Externally Powered Management of the Quadramembral Amputee Using a Modified Thoracic Suspension Orthoses as a Platform

John R Zenie MBA, CPO

The female client was initially evaluated, at a regional rehabilitation center, specializing in early development and adolescent reintegration of children to maximum mainstream capacity. The initial presentation of this seven-year-old female multilevel congenital amputee was in the presence of the therapeutic rehabilitation team, the child presented with independent mobility in an externally powered wheelchair. Direction and speed of the wheelchair are controlled, utilizing a proportional multidirectional chin switch mounted on the right upper corner of the powered chair. The clients’ body position is maintained using custom fabricated seating interface system complete with bolsters. At the time of initial evaluation a platform based thoracic suspension orthoses was being fabricated. The design was to incorporate an erect posture when outside the chair. Removal of the bolsters from the seating system allowed the orthoses to be utilized in the chair. The objective of prosthetic intervention was to provide functional grasp and release as well as positioning of the terminal device in space. In an attempt to simplify and increase the utilization of a prosthetic device the decision was made to utilize the exterior wall of the suspension orthoses as the platform to incorporate an externally powered arm. Physical evaluation finds the patient’s anatomy compatible with a frame type, shoulder or scapular thoracic prosthetic socket. This alternative was rejected on the basis that it would require removal of the positioning orthoses for utilization. The positioning orthoses is modified proximally on the left upper margins so as to allow increased scapular and shoulder girdle movement. The left quadrant of the body was selected for prosthetic management so as not to interfere with the existing chin switch control of the powered wheelchair. It was believed that the ability to have independent mobility and grasp/release was a prerequisite for the patient to achieve maximal independence.
Evaluation of the patient’s physical anatomy found the range of motion about the shoulder girdle to be within normal limits. Electromyographic testing finds major muscle groups that are intact produced sufficient signal to control an externally powered prosthesis. However, signal consistency, and differentiation of individual muscle groups provided cause to believe that myoelectric control may not prove viable with this particular client. An evaluation of the clients’ ability to target specific areas on a frame superstructure provided encouraging results and prompted further exploration of force sensitive resistors orientated in a highly specific array to gain control of multiple output devices. The devices considered initially for the system included a proportionally controlled terminal hand device, a wrist rotator, and an electric elbow. The electric wrist rotator is also fitted with a constant friction multidirectional wrist flexion unit. Proximal orientation of the prosthetic extremity was to be achieved utilizing a constant friction shoulder joint that permitted flexion and extension as well as controlled abduction. Particular attention is paid to the orientation of the shoulder joint so as to maximize functional tasks near the face with the elbow in maximal flexion and the wrist in normal pronation.

The initial production of the frame type superstructure began with a direct casting of the client’s residual anatomy in neutral orientation in an erect position within the modified suspension jacket. This casting technique allowed for the trimlines of the suspension orthoses to be captured in the model. The initial fitting was conducted using a low temperature clear thermoplastic to permit precise target location for the proposed force sensitive resistors. The anterior F. S. R. was conceived as the input to close the terminal device, initiate pronation and provide elbow flexion. The posterior FSR was conceived as the input device to open the terminal device, supinate the wrist and extend the elbow. A small rocker switch was mounted on the superior anterior margin of the suspension jacket as a mode selector between hand and wrist. Through initial trials and experimentation precise placement of the rocker switch for hand/ wrist mode selection was determined and consistently operated via a brief momentary contact with the chin. Additional experience with the system found that the number of output devices became difficult for the client to operate consistently. As a result of this experience in additional F.S.R. type switch was mounted directly superior to the residual anatomy. The client had difficulty targeting the relatively ambiguous input device. As a result the input was replaced with a second rocker style switch. Utilizing only one pole on this switch momentary contact was used for elbow flexion/extension control. The microprocessor controllers utilized allowed for refinement of this strategy so that contact with the active pole produced elbow movement for as long as contact was maintained. Any interruption in this contact resulted in reversing previous elbow drive pattern and direction. This methodology of control in the elbow sacrifices proportional control of the elbow speed in favor of consistent operation. It is believed that this compromise is favorable in the contexts of functional activities. Further, it is believed that proportional output at the terminal device is significantly more important. Therefore utilizing two FSR inputs and two rocker type contact switches three output devices are controlled effectively. Once this strategy was programmed the client was able to demonstrate within a very short period of time prepositioning of the components in space in order to favorably approach
small objects of varying shape, size and durometer. These functional activities were demonstrated both while erect utilizing the standing base of the thoracic suspension orthoses, and while positioned in her electric wheelchair.

Internal lithium cells provide adequate power on a single charge for greater than one full day of use. This cell configuration allows for easy charging when the client retires to bed in the evening. The therapeutic staff has increased the complexity of tasks, progressively as the client has mastered each series of objectives. The single most exciting, and probably most significant task has been for the client to extend the elbow, rotate the wrist to an appropriate position and grasp a food product. Then reversing the sequence and consuming the food unassisted has been demonstrated. Upon achieving this goal the principal objective of independent mobility utilizing chin control of a powered wheelchair and the ability to manipulate objects in space unassisted has been achieved. The client to this day continues to utilize the system in excess of eight hours each day without significant incident or difficulty. Of particular interest is the increasing effectiveness client demonstrates in preplanning and executing ADL tasks. The clinical staffs unfounded concerns that the “novelty” of the system would wear off, resulting in an underutilized device has not been realized. To this end it was very encouraging that the child is now in fact requesting an upper extremity device for the contralateral side. As of this date, this request is being considered on its merits, and the implications and possible negative impacts of compromising the existing control strategy for the powered wheelchair are being evaluated.