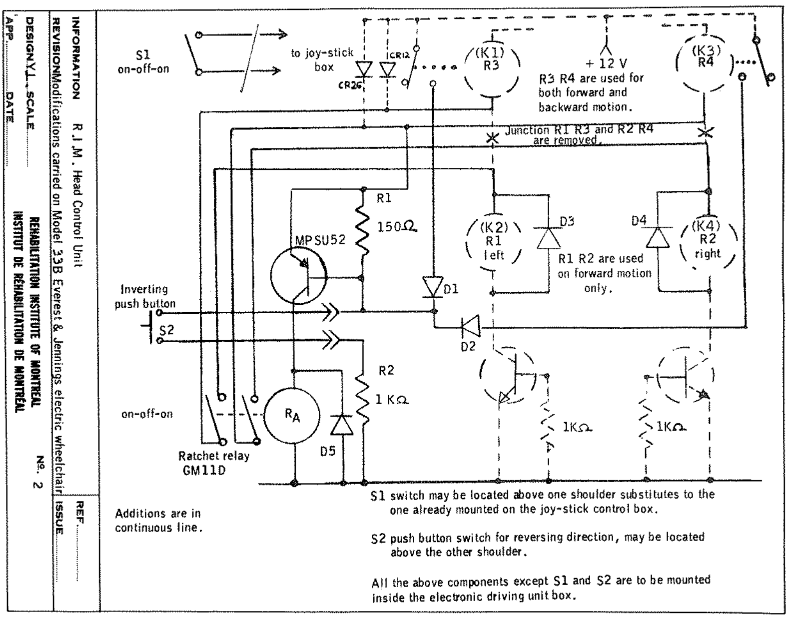

FIGURE 2.—Electronics modification carried on model 33 Everest & Jennings electric wheelchair.

WHEELCHAIR ADAPTATIONS AND TRAINING PERIOD

From the onset of the project, the patients were closely followed by the physical and occupational therapists in order to establish which types of wheelchair adaptations and adjustments were necessary. The areas observed which affect the use of the head control unit and the subsequent control of the chair were posture and positioning, sitting tolerance, and spasticity.

All the patients required some form of rigid external support which enabled them to be positioned in the same manner whenever they were placed in the chair. Accuracy of positioning was fundamental in adapting the chair because it was observed that the patient had difficulty in using the head unit if he was too low or too far to one side in the chair, or because of a deformity such as a scoliosis.

The wheelchair backrest provided some trunk stability and varied from regular to very high. In one particular case, for better support a standard wheelchair table was used, and two wings constructed of thin metal covered with felt were attached onto the lateral aspects of the cutout portion (Fig. 3). These wings, approximately 4 in. × 4 in., were shaped to follow the curvature of the midthoracic area. In the above case, the patient used several adaptations and orthotic devices and therefore required the table. However, in the majority of the cases, patients had no upper-limb function. Therefore, the supportive wings were attached directly onto the backrest tubing of the chair. Of the two wings, one was solid and the other hinged; the latter could be folded flat in order to facilitate transferring the patient into the chair without danger of scraping or bruising. Armrests were sometimes widened and lengthened in order to provide greater support.

Varification of sitting tolerance involved testing several types of cushions and choosing the one on which the patient could sit for the longest period of time. It was found that with some of the very soft cushions, incorrect pelvis alignment occurred more frequently, causing uneven pressure distribution on the ischia.

To reduce muscle spasticity, patients were treated with muscle relaxant and/or antispasmodic medication. With some of the patients, wrist and ankle straps were employed to prevent the limb from being displaced as the chair was in motion.

The patients required several hours to adapt to the sensitivity of the head control unit. Following this, formal training consisted of approximately 1 to 2 hours per day for a week. Activities practiced included going along corridors, passing through a narrow doorway, turning around in a restricted area such as an elevator, approaching a table or desk without jarring it, going both uphill and downhill on a slightly tilted sidewalk, and riding over an uneven surface such as a lawn.

Finally, the patient's individual preferences and needs were always considered in producing the required modifications and adaptations.

CLINICAL EVALUATION

The clinical evaluation was performed in close collaboration between the Occupational and Physiotherapy Departments and the Research Department. This has consisted mainly in obtaining a continuous feed-

FIGURE 3.—Everest & Jennings electric wheelchair equipped with the RIM head control system.

back from the patients for a period of time ranging from 9 to 16 months. Three of our patients and one from the Health Sciences Centre of Winnipeg have been equipped with this head control unit and followed very carefully for the above-mentioned period. A fifth unit was made for Everest & Jennings, who had shown an interest and a desire to carry their own evaluation on our control unit.

Case Histories of Three Quadriplegic Patients

Case 1. A 20-year-old man suffered a spinal cord injury at the C3-C4 level, following a tackle during a football game. His injury resulted in breathing difficulties, weak neck muscles, and movements of the upper limbs limited to slight shoulder elevation and retraction. The degree of spasticity is moderate to severe. He received his chair in January 1973, and lives at his parents' home.

Case 2. A 20-year-old man suffered a spinal cord injury at the C4 level in a car accident. The remaining active movements of the upper limbs are limited to elevation, protraction, and retraction of the shoulders; the neck muscles are intact. The degree of spasticity is moderate to severe. He received his chair in June 1973, lives at his parents' home, and attends the university as a full-time student. He uses his chair on a full day's basis.

Case 3. A 22-year-old man suffered a spinal cord injury at the C4 level in a skiing accident. The remaining active movements of the upper limbs are limited to elevation, protraction, and retraction of the shoulders. The degree of spasticity is moderate to severe in the upper limbs. This patient was previously equipped with a modified manual control system with which he had experienced a number of control difficulties. These difficulties were aggravated with spasms to the extent that he had completely lost control over his chair on many occasions. He received his new chair in June 1973, lives in an institution, and attends the university as a full-time student, but on a half-load basis only.

All three patients have a slight to moderate tendency to go into hyperextension while under spastic influence, but this body hyperextension does not cause any control problems, since two were able to control their head position for the entire spasm duration. Moreover, all three were sufficiently aware of their oncoming spasms, so that they had enough time to switch off the control using the emergency switch.

CONCLUSION

Following a few months of clinical evaluation, the feedback from the four patients (including the Winnipeg patient) has shown that:

1. They are all very pleased with this control system which gives them a greater degree of freedom.

2. The patients' adaptations to the control and the learning speed have proved more successful than expected, even to the extent that two of the patients wished for an increase in the maximum forward speed.

3. The unit appears to be reliable, and we feel that it should be made available as a standard rehabilitation device, which could be fitted in most centers with minimal custom adaptation made for each patient.

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