UPPER EXTREMITY SPLINTS AND ORTHOSES

INTRODUCTION

Since the 1940s, knowledge of upper extremity (UE) management after tetraplegia has grown significantly, particularly in respect to optimizing functional outcomes across the continuum of care.[3] The main goals of UE management are to restore as much function as possible while maintaining normal appearance, preserving joint integrity, preventing edema, preventing pain and controlling spasticity.[17] A key component of UE management is focused on use of splints or orthotic devices to promote function and preserve normal appearance of hand by maintaining joint mobility, preventing contractures/deformities, and preventing skin breakdown. It is important to keep in mind that the splints/orthoses may change during the continuum of care in response to individuals' change in tone, spasticity, or neurological recovery.[3,20]

GENERAL CONSIDERATIONS

The Consortium for Spinal Cord Medicine has published clinical practice guidelines for upper limb function and preservation following SCI[9] and on Outcomes following traumatic SCI,[8] both of which provide important UE treatment guidelines for tetraplegic rehabilitation. Clinicians working with persons with SCI should know and understand these practice guidelines and integrate them into existing clinical pathways in their clinical setting.

An understanding of SCI classification systems is important in making decisions about UE splinting and equipment needs. The International Standards for Neurological Classification in Spinal Cord Injury (ISNCSCI) remains the most widely used assessment of motor and sensory impairment after SCI.[1] The International Classification of the Hand in Tetraplegia (ICSHT) is a more specific assessment of muscles in the upper limb below the shoulder, and is used for decision-making about surgical procedures to enhance function for people with cervical SCI.[16] The ICSHT augments the motor and sensory information gained from the ISNCSCI. In addition to the motor and sensory systems, joint range of motion and pliability of the hand are essential to evaluate, as limitations in these areas will greatly impede use of devices and application of orthoses.

In select SCI centers world-wide, surgical reconstruction of the UE has restored elbow extension, wrist extension, forearm rotation, and hand grasp and release. While a discussion on surgical restoration of UE function is beyond the scope of this chapter, readers are referred elsewhere.[5,7,11,14,20,21]

EQUIPMENT RECOMMENDATIONS

This chapter provides guidelines for splints/orthotics and other equipment to augment or replace UE function lost to paralysis from spinal cord injury or dysfunction. Orthotic management in SCI involves static protective splinting, static functional orthoses, and dynamic functional orthoses. The selection of orthotic intervention is dependent upon neurological level, time post injury, and goals of the user. Comprehensive management usually involves a combination of different types of splints and orthoses. This chapter addresses equipment that can be placed on the upper limb (for example a functional orthosis) and equipment that the upper limb can be placed in (for example, a balanced forearm orthosis). Although serial casting is not considered durable medical equipment, the chapter briefly addresses serial casting.

Since upper extremity splints/orthotics are intimately related to adaptive devices, upper extremity equipment recommendations, and assistive technology, references will be made in this section, however discussed in detail in their respective chapters. Finally, therapeutic and functional UE devices such as robotics, or prosthetics that employ electrical stimulation are outside of the scope of this chapter.

With this in mind, this chapter will examine the use of splints/orthotics by purpose at each joint, concluding with a brief summary of devices by level of injury and function.

When recommending upper extremity splints, care must be taken to provide proper training to the client and their caregivers. People with spinal cord injury are at risk for skin breakdown from UE devices and wearing schedules should begin with short trials. If skin inspection reveals no issues, wearing time can be increased. Training should also include how to don and doff the device and proper use and care. Some devices have specific instructions for cleaning that must be followed to optimize the lifespan of the device.

Client acceptance of upper extremity devices includes many factors such as their understanding of the benefits, their perceived comfort, and the cosmetic appearance of the device (Kuipers et al, 2009).[12] Engaging the client in decision making will promote carryover of selected devices.

Finally, it is important to note that while some types of orthoses or splints are available off the shelf, custom orthoses or splints should be evaluated and then fabricated by trained occupational therapists or certified hand therapists to ensure proper fit.

SHOULDER

Proper positioning of the shoulder is essential to prevent: shoulder pain, prevent shortening of upper chest muscles resulting in rib tightness that can impede respiration, and enhance proximal stability necessary for distal function.[3] Proximal instability is often caused by weakness in muscles that stabilize the glenohumeral and scapulothoracic joints, resulting in instability, poor positioning, and poor biomechanics.[3] Proper positioning of the shoulder at all levels of injury during both static and dynamic activities should be carefully considered to prevent secondary conditions such as impingement syndrome, recurrent dislocations, rotator cuff injuries, bicipital tendinitis, capsulitis, osteoarthritis, and myofascial pain syndrome involving the cervical and thoracic paraspinals.[9] Achieving proximal stability through taping or an orthotic device should be considered to counteract protracted resting shoulder position.

Sidelying Shoulder Pillows

Some pillows can be used to help promote good shoulder positioning while in side laying position however they should be used with caution in persons with SCI/D as they should not be used with someone who is too weak to reposition off of the shoulder.

Daytime Static Shoulder Positioning

For individuals with high cervical injury and significant paralysis in the shoulder, proper positioning of wheelchair armrests is paramount to provide optimal shoulder support and prevent subluxation. Examples can be found in the Wheelchairs and Seating chapter.

Shoulder Supportive Slings

These have been developed to prevent or correct shoulder subluxations in order to reduce pain.[10] There are many styles of slings that help with this. Below are a few examples.

Giv Mohr Sling

Giv Mohr Sling used to provide upper extremity support during standing and ambulation.

Shoulder brace with compression sleeve support strap

Figure 8 Brace

A scapular retraction, or figure 8, brace provides a postural cue to facilitate shoulder retraction.

https://www.doctordorsey.com/wp-content/uploads/2015/01/Olive-Posturific-Brace-Posture-Brace.jpg

Giv Mohr Sling

Shoulder Brace with Compression Sleeve

Figure 8 Brace
Posture Corrector Brace
https://posturificbrace.com

Suspension Arm Devices

These devices were found as early as the 1940s in occupational therapy clinics. They are low cost, easy to manage and have the ability to support proximal weakness of the upper arm. They are made up of overhead suspension rods and can be attached to the wheelchair, a child's body jacket, highchair, or overhead track system for ambulatory patients.[19] See page 76 for a few examples of commercially available suspension arm devices.

Mobile Arm Supports

Mobile arm supports are devices that allow individuals with significant weakness in the shoulder to perform activities of daily living.[2,15] May provide individuals with proximal arm weakness due to tetraplegia improved independence. Conventional mobile arms supports use elastic bands connected to a forearm trough to reduce gravity and elevate the arm. Power-assisted mobile arm supports (also called powered exoskeletons) have been offered in more recent years. Often, a mobile arm support is combined with other devices, such as a wrist splint and universal cuff for tabletop activities such as feeding or tablet use.

ELBOW

For people with tetraplegia, maintaining a good arc of motion is essential to promote an expanded workspace and weight-bearing function in mobility activities.[3] People with C5 and C6 motor function are at risk of developing elbow flexion tightness or contracture from the unopposed activity of the elbow flexors.[3] Elbow flexion contractures have been associated with lower motor neuron damage of the triceps in addition to upper motor neuron paralysis.[4] Though uncommon, elbow extension tightness or contracture may develop from absence of elbow flexors resulting in unopposed elbow extension from spasms or spasticity in people with C4 or higher level injury. Regardless of the type of contracture, the following static and dynamic splints and orthotics should be considered.

Pillow Splints

Pillow splints are a good option to promote static elbow extension, and are a preferred method for nighttime use due to comfort.

Static Elbow Extension Splints

Static elbow splints can be made from low or high temperature thermoplastics. These splints may be a better option for nighttime use to oppose moderate to high elbow flexion forces.

Dynamic Elbow Extension Splints

This splint is often used when a low load constant stretch theory is needed. The dynasplint is available for both elbow flexion and extension contractures.

Hinged Elbow Braces

Hinged braces are useful for blocking active or passive movement in one direction while allowing movement in the other. This brace is often used after a surgical procedure to restore active elbow extension, such as a biceps or posterior deltoid to triceps transfer.

Serial Casting of the Elbow

Serial casting is a more aggressive intervention used to increase range of motion when moderate to severe spasticity is present. The goal of casting is to gradually decrease tone while increasing range of motion. Casts are often applied for several days to achieve prolonged stretch and reduced tone. Skin tolerance often determines length of casting. Casting may often be used in combination with motor blocks, nerve blocks or botulinum toxin injections.[19] Following achievement of maximum range of motion, splints or bi-valve casts can be used to maintain range of motion.[6] Below are examples of serial casing at the elbow, a drop out elbow cast which uses gravity to assist with elbow extension, and a bi-valve night cast.

SHOULDER

0540 PoweRED Arm Support | Partners in Medicine LLC
https://partnersinmed.com/o540-dynamic-arm-support

ELBOW

Pillow Splint

Custom Elbow Extension Splint

Elbow Extension Dynasplint® System

Hinged Elbow Braces

Full Elbow Cast

Drop Out Elbow Cast

Bi-valve Cast

FOREARM

Supination deformities can result from muscle imbalance between voluntary biceps/supinator and weak or paralyzed pronator teres/pronator quadratus. As a result, resting position is a consideration of the forearm to prevent fixed contractures. Supination deformities are most commonly seen in C5, C6 and in some C7 injuries, and often accompany elbow flexion contractures. Additionally, prolonged position of the forearm in supination can adversely affect passive range of motion at the wrist through shortening of the wrist extensor muscles and over-lengthening of the wrist flexor muscles. Good forearm range of motion and promoting a resting positioning in pronation is essential for nearly all functional activities, especially personal ADLs such as feeding and grooming.

Supination/Pronation Straps

Supination and pronation straps are useful for supination deformity that can be passively corrected and has not developed into a fixed joint contracture. The straps are made from a semi-elastic material such as neoprene and extend proximally from just above the elbow and wrap around the forearm in the direction of pronation. The distal end of the strap extends past the wrist and is attached with velcro to a neoprene thumb sleeve. These straps can be incorporated with an elbow extension splint to maintain neutral or pronated position of the forearm. The distal portion of the strap can be attached to wrist stabilization splint if necessary.

Custom Neoprene Forearm Strap

The straps may also be fabricated with or without a wrist splint to be positioned in pronation.

Static Pronation Splints

These are a better alternative for supination deformities that require more force to be passively reduced, or are starting to become a fixed joint contracture. For individuals with high cervical injury and significant paralysis in the shoulder and upper arm, proper positioning of the elbow and forearm in the wheelchair is paramount to provide support and prevent adverse positioning. Examples of wheelchair armrests can be found in the Wheelchairs and Seating chapter.

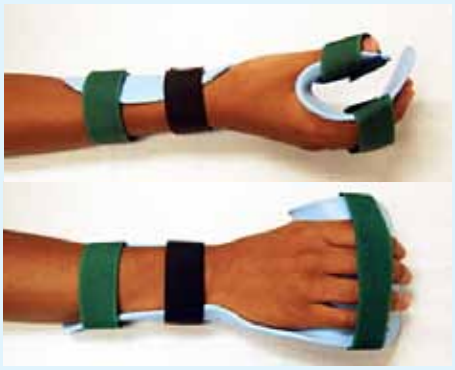
WRIST AND HAND

The wrist and hand are closely related when it comes to functional ability in cervical spinal cord injury. When wrist muscles are weak or completely paralyzed, it is important to support the wrist and hand both at night and during the day to prevent contractures from occurring. When wrist extension is active, the individual can achieve function with a tenodesis grasp, even without active hand and thumb motion.

A tenodesis grasp takes advantage of biomechanical properties of the hand. For example, active wrist extension passively tightens the finger and thumb flexors, and passive (gravity-assisted) wrist flexion tightens the finger and thumb extensors. The result is passive hand closing with active wrist extension, and passive hand opening when the wrist is flexed. An important concept to consider when splinting for an effective tenodesis grasp is tendon tightness. Splinting can encourage tendon shortening, or tightness to maximize function. For example, shortening the finger and thumb flexor tendons can provide stronger passive grasp with wrist extension. Care should be taken to preserve joint mobility and avoid joint contractures. Conversely, splinting the fingers in extension will shorten the extensor tendons, encouraging hand opening with passive wrist flexion. Clinical judgment, hand resting posture/physical characteristics, and participant goals dictate whether splinting goals focus on encouraging passive grasp or release.

When hand musculature is returning, it is important to maintain equal length on both flexors and extensor muscles again both in day and night splinting. In all stages, it is important to encourage proper positioning of the wrist and hand to prevent secondary injuries such as compression of the carpal tunnel (PVA guide) or adverse shortening or lengthening of muscles which can limit function. Spasticity and tone may influence choices of both the day and night splints. These principles along with clinical judgement should be considered when choosing splints and orthotics for optimal wrist and hand function.

NIGHT SPLINTING



Custom Molded RHS

INTRINSIC PLUS SPLINTS

Volar Intrinsic Plus Splint

Dorsal Based Intrinsic Plus Splint

ANTI-SPASTICITY SPLINTS

Custom-Fabricated Anti-Spasticity Splints

SERIAL CASTING

Serial Casting of the Wrist and Hand

NIGHT SPLINTING

Resting Hand Splints (also known as resting pan splints)

This splint encourages a natural position of the hand and thumb that allows for a tip pinch to pick up light objects by placing the thumb and finger in a "tong" position.[18] To initially achieve this position, a resting hand splint places the wrist in 0-20 degrees wrist extension, 20-30 degrees MCP flexion, 10-30 degrees PIP flexion and slight DIP flexion with the thumb in slight extension and abduction.[10] Modifications can be made to encourage more flexion or extension of the fingers and thumb, depending on clinical goals.

Prefabricated options are available. Some have a thermoplastic base that can be adjusted with a heat while those made from padded stainless steel are available and can be easily shaped to fit the wrist and hand without heat. Another option is to fabricate custom molded resting hand splints from low temperature thermoplastic materials).

Intrinsic Plus Splints

This splint positions the wrist in 10-20 degrees extension in combination with MCP in 80-90 degrees of flexion, IP joints in full extension and thumb aligned in neutral position of lateral pinch position. This splint will often help with edema as it allows for maximum tightness in the extensor mechanism which allows the viscoelastic properties of flexor muscles of the to cause a pumping action to move edema from the hand.[3]

Anti-Spasticity Splints

The anti-spasiticty splint is often utilized as tone increases or hand function is returning. This splint positions the wrist and hand in functional position and abducts the thumb and fingers. The position is known to decrease tone as well as place stretch on dorsal interossei, palmar interossei and lumbricals.[10] This splint can disrupt tenodesis or counteract tenodesis splinting therefore it is often used as recovery of the hands is noted. The separation of the fingers and strapping may vary based on patient need. Custom and pre-fabricated options are available.

Serial Casting of the Wrist and Hand

As with the elbow, a more aggressive approach with serial casting can be employed for the wrist and hand. Consideration of wrist positioning and hand range must be taken into consideration for maximum effect. Upon final serial cast, one of the above night splints can be incorporated.

Dynamic Splints

Dynasplint This splint is often used when a low load constant stretch theory is needed. The Dynasplint is available for both wrist flexion and extension contractures. There are a variety of hand pieces that can be added to match a patient's need. A few examples are at the bottom of the page.

DAY SPLINTING

When active wrist extension is absent, wrist support is recommended during the day to prevent overstretching of the wrist extensors.[12]

Wrist Supports

Volar or Dorsal wrist supports are used to support the writ, leaving the thumb and fingers free. This type of splint is often used during the daytime for functional activities, as it contains an adaptive slot for utensils or other items for daily activities. Dorsal long based splints also protect the integrity of wrist joints.[3]

Wrist Extension Dynasplint with ASB Hand Piece

Alternate Hand Pieces Attachments

DAYTIME SPLINTING



Custom Fabricated Volar Wrist Cock Up Splints

Custom Fabricated Dorsal Wrist Cock Up Splint


The Green Splint – North Coast Medical and Rehabilitation Products – www.ncmedical.com


Custom Fabricated Thumb Spica Splints

The Green Splint is a common dorsal wrist splint that is pre-fabricated. The Green splint is designed to place the wrist in a stable neutral position,[13] however the splint can be bent to allow some wrist extension.

At times wrist splints are fabricated volarly or dorsally with a variety of cut-outs to accommodate thumb position. A universal cuff can be used over the custom fabricated splint as well. With fabricated wrist splints, the angle of the wrist can be adjusted for progression with the patient's phase of recovery.

Long Opponens Splints

Long opponens splints are important for pre-tenodesis function, as they maintain support of the wrist and place the thumb in a functional position. This splint is incorporated in an individual who lacks antigravity wrist extension.[13] While stabilizing the wrist, it positions the index finger as a stable post against which the laterally-positioned thumb can achieve a functional key pinch position.[3] Because this splint is used when aggressive thumb positioning is needed, custom splints are widely used in clinical practice although

pre-fabricated splints which include universal cuffs slots for functional use are also available.[12] Below are examples of custom fabricated and pre-fabricated splints.

SPLINTING TO FACILITATE TENODESIS GRASP FUNCTION

Tenodesis splints are useful to facilitate picking up and releasing objects.[13] Tenodesis Trainer Splints (also known as RIC Tenodesis Splint) can be helpful to encourage functional use of the hand as wrist extension returns. They are also useful for determining whether a more permanent (and more costly) wrist driven flexor hinge splint (see below) is of interest to the patient and worth the financial investment. Kits are available to guide fabrication, as seen below.

Wrist Driven Flexor-Hinge Splint

This device uses wrist movement to generate finger flexion and extension forces. If wrist movement only exists in one direction, springs can be added.[13] Prefabricated models can be ordered, however, a local orthotics and prosthetics company can provide a customized fit.

Short Opponens Splints

Short opponens splints are utilized for individuals who have anti-gravity wrist extension, however, are unable to produce a productive tenodesis pinch. This splint promotes tenodesis grasp by aligning the thumb in a functional pinch position against the index finger.[3] This splint can be incorporated when an individual is able to maintain a stable wrist against gravity and against additional forces but assistance is needed in positioning of thumb to allow for pinch/grip of objects.[13] These splints are often used to prevent overstretching of the thumb during functional tasks.[12] Below are examples of prefabricated and custom fabricated splints. Note that many prefabricated splints may also include universal cuffs slots for function.

A wrist cock up with MCP pull downs can be incorporated when the MCP tightens in extension and the tenodesis flexion or lateral pinch is not aligning well. The MCP pulls apply a gentle force to increase joint mobility when the motion is limited by extensor tightness. As function returns, the tension on the pull system can be increased to active as an active assistive motion.[6]

SPLINTING FOR RETURNING HAND FUNCTION

Ulnar Gutter Splints

As the hand regains function, an ulnar gutter splint can be used to stabilize the wrist for opening and closing the hand, thus allowing the intrinsic and extrinsic muscle to work together and strengthen. This splint is incorporated when sufficient strength exists to break the use of tenodesis grasp.

Weight Bearing Splints

The weight bearing splint can be used to inhibit increasing flexor tone.[10] When hand function is returning and residual tightness remains, the weight bearing splints can be utilized to provide a stretch prior to active motion and activity of the hand.

MCP Blocking Splint

MCP blocking splints can be incorporated for emerging grasp when intrinsic hand weakness leads to MCP hyperextension and a claw hand position thus losing posture needed for cylindrical grasp.[12] Care should be given not to overstretch the thumb (CMC) during fabrication.[3]

Finger and Thumb Hyperextension Blocking Splints

As hand function returns, imbalance between intrinsic and extrinsic muscles can occur leading to finger and thumb deformities. A common emerging deformity is a swan neck deformity. When this occurs, a PIP hyperextension blocking splint is used to restrict the undesired motion. The splint can position the PIP joint in slight flexion, which allows full hand closure without a catch motion.[10] There are prefabricated Oval 8 splints as well as custom molded splints. Consideration should be given to custom fabrication of this splint as adjustments of the angle of the joint can be easily made as muscle strength returns.

SPLINTING TO FACILITATE TENODESIS GRASP FUNCTION

Wrist-driven Flexor Hinge Orthosis
https://jaecoorthopedic.com/product/wrist-driven-flexor-hinge-w-mapel/

Custom Fabricated Short Opponens Splint

Static Progressive Wrist Cock Up with MCP Pulls

SPLINTING FOR RETURNING HAND FUNCTION

Ulnar Gutter Splints

Weight Bearing Splints

MCP Blocking Splint

Norco® Soft MP Ulnar Drift Support

Oval 8 Splint

Custom Molded Splint

RESOURCES FOR SPLINTS AND SPLINTING SUPPLIES

(adapted from Deshaies 2008)

Alimed, Inc.
Phone: 800-225-2610
www.alimed.com

Bioness, Inc.
Phone: 855-902-5252
www.bioness.com

DeRoyal
Phone: 888-938-7828
www.deroyal.com

Dynasplint
800-638-9530
www.dynasplint.com

Jaeco Orthopaedic
Phone: 501-623-5944
www.jaecoorthopedic.com

Joint Active Systems, Inc.
Phone: 800-879-0117
www.jointactivesystems.com

North Coast Medical, Inc.
Phone: 800-821-9319
www.ncmedical.com

Otto Bock Medical
Phone: 800-328-4058
www.ottobockus.com

Performance Health
Phone: 800-323-5547
www.performancehealth.com

Restorative Care of America, Inc.
Phone: 800-627-1595
www.rcai.com

Saebo, Inc.
Phone: 888-284-5433
www.saebo.com

Silver Ring Splint Company
Phone: 800-311-7028
www.silverringsplint.com

3-Point Products
Phone: 888-378-7763
www.3pointproducts.com

UE Tech
Phone: 800-736-1894
www.uetech.com

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