Sling for Brachial Plexus Injury

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Background

The brachial plexus is a set of nerves that is responsible for control and sensation throughout the shoulder, arm, and hand. Injury to the brachial plexus can cause arm paralysis and the patient can lose feeling in the hand and arm. Although surgery can lead to full recovery, some surgeries are not successful. For these instances, there can be little to no return of sensation or movement. As a result, the limb muscles atrophy, ultimately leading to subluxation. Many brachial plexus patients must rely on shoulder and arm slings to fix this subluxation.

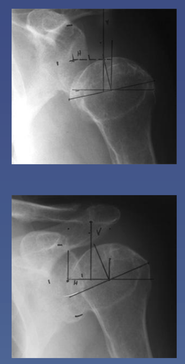


Figure 1: Subluxation of the humeral head from the acromion (top). Reduction of subluxation (bottom).

Motivation

This semester our project focused mainly on one patient. He suffered a brachial plexus injury in 2007. Since then he has used many different slings and supportive braces, but none of them have met his needs. Figure 2shows the patient's injured shoulder.

Requirements

- Reduce shoulder subluxation to less than 1cm
- Conceal under clothing
- Support arm with elbow at 90^o angle
- Adequately distribute the weight of the right arm (73.40 N)
- Breathable and lightweight (<9.81 N)
- Fabrication cost less than $200
- Allow easy one-handed application and removal (< 3 minutes to put on/remove)
- Enhance cosmetic appeal of shoulder (increase shoulder circumference to that of left shoulder)
- Withstand repeated loading at 8 hours of use per day
- Hypoallergenic, soft, and non-irritating

Budget

Description	Vendor	Cost
Perforated neoprene sheet (51" x 41.5")	Foamorder.com	$60.87
Neoprene tape and glue	Aqua Center of Green Bay	$16.57
3 packages of Velcro strips	Jo-Ann Fabrics	$6.77
Sewer's lubricant	Jo-Ann Fabrics	$3.42
D-ring	Ace Hardware	$1.57
Slip-resistant neoprene	UW Health Orthotics	Donated
Dacron strapping	UW Health Orthotics	Donated
Thermoplastic and copper rivets	UW Health Orthotics	Donated
Strap adjusters	UW Health Orthotics	Donated
Total		$89.20

Final Design

Neoprene Backbone

- Perforated neoprene (polychloroprene) offers breathable yet strong backbone
- Velcro patch allows fastening of sling to rest comfortably and tightly
- Adjustable sleeve with non-slip neoprene adds stability at load bearing shoulder
- Dacron strapping offers maximum tensile strength
- Completely washable in cold or warm water-suggest air drying

Thermoplastic Frame

- 0.5 cm polypropylene thermoplastic lined with 0.6 cm aliplast foam padding
- Useable under 99^o C and formable between 154^o and 163^o C
- Custom-fit to patient's arm
- Nylon loop webbing strap attached to thermoplastic with copper rivets
- Nylon webbing is held by D-ring on subluxation strap

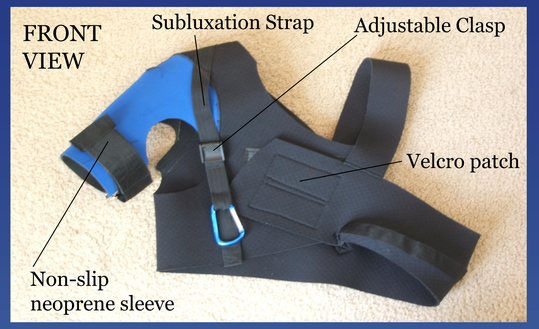
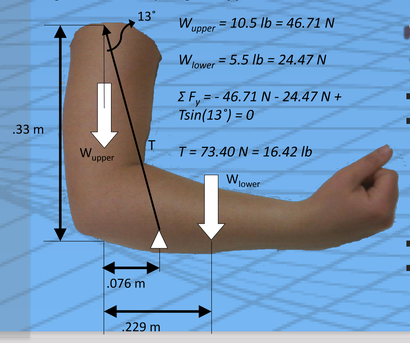


Figure 2: Final prototype (Clockwise from top left): front view of backbone; thermoplastic frame; back view of backbone

Figure 3: Creating a fiberglass mold of patient's arm

Figure 4: Free body diagram of forces on arm



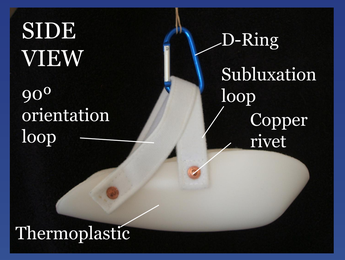
Fabrication

- **Thermoplastic Frame**
  - Wrapped wet fiberglass casting tape around patient's arm ~3 layers thick
  - Let dry, cut off, and stapled seam
  - Filled fiberglass cast with plaster-vermiculite mix and steel frame bar
  - Removed fiberglass from plaster mold
  - Heated 3/16"polypropylene to 320^o F and stretched around plaster/vermiculite mold
  - Let cool and fill inner thermoplastic with 1/4"aliplast foam padding
- **Neoprene backbone**
  - Created felt pattern from measured sizes to make adjustments before cutting neoprene
  - Sewed pieces with non-overlapping zig-zag stitch and covered with iron-on neoprene tape
  - Stitched Dacron straps on with appropriate stretch in perforated neoprene
  - Stitched Velcro patches to Dacron/neoprene accordingly

Testing

- Measured load of the arm using a force gauge (results in Figure 4)
- Subluxation testing
  - Testing was carried out by palpitating the posterior side of suprahumeral space with and without the device
  - Without the device, subluxation was at approximately 3.7 cm
  - With the device, subluxation was reduced to 0.7 cm
- Weighing prototype
- Comfort testing—Eric wore sling and gave feedback
  - Reduced subluxation, easliy concealed, functional forearm position
  - Traps excess heat, bulky

Figure 5: Measuring load of lower and upper arm



Adjustments

- The forearm sagged from the desired perpendicular elbow orientation. To address this issue, a secondary nylon loop webbing strap was added to the thermoplastic frame and also clipped into D-ring.
- The subluxation strap had a tendency to slide towards shoulder and off of the collarbone due to the high tensile force placed on it. To correct this, a Dacron strap was sewn to the subluxation strap and around the sling.

Future Work

- Further minimize heat generation and improve breathability by reducing the amount of neoprene used and adding ventilation
- Commission a professionally fabricated prototype for enhanced fit and durability
- Refine forearm positioning so the hand is more in front of the body (may affect concealment.)
- Add bulk to right arm and shoulder
- Incorporate a hinge mechanism at the elbow to allow for varied positioning
- Adapt prototype for use with other brachial plexus or stroke patients

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