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Mobility and Mobility Devices for the Spinal Cord Injured Person

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Introduction

In the dictionary, the preferred definition of mobility is "the quality of being movable."[13] A second definition, more sociological in scope, defines mobility as "the movement of people in a population, from place to place, or job to job, or social position to social position." The second concept captures the significance of mobility as it relates to the life of a spinal cord injured individual. Spinal cord injury is a condition that most commonly affects young, physically active adults who have already established a social pattern in their lives. Certainly, spinal cord injury (SCI) causes impairment of movement, but more importantly, it may constrain a person's capacity for self-directed, purposeful movements, which are important to almost all activities. Much of the medical rehabilitation of a SCI patient involves therapeutic interventions aimed at increasing the range, strength, and coordination of body movements that have been impaired by an insult to the central nervous system. To fully appreciate the scope of mobility impairments encountered by SCI patients, we must examine the entire spectrum of activities that can be affected by limitations of movements. Independence, social and personal interactions, career development, and access to public facilities are some of the freedoms that can be adversely affected by mobility impairment.[9]

A thorough discussion of the methodology for reestablishment of mobility for SCI patients must include topics such as therapeutic interventions, orthotic appliances for stabilizing and enhancing the performance of musculoskeletal components, devices for extending the range or speed of movements, and substitutions for lost or severely limited functions. This article will not dwell on therapy, which is more appropriate for other authors, nor on orthotic appliances, since that subject is covered well in the accompanying articles on spinal stabilization and upper limb orthotics. Rather, it will attempt to represent some of the mobility considerations that are common to SCI and to discuss the application of products and techniques associated with ameliorating movement limitations. For the sake of simplifying the myriad array of details that can be covered under the general heading of mobility, this article will survey a sequence of activities that start with static support of the body and proceed to increasingly more complex movements in terms of range, speed, and energy demand.

The author admits to a bias toward devices and technologies, which will be reflected in the discussions that follow, but he wishes to emphasize his belief that the only successful technical solution to a mobility problem is the one that integrates well with other rehabilitation interventions and withstands the test of time and use by the patient. Simplicity, cosmetic design, and reliability are essential to the immediate and long-range acceptance of adaptive technology by the user.[8]

Background

Spinal cord injury commonly results in permanent paralysis of some of the large and powerful skeletal muscles of the body. The location of the injury along the spine correlates roughly to the cumulative amount of paralysis that results. The closer the injury site is to the head, the greater the involvement. Trauma incurred at the spinal column can affect the transmission of the nerve signals to all parts of the body served by the injury site and beyond. However, functional deficits incurred by SCI are almost always incomplete, meaning seldom is there complete loss of function or bilateral symmetry of effects below the site of the injury (lesion). For the sake of this paper, however, it will suffice to consider only two general types of functional paralysis: paraplegia and quadriplegia.

Impaired voluntary control of skeletal muscles is not the only significant impediment resulting from SCI. Other organ functions can be affected as well. Bowel elimination, bladder voiding, sexual function, sweating, bone strength, and peripheral vascular circulation can all be altered in response to spinal cord insult. A common and troublesome side-effect is involuntary contraction of a muscle, spasm. Not only is the motor function of a nerve network affected, but also the sensory aspect. The combination of loss of sensation and reduced tissue blood circulation resulting from everyday bumps and pressures incur a high risk of undetected soft tissue damage. In insensate tissues, such seemingly minor injuries can easily progress into massive tissue death in the form of a decubitus ulcur. ''Decubiti'' are immensely threatening to a spinal injured person, not only because of the irreversible tissue damage, but also due to the extensive time loss and expense incurred in the treatment. All of these conditions must be kept in the forefront of planning for mobility and will be mentioned from time to time in the text that follows.

Transfer

The initial and simplest tasks of SCI mobility begin with rising from a reclining position, from which seated tasks, ambulation, or wheeled mobility can proceed. If starting from a bed, the person must first be able to sit up. A paraplegic or quadriplegic with good shoulder strength, may be able to sit up without assistance. Some may prefer to use an overhead handle, often called a trapeze, or a looped strap, to pull up into a sitting position. Sometimes a hospital type bed, with a powered drive to the articulated back section, can raise the person to a sitting position from which he can turn and let his legs off the bed in preparation for standing. A standing transfer, even with an attendant assisting is desirable because the weight is borne on the legs, but not by the attendant or a transfer device. If the legs are capable of supporting body weight, with or without bracing, the person may develop greater independence.

When the quadriplegic or high paraplegic is not able to stand without braces, the transfer from a sitting position to another seat is somewhat more complicated because of the physical strength required to lift the body, change levels between sitting surfaces, and traverse the distance. Transfer aids foster independence and supplement the work of an attendant. For wheelchair transfers, it may be helpful to use a sliding board (also called a ''transfer board''), a short length of wood or rigid artificial material that bridges the gap between two sitting surfaces, such as the bed and wheelchair. A paraplegic, and some low level quadriplegics, can momentarily life his weight and move in short, sideways increments from one surface to another. A strong and active paraplegic will probably vault by pushing downward with his hands or swing from an overhead handle, in lieu of being burdened with a transfer board. Even a person who cannot transfer himself can be aided by sitting on a piece of sturdy fabric which may be pulled sideways across the sliding board by an attendant.

If a sliding transfer is not possible, a person can be lifted while sitting in a fabric hammock by a mechanical patient life that incorporates an electrical motor or hydraulic jack mechanism to provide the lifting force. The hammock is attached overhead to the lifting device which is usually operated by an attendant. Some can be self-operated if appropriate fail-safe or emergency mechanisms are built in to compensate for equipment failure. Elaborate custom installations of overhead tracks can allow a person to be transported from bedroom to bathroom and beyond. Overhead lifts are also available for transferring from a wheelchair into a car, but with the advent of van adaptations, they are losing acceptance among users.

The lifting and sliding principles used in transfer aids are applied in many products used in home and institutional settings, especially in the bedroom and bathroom. A common application of the sliding-lifting principle is the bathtub transfer aid, a device used to help a person transfer safely into the bathtub and lower himself into the tub for bathing. Some products are completely passive, incorporating a sliding pathway for the user to traverse across the tub rim. Some are powered seats, often driven by faucet water pressure, that raise and lower the seated occupant relative to the tub bottom.

A more expensive form of lifting aid for the home is the vertical shaft home elevator that is used to give mobility between vertically separated living areas. Installation usually requires alterations to the structure of the building. A somewhat less expensive approach, where applicable, is the stairway elevator, which can be added to an existing staircase. Available as a chair for ambulatory persons and a platform for wheelchair riders, it typically follows the path and incline of the stairs and usurps a portion of the walking path. The least expensive adaptation for moving between levels, especially from outside, is the ramp. Ramps have been well defined in standards produced by the American National Standards Institute.[12] Outdoor elevators that are added on, rather than built into a building, usually called porch lifts, are made primarily for wheelchair users where ramp construction is impractical and a landing platform can be placed next to an outer door. Home elevators of all forms are usually sold and custom-installed by specialty vendors that are associated with vendors of other mobility aids.

Standing Aids

Paraplegics and quadriplegics, although unable to stand unassisted, can derive both physiological and psychological benefits from standing.[1] Being able to stand allows a wheelchair user to reach work surfaces and interact with standing people at their level. There are static devices, called standing frames, that hold a person in a standing position by binding him to an upright, rigid structure. The user must pull himself up from a seated position into the device and secure the binding straps or close and latch a supporting gate. The manipulations involved may require the assistance of another person.

A more complicated device that allows more independent operation by the user is the mobile stander that uses a power source to raise the person to a standing position and support him there. This principle has been incorporated into two forms of wheeled mobility. In the one form, the person may move slowly around for short distances on smooth surfaces after he rises to the standing position by controlling an electrically powered drive mechanism. In the other form, the assistive force standup mechanism has been added to a wheelchair. When the occupant is standing, the device is immobile. When the occupant is seated, it functions as a regular wheelchair.

Another standing device, but one that provides a modicum of mobility is the swivel walker, or "parapodium," that is used by a very few paraplegic adults.

Ambulation

Walking is the most common form of mobility for humans and the mode most desired by people who have limitations that diminish or eliminate their ambulation abilities. Where there is any possibility of a mechanism to regain the ability to walk or move about in a standing posture, even if it is slow and requires great expenditure of energy, a person often prefers to ambulate rather than use wheeled mobility. Even temporary standing, without walking, can be used to enable a person to get through narrow entryways, such as toilet compartments, bathrooms, and closets. The desire to remain upright has sustained the development and application of torso and leg braces, standing aids, and even artificial stimulation of paralyzed muscles by externally supplied electrical signals. At a lesion level around high thoracic, the instability of the torso suggests that ambulation may be less secure and more demanding of energy than wheeled mobility.

Stability

One of the more important considerations in assuring the fullest functional mobility of the SCI patient is stabilizing the proximal parts of the body in order to facilitate the most controlled movements of the distal portions. The person fitted with the finest of upper limb orthoses or supplied with the most elaborate vehicle control system will be substantially incapable of adequate performance if the body is not appropriately stabilized. Securing the proximal portions of the body is a critical consideration and can easily be both underestimated and overdone. It is quite common that a patient will be trained to substitute certain spared muscle functions for those that have been impaired. If a substitute muscle is occupied with stabilizing the torso, it will be effectively unavailable for its substitute function. Similarly, if the proximal base of distal limb segments has been too severely confined, the distal functions will be limited. In general, the SCI patient will be concerned with use of the upper body for control and work tasks, so the primary concern should be focused on providing a secure base for the torso, while retaining a sufficient range of upper body motion to allow the arms and hands to perform functional tasks. These principles will be restated more specifically in the sections that follow.

Wheeled Mobility

When walking is not an option, or when the upper limits of speed and range of ambulation are too low for the mobility needs of the person or the occasion, the indicated mobility aid is the wheelchair or any one of a variety of wheeled devices. The basic, most familiar form of the wheelchair is a shiny, tubular metal, open-framed structure that has four wheels, two small casters in front and two large drive wheels in the rear. Details of implementation vary slightly, but the design remains essentially the same from brand to brand. They are intended to fit an average sized person, withstand heavy use with minimal maintenance, and be propelled primarily by an attendant. A wheelchair produced for these purposes is known in the industry as a commodity wheelchair and is intended for temporary use by any one person but repeated use by many people. This is the type of wheelchair that insurance companies and government-based reimbursement programs provide for nursing home and convalescent use.

Chronic users of wheelchairs should not use a commodity chair, but should be guided toward the use of a prescription wheelchair, which looks similar to the commodity chair, but is available in a variety of dimensions that can be more carefully sized to the user and embodies some optional features that better suit the demands of everyday, independent usage. Prescription wheelchairs tend to be lighter in weight, more durable, and offer less resistance to rolling than the commodity type because of the use of more specifically suitable materials and components and more exacting tolerances in their manufacture. Available options include variations in wheel and tire size and type, variable seating dimensions and configurations, removeable armrests and footrests, and selection of frame and upholstery material and color.[15] The diameter of the wheel and type of tire affect the maneuverability, rolling resistance, and riding comfort. Hard rubber or polymeric tires offer less rolling resistance than pneumatic tires, but transmit more of the shock of pathway irregularities to the rider than the softer, pneumatic tires. Similarly, small diameter wheels offer less inertial resistance to rolling than larger diameters, but the greater curvature imparts higher impact forces to the rider and inhibits movement over rough surfaces.

For a chronic user, a wheelchair should be very carefully sized and the components and accessories selected to assure efficiency of operation, postural support, and prevention of medical complications of disability. In general, a wheelchair should be as narrow as possible without pressing against the hips, thereby allowing the greatest freedom of access through narrow passageways and the maximum of mechanical advantage for propulsion and control. The back height should provide good postural support, but minimize interference with the arms during a propulsion stroke. Low level, active paraplegics may prefer a very low back to maximize freedom of arm and upper body movements. The height of the seat bottom is governed by three dependent variables; arm access to the pushrims, footplate clearance above the ground, and even distribution of the sitting load along the underside of the thighs and buttocks (taking the compressed thickness of any cushion into consideration).[3]

The wheelchair seat cushion is a crucially important accessory component for a person who does not have sensation in the lower body and legs.[16] A cushion is intended to help distribute the gravitational loading forces of the occupant over the broadest possible area of the sitting surface and minimize the point pressure that occurs near the bony prominences of the pelvis and hips. There are many types of cushions that utilize a broad variety of materials and configurations, such as polyethylene foam, air and fluid-filled pillows, and semi-rigid and custom contoured devices. Each design has proponents who claim it is the best universal solution to the problem of pressure sores (decubitus ulcers), a major health problem for paralyzed persons with diminished or absent sensation. Since the formation of decubiti is related to many factors, such as pressure distribution and duration, temperature, moisture, diet, activity level and seating geometry,[10] it follows that no cushion can serve as a universal preventative measure. However, it is generally accepted by clinicians and users that there is a type of cushion best suited to each individual and careful selection for each person is important.

It has also become increasingly more common for wheelchair seating experts to recommend that the hammock-style seat be replaced with a rigid member to provide a solid support structure for the type of cushioning material that is chosen. Hammock seats tend to wrap around the buttocks, creating a squeezing and shearing force pattern that tends to restrict tissue circulation. Also, the hammock is inherently unstable as a support for a high center of mass.

The prescription wheelchair has recently undergone a rapid evolution in materials and design, resulting in lighter weight, smoother operation, greater durability and a change of image for the user. Wheelchairs are now offered in a mosaic of materials, colors, frame styles, and applications.[4] Largely because of the demand and innovations arising from the wheelchair sports movement, a new breed of daily use wheelchair has been developed and the market has accepted it with enthusiasm and buyer support. The new breed of wheelchair, now being labelled the "ultralight," embodies higher performance materials and design innovations including radial, rather than crossed (bicycle style) spoke patterns, aluminum alloy rims and hubs, die cast metal or injection molded polymeric wheels, adjustable position (fore/aft and up/down) and angle of axles, rigid (non-folding) and take-apart frames, and designer colors in anodized and polymeric finishes. The new product is less medical in appearance, more energy efficient to use, and more reliable and durable to the user. Although most of these changes have been directed at the manually propelled wheelchair for active adult paraplegics, some of the same innovations are beginning to be applied to powered chairs as well.

The addition of mechanisms that propel the vehicle using electric motor power has provided a means of independent mobility for previously dependent users with quadriplegia. The most commonly used powered wheelchairs are supplied from the manufacturer as an integrated product that combines conventional frame and seating design with motorized propulsion. The power drive wheelchair (also called "electric" and "battery powered") was originally the result of relatively minor design improvements to the basic tubular metal wheelchair.

Beginning in the early 1970s, the concept of a wheeled device, especially for severely disabled users, was reexamined by designers in North America and Europe. The result of that scrutiny was a proliferation of design ideas and clinical studies, some of which have resulted in commercially viable products. Out of that innovation revolution, stimulated in part by government supported research programs and workshops,[14] have come significant changes in propulsion and control of the electrically powered vehicle, an understanding of the health and performance benefits of carefully seating and positioning the occupant, and two new distinctly different types of powered vehicles.

The first thrust of innovation dealt with obtaining new control modes for the user who could not operate the conventional joystick controller. One of the most common modifications of the powered wheelchair, and most important to the independence of the user, is the relocation or other alteration of the operator control device (typically an electromechanical joystick). It is now possible, with the purchase of options from the wheelchair manufacturer, or modifications developed by separate suppliers, for a severely impaired person to drive a powered wheelchair using any available physical movement on the body, including the head, chin, eyes and feet. It is also possible now to control a powered wheelchair with oral modulation of the breath and pneumatically powered electronic switching (the "sip and puff" control).

The second most noteworthy trend in the redesign of the basic vehicle has been the separation of the seating function from the vehicular function. Conventional wheelchairs had been designed so that the chassis of the vehicle and the frame supporting the seat were the same. Therefore, changing the seat meant changing the total unit. The current focus on separating the functions has freed the vehicle designers and body positioning designers to pursue independent courses of study, resulting in both improved vehicle performance and enhanced comfort and health for the user. Scientific knowledge of the biomechanics and physiology of the wheelchair occupant is now being more appropriately applied to the development of specialized seating systems that position the body statically, and periodically reposition it, to promote improved vascular circulation and breathing, pressure relief and posture, leading to greater comfort, health, and prolonged periods of functional independence for the user.[5]

An entirely different form of vehicle, the powered cart, has also been developed during the past decade, primarily for people who are ambulatory, but limited in speed and range of ambulation. The cart does not look like the basic wheelchair, rather a scaled-down, one person version of the familiar golf cart. Intended primarily for public use by less severely disabled people, the cart is available in a variety of three and four-wheel versions with either tiller or joystick control. People who might otherwise use ambulatory aids or manually-propelled wheelchairs may choose a cart to gain greater speed, range, and (in some models) rough terrain travelling capabilities. Use of the cart should be confined, however, to areas where motor vehicles are not likely to travel. On the road travel for wheelchair users should be limited to persons riding in specially adapted automobiles, trucks, and buses.

Adapted Motor Vehicles

As a passenger or as an operator, a spinal cord injured person can greatly extend his range of travel by using a motor vehicle. The motor vehicle, whether a passenger car, a truck, or a mass transit vehicle, presents some significant impediments to use by an SCI person and typically must be modified to accommodate him. The impediments can be roughly grouped into three categories: access, securement, and control. In order to safely and comfortably use a motor vehicle, a person must be able to get into (and out of) the vehicle, be seated comfortably and secured against any hazards that are presented by vehicle motion, and, if feasible, he must be able to exercise guidance or accessory control over the vehicle.

Access to the vehicle is the pivotal concern, for if the individual cannot enter the vehicle, securement and control functions are moot. Entry into a vehicle is affected by the size and shape of the doorway, the height and slope of the ground just outside the vehicle, and the amount of time consumed in the boarding process; these parameters can be effectively controlled with an adapted personal vehicle.

Mass transit vehicles, which are designed to quickly transport large numbers of people, present a great challenge to people who use ambulation aids and wheelchairs because transit systems typically operate on hurried schedules and boarding occurs in tight spaces. Access to busses, trains, and airplanes is a problem if the person cannot enter the vehicle where it is normally available for boarding without displacing other passengers or delaying the route schedule. Despite these conflicts, many of the modern mass transportation systems have incorporated accommodations for mobility limited people and their mobility devices.[2] Older systems are typically not accessible and not feasible for retrofit. Personal vehicles and small busses for groups of mobility impaired people, however, can be selected and effectively adapted with structural modifications and add-on products.

Personal vehicles are more adaptable. Many people prefer to use a passenger sedan, rather than a van or bus, simply because it is smaller and less costly to own and operate. Paralyzed people, except for those who ride power drive wheelchairs, can get into a sedan without using special access equipment, but may need a little more time than able-bodied people. They must learn to be selective about the place on the sidewalk, at the curb, or in the garage where they board, because the height and slope of the ground often affect the ease of boarding. Generally desirable features in a car include a tall, wide door opening, a door that swings open to a large angle, and a seat at chair height with firm padding and low friction upholstery. A broad driprail or handle located overhead near the door opening can give a person something to hold or pull against during the transfer process. Large interior leg space is important, especially to someone who wears a long leg brace.

Seating is only part of the access problem, since once the person is seated, the mobility aid must be stowed. A crutch or cane can be stowed inside the car, but a walker may be too bulky unless it is the type that folds up for storage. A wheelchair creates a special problem which will be discussed later.

The person who can enter a passenger car, even with difficulty, may find entry to a van or bus to be impossible because the height of the seat from the ground is typically too great to enable direct sitting from outside the van. The person must enter the van before sitting. Van seats more nearly resemble a chair in height and attitude, so they are more accommodating to a mobility impaired person than the seats of a passenger car, but the height of the entry step on a van is as much an impediment to an ambulatory SCI person as stairsteps in a building. Even if he can surmount the stepwell and get inside, he cannot stand upright either for sitting or moving about, unless the roof has been extended. On vans that have been modified for a raised roof, the side or rear cargo doorway is also modified to give more head clearance to people entering and leaving the passenger area.

To accomplish the transition from ground level to the level of the van floor, both ambulatory people and wheelchair users can be aided by a ramp or a platform lift. The ramp is the least expensive access device and offers the most trouble free service, but another person is needed both to deploy it into operating position and to assist the user while he is traversing the bridge. The lift, though more expensive, is frequently preferred over the ramp. For attendant operation, a lift carries the load, thereby reducing the labor and risk of injury. Unlike a ramp, certain types of lifts can be self-operated by a passenger in a wheelchair. There are two general designs of platform lifts: the folding lift (also called flop-out) and the swinging lift (also called rotary). A lift of the folding type consists of a platform for supporting and carrying the passenger and an electromechanical or electrohydraulic power mechanism that provides the lifting force. Deployed for operation, it unfolds outward to a horizontal attitude ready for moving the passenger between the floor and ground levels. The folding lift is usually offered in semi or fully automatic operating modes. The semi-automatic version raises and lowers under power while an attendant provides the controlling function as well as the stowage operation (opening/closing doors and folding/unfolding the platform). The more complicated, and more costly, fully automatic version is further equipped with switches and drive mechanisms that allow the user to control the entire process independently. Typically, the installation of a fully-automatic lift is accompanied by the installation of a powered door opener and an external lift access control panel to complete the total system of components that provide the user with a capability for independent access to the vehicle.

The swinging lift is almost always provided in a fully-automatic configuration. The platform travels vertically outside the opened cargo door between ground and vehicle floor levels. At the floor level, the platform swings (rotates) about a vertical axis into the vehicle and remains there for its stowed position, thereby limiting the available floor space inside the vehicle. This type of lift is somewhat less expensive to purchase and is lighter in weight than the folding type, but typically will not accommodate a full-sized powered wheelchair or cart.

Many users of wheelchairs can transfer to the automobile or van seat without assistance. Often the transfer is aided by the sliding across a transfer board and sometimes by pulling up on an overhead handle or wriststrap. Each person must develop his own transfer technique based on the spatial geometry of the opened doorway, the location of the seat and vehicle interior appointments, and the nature of his physical ability. The transfer process will also vary with the vehicle being used and nature of the trip. Use of a taxicab, rental car, or a friend's car presents a greater challenge because of the variability of vehicle type, many of which are not suitable to the individual wheelchair user. After transferring themselves into the car, passengers (or drivers) of sedan-type vehicles must load the wheelchair into the car or park it at the debarkation point before they can close the door. If an attendant (or cab driver) is present, the chair can be placed in the trunk, in the back seat, or on a special rack attached to the back bumper. The independent wheelchair user must either stow the wheelchair (folded or dismantled) inside the car behind the front seat or on the roof outside. Strong and agile paraplegics can usually fold the chair and pull it inside. Those who are less able sometimes use a rooftop carrier to stow the chair. A passenger who transfers to a seat inside a van (a desirable practice from the standpoint of safety) can usually tether the empty wheelchair next to him inside the van, making it readily accessible for re-transfer and exiting the vehicle.

Access to the vehicle seat does not complete the process of safely preparing for travel. The passenger should be secured. With many SCI people, safety securement is more than a crash protection mechanism, because they may have insufficient upper body strength to withstand common vehicle accelerations. A seatbelt or over-the-shoulder harness can be very important for both purposes. When an ambulatory person is seated in a vehicle, he can almost always use the conventional safety restraint belt for passenger security. So can a wheelchair user who is able to transfer from the wheelchair to the vehicle seat. When a wheelchair user cannot transfer, he should use some form of restraining device. As a general rule, both the wheelchair and its occupant should be restrained (separately) by a vehicle structural member. Many designs of restraining devices have been tried and tested by researchers and manufacturers. To date, only two relatively satisfactory approaches have been produced. In one, the wheelchair is permanently fitted with an additional structural subassembly which serves to reinforce the structural integrity of the wheelchair and engage a mating assembly that is securely anchored to the frame of the van. Though demonstrated to be an impact resistant combination,[11] this approach has the disadvantage of restricting a passenger to the use of a van that carries the mating structure and of imposing additional weight on the routine mobility of the wheelchair, demanding additional propulsive energy from either the arms of the occupant or the batteries of the power system. A second approach separately tethers the wheelchair and the wheelchair occupant to the vehicle structure, using belts. The tethering operation is virtually impossible for a wheelchair user to perform independently and is time-consuming even for an attendant. Some of the restraint devices that are provided for wheelchairs, however adequate to the task for wheelchairs of the basic design, will not engage certain forms of wheeled mobility aids at all. Passengers using such non-standard aids must often travel unrestrained.

Many SCI people can be adapted to driving.[7] Although they may lack the leg and arm function required to operate the pedals and steering wheel, they may employ specialized products called automotive adaptive controls (also called hand controls and foot controls). Such devices transfer the locus of driving control from its conventional position in the vehicle to a location and configuration that can be operated effectively by parts of the body that are functionally able to handle the task. If the feet are not able to operate the throttle or brake pedals, a mechanical linkage can be added to transfer the input to a hand-operated lever. For most products, the throttle and brake are combined into a single lever.

Since the hand-control completely occupies one hand with starting and stopping, the other hand must do all the steering. If that hand is limited in strength, common to quadriplegics, a steering wheel spinner may be needed to assure constant hand contact with the wheel throughout its rotational circuit. Spinners are available in a variety of configurations, depending on the nature of the hand disability. Other adaptive devices take the form of extensions of vehicle control levers, shafts, and pedals (such as turn signal, gear selector, steering column, throttle, brake, and emergency brake) that improve the mechanical advantage, extend the locus of activation, or transfer the operation to the opposite side. Hand controls typically do not prevent another person, who is not disabled in driving function, to drive the car since the conventional controls remain intact, having been added-to rather than replaced.

Just extending and relocating the application of forces is sometimes inadequate to enable a quadriplegic to drive. Where conventional power assisted steering and braking requires more force than the driver can exert, it is possible to further reduce the force or range of movement required to operate the controls by performing a more extensive modification of the vehicle control components. Reduced effort steering, throttle, and brake conversions diminish the force the driver must supply. Since the driver who needs force amplification is unable to operate the vehicle without the modification, the complete reduced-effort system should be supplied with backup power that will sustain hydraulic and vacuum reserves, even if the engine (the primary source) fails. With the use of a reduced-effort system, the mechanical advantage of a large diameter steering wheel and extended lever arms is no longer needed, so the range of movement of the input controls can be reduced to accommodate limitations in upper extremity movement. A small diameter steering wheel, even one that is repositioned through universal joints and angular drives (so-called "horizontal steering"), extends the possibility of driving to people with even greater limitations of limb movement.

As with all mobility aids, professional help with selection and training is very important to the ultimate successful application of automotive adaptive aids. Specialized assessment and training facilities have been established in conjunction with major rehabilitation centers worldwide. The staff of these centers typically includes a therapist, a driver trainer, and an equipment specialist who combine their expertise to provide the disabled driver candidate with comprehensive assessment, equipment selection, vehicle modification, and driver training.[6] In some areas, the vendor of vehicle adaptive equipment and modifications is responsible for the recommendation of products and services, but the more comprehensive clinical team approach seems to be more objective.

Conclusion

Helping to attain mobility for the spinal cord injured individual is a multiparameter equation. Mobility is key and essential to almost all aspects of the process of rehabilitation and return to active life postinjury. Many products and technologies are available to help extend the residual capabilities of the patient. A team approach to mobility assessment, prescription, and training will greatly encourage the development of a system approach that can lead to a well integrated plan for the user.

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