A mailed survey was conducted to collect information about the application of hand splints to patients with spinal cord injuries resulting in quadriplegia at levels C-5, C-6, C-7, and C-8. Survey respondents were occupational therapists in spinal cord injury centers nationwide. Frequency and descriptive statistics were collected concerning both static and dynamic splints, the clinical reasoning behind splint selection, and methods used for the evaluation of hand function. The results of the survey indicate that hand splinting is an accepted intervention for the target population. A variety of static splint designs were used, depending on level of injury, muscle strength, and the patient’s acceptance. The dynamic splint designs were used most frequently with patients whose lesions were at C-6 and C-7. The reasons for not splinting were primarily related to the patient’s compliance and acceptance. Observation of patients’ performance of functional tasks was the preferred method of evaluation of hand function, as there are no appropriate standardized tests available for this population.

**Literature Review**

**Static Splints**


The reason for early intervention is clear given the pathophysiology of the hand following spinal cord injury. Edema develops below the level of the lesion as a result of interruption of vasoconstriction. Collagen is deposited in the edema fluid. If the edema is not overcome by frequent movements of the upper extremity joints and elevation of the limb, the collagen is transformed into fibrous tissue that adheres to the ligaments, resulting in loss of elasticity. It also adheres to the fascia and joint capsules, resulting in contractures (Cheshire & Rowe, 1970; Gutman, 1976). Contractures develop quickly in association with immobility, muscle paralysis, or imbalance (McCagg, 1986) and interfere with nursing care, rehabilitation potential, functional activities, and cosmesis (Fess & Phillips, 1987; Latham, Gregorio, & Garber, 1985; Yarkony et al., 1985).

Prevention of contractures involves elevation of the body part, maintenance of passive range of motion, and splinting. The focus of this study was on the latter intervention as it pertains to the hand.

Static hand splints serve several purposes in the

**Persons with C-5, C-6, C-7, and C-8 quadriplegia resulting from traumatic spinal cord injury are at risk for loss of hand architecture and range of motion. These problems can be prevented in part by the application of hand splints. Most specialists agree that, for optimal results, management of the quadriplegic hand through positioning and range of motion exercise must begin soon after injury. Despite this consensus, it was clear from clinical observations and the results of a pilot survey we completed prior to the present study that splints are not always applied to these patients.**

The purpose of this paper is to present the findings of a study in which we sought to identify the extent to which occupational therapists use hand splints with persons with quadriplegia. Both static and dynamic splints were examined in the survey. We were interested in the splint designs used, the frequency with which splints were applied, the clinical reasoning regarding splinting, and how therapists evaluated the hand function of this population.
treatment of quadriplegia, including (a) prevention of overstretching, particularly of the wrist extensors (Freehafer, 1969; McCagg, 1986; Ruge, 1969); (b) maintenance of a functional position (Freehafer, 1969; Henshaw et al., 1986; Latham et al., 1985; Pierce & Nickel, 1977; Sargent & Braun, 1986; Trombly, 1983; Zejdlik, 1983); (c) prevention of deformity, such as claw hand (Bloch & Basbaum, 1986; Braun, 1986; Eisenberg & Falconer, 1978; Fess & Phillips, 1987; Ford & Duckworth, 1987; Hanak & Scott, 1983; Latham et al., 1985; McCagg, 1986; Ruge, 1969; Sargent & Brown, 1986; Zejdlik, 1983); and (d) protection and stabilization of flail joints (Bloch & Basbaum, 1986; Hanak & Scott, 1983; Pierce & Nickel, 1977; Zejdlik, 1983).

A variety of static splint designs are available. Resting hand splints (also referred to in the literature as volar cock-up, or platform splints) are advocated by some (Bloch & Basbaum, 1986; Hanak & Scott, 1983; Latham et al., 1985; Ruge, 1969; Sargent & Braun, 1986). Opponens splints keep the thumb in opposition to the first two fingers. A long opponens splint is necessary when the wrist is flaccid; a short opponens splint is used when there is good wrist movement (Bloch & Basbaum, 1986; Zejdlik, 1983). Some short opponens splints include a bar that holds the metacarpophalangeal joints in flexion (Bloch & Basbaum, 1986; Kiel, 1983).

Cheshire and Rowe (1970) developed the boxing glove splint, which is a wrist cock-up splint with a palmar pad. It is bandaged to the patient’s hand, thereby providing compression to prevent edema. The developers contended that this design is necessary to maintain the length of the collateral ligaments of the metacarpophalangeal and interphalangeal joints and the muscles of the thumb adductor web, while minimizing the development of edema. Palmar rolls or pads, which are placed so that the thumb opposes the fingers, are advocated by Freehafer (1969) and Bromley (1985), but Cheshire and Rowe (1970) and Guttman (1976) pointed out that these are only effective if they allow flexion of the metacarpophalangeal joints well beyond 45°.

Trombly (1983) described a splint for C-6 quadriplegia that includes a hand roll to support the fingers in a flexed position and to preserve the width of the thumb web space while extending over the volar surface of the wrist to prevent the extensors from being overstretched. Finally, Minns, Mattison, and Sutton (1982) described a vacuum splint designed to prevent contracture of the upper limbs by keeping the arm and hand in extension. Small polystyrene beads are encapsulated in a vinyl envelope that becomes rigid when the air is evacuated, providing support along the length of the splint surface that contacts the skin.

Many authors have indicated that the hand should be splinted in a functional position; however, there is no consensus as to the exact specifications of such. Recommended wrist position varies from neutral (Fess & Phillips, 1987) to 45° of extension (Bromley, 1985; Cheshire & Rowe, 1970). Recommended metacarpophalangeal positions include slightly flexed (Bromley, 1985); 45° of flexion (Bloch & Basbaum, 1986; Malik & Meyer, 1978); and 70° to 90° of flexion (Cheshire & Rowe, 1970; Eisenberg & Falconer, 1978; Fess & Phillips, 1987), while interphalangeal position varies from 0° (Fess & Phillips, 1987) to 30° of flexion (Cheshire & Rowe, 1970).

Despite much information in the literature regarding the use of static hand splints, no comparative studies of long-term functional hand use were found of persons who had been splinted versus those who had not been splinted.

Dynamic Splints

Patients with spinal cord injury may be candidates for dynamic splinting. The literature review revealed that the long-term use of dynamic splints has been a topic of investigation. Knox, Engel, and Siebens (1971) conducted a postdischarge survey of 41 patients with quadriplegia who had been fitted with a wrist-driven splint for prehension. The length of time since initial fitting varied from 3 months to 9 years. Thirty-nine subjects responded, and 35 (approximately 89%) of them were still using the splints. The authors concluded that “both subjective and objective responses indicate that the device is a useful one” (p. 109). What is not evident from the article is the mean or median length of time these subjects had had their splints, thus it is difficult to conclude what the long-term use of these splints may be.

A similar problem is found in a follow-up study of 42 patients who were fitted with wrist-driven flexor hinge splints over a 10-year period (Allen, 1971). Less than 43% of these subjects were still using the splints at follow-up. Although it is difficult to compare the two studies because of lack of detail, the reasons subjects used the splints are consistent between both studies. The splints were most often used for eating, particularly for handling silverware; for grooming activities, such as brushing teeth; and for writing.

In Rogers and Figeone’s (1980) study of self-care skills, they found that a percentage of subjects similar to Allen’s findings of less than 43% with lesions at C-6 and C-7 continued to use splints. Subjects with C-4 and C-5 lesions preferred the ratchet hand splint over the more cumbersome, externally powered flexor-hinge splint.

The literature has little specific information on how the hand function of these patients is evaluated. Generally, observation of functional activities, such as self-care and avocational tasks, was the evaluation method of choice (Allen, 1971; Knox, et al., 1971; Newsom, Keenan, Maddry, & Aguilar, 1969; Nichols, Leach, Haworth, & Ennis, 1978; Rogers & Figeone, 1980).

The ratchet and wrist-driven flexor hinge splints were the subject of two studies conducted by Wise, Whar-
ton, and Robinson (1986). They reported a high rate of continued splint use, 80% and 82%, respectively, but failed to indicate the duration of follow-up. In both studies, less than 40% of all patients who were fit bilaterally continued to use both orthoses. Wise et al.'s second study group included an increased number of patients with incomplete lesions who were more likely to discontinue splint use.

In summary, there is agreement in the literature regarding the need for early splinting of the upper extremities of persons with quadriplegia, but there is little evidence as to the long-term efficacy. There is lack of agreement as to the definition of functional position, and it is not clear what criteria therapists use in selecting specific splint designs. Little information is available regarding evaluation of the hand function of these patients; therapists seem to rely on observation of daily activities. There was little discussion of concepts specific to quadriplegic hand function. The literature suggested that dynamic splints are used long term by patients with quadriplegia, particularly for eating and grooming.

Method

This was a descriptive survey that involved the use of a mailed questionnaire. The study was delimited to newly injured persons with quadriplegia who had sustained complete lesions resulting from traumatic injury.

Two-hundred questionnaires were mailed to occupational therapy department heads in hospitals and rehabilitation centers purporting to provide services to persons with spinal cord injury. The mailing list sources were Spinal Network (Maddox, 1987) and the current Commission on Accreditation of Rehabilitation Facilities listing.

Of the 200 questionnaires mailed, 120 were returned. Of these, 101 were usable. The remainder were not completed because the recipients were academics or did not think they treated sufficient numbers of persons with complete spinal cord injury to warrant participation in the survey. Of the final 101 returns, 89 came from occupational therapists working in rehabilitation settings and 12 from occupational therapists in acute care settings. The survey addressed static splints, dynamic splints, and hand function evaluation.

Results

Respondents' years of practice ranged from 1 to 29 years ($M = 8.11$ years). Years of experience with patients with spinal cord injury ranged from 3 months to 25 years ($M = 5.7$ years). Approximately 42% of the respondents spent less than half of their week working with spinal cord injury patients. The remainder (57.3%) spent at least half of their time with these patients (see Figure 1).

Static Splints

Table 1 summarizes the frequency with which the respondents apply static splints. Given a list of 11 reasons for applying static splints, respondents were asked to indicate all of the reasons they subscribe to and to rank order what they considered to be the 5 most important reasons, which are listed below:

- Prevent contractures of wrist and hand (28.7% of respondents)
- Prevent overstretching wrist extensors (18.8%)
- Protect and stabilize joints (12.9%)
- Maintain arches of hand (8.9%)
- Maintain thumb web space (8.9%).

Additional reasons listed in rank order were to (a) promote optimal tightening of the hand, (b) maintain passive range of motion, (c) correct deformity, (d) prepare the
Table 1
Frequency With Which Respondents Apply Static Splints (N=101)

<table>
<thead>
<tr>
<th>SCI Level</th>
<th>Always</th>
<th>Most of the Time</th>
<th>Often</th>
<th>Seldom</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-5</td>
<td>56.7</td>
<td>26.8</td>
<td>8.2</td>
<td>8.2</td>
<td>0.0</td>
</tr>
<tr>
<td>C-6</td>
<td>31.3</td>
<td>34.4</td>
<td>19.8</td>
<td>13.5</td>
<td>1.0</td>
</tr>
<tr>
<td>C-7</td>
<td>7.3</td>
<td>25.0</td>
<td>25.0</td>
<td>35.4</td>
<td>7.3</td>
</tr>
<tr>
<td>C-8</td>
<td>2.1</td>
<td>12.6</td>
<td>17.9</td>
<td>52.6</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Note: Numbers indicate percentage of respondents. SCI = spinal cord injury.

hand for future dynamic splinting, (c) improve appearance, and (f) preserve the hand for future surgery.

The reasons respondents cited for not applying static splints were elicited with a write-in question. The responses were organized into emergent categories post hoc. Patient noncompliance was cited as a reason by 40.7% of the respondents; 30.2% said that when tenodesis was adequate without a splint, they would not apply one; and 24.4% gave interference of medical complications as a reason. Additional reasons given were skin intolerance (by 19.8%) and adequate passive range of motion (by 12.8%).

As indicated in the literature review, there are many static splint designs. The survey respondents were presented with a list of five common designs and asked to indicate those that they usually prescribed for each level (i.e., C-5, C-6, C-7, C-8). Unlisted splint designs could be written in. The static splint designs commonly used with each level of lesion are summarized in Figure 2.

To probe the clinical reasoning behind splint choice, the respondents were asked to indicate which of seven listed criteria they used when selecting splint designs and then to rank order the five most important criteria to consider. The three highest ranked criteria were muscle strength (48%), level of injury (32%), and patient and family acceptance (9%). Criteria considered less often were time since injury, medical complications, nursing follow-through, the patient’s education level, degree of spasticity, range of motion, funding, and reimbursement.

We attempted to identify how soon after injury static

Figure 2. Summary of static splint designs by level of lesion. Note. MCP = metacarpophalangeal.
splints were applied. The responses to this question indicated that patients are splinted early in both acute and rehabilitation settings. We also tried to identify a standard schedule for wearing static splints. The results failed to yield any consistent patterns. There were almost as many wearing schedules as there were respondents, thus it appears to be highly individualized to patient and setting. In general, the splint most used at night was the resting hand splint, while daytime splints were typically wrist supports and opponens designs.

**Dynamic Splints**

Table 2 shows a summary of the frequency with which the respondents applied dynamic splints by level of lesion. When asked to indicate what they believed to be the optimal tenodesis position, 58.4% of the respondents indicated oppositional, or three-point, pinch; 29.7% indicated lateral pinch; and 15.8% indicated both oppositional and lateral pinch. Those who indicated both stated they preferred the oppositional position if a splint is worn and lateral if no splint is worn.

The dynamic splint designs that respondents usually used are presented by lesion level in Figure 3. Clearly, persons with lesions at C-6 are more likely to be fitted with dynamic splints.

As with the static splints, we investigated the respondents' reasons for not applying dynamic splints. The most common reasons were patient nonacceptance (82.2%),

<table>
<thead>
<tr>
<th>SCI Level</th>
<th>Always</th>
<th>Most of the Time</th>
<th>Often</th>
<th>Seldom</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-5</td>
<td>2.1</td>
<td>12.4</td>
<td>16.5</td>
<td>47.4</td>
<td>21.6</td>
</tr>
<tr>
<td>C-6</td>
<td>9.2</td>
<td>31.6</td>
<td>28.6</td>
<td>24.5</td>
<td>6.1</td>
</tr>
<tr>
<td>C-7</td>
<td>8.4</td>
<td>15.8</td>
<td>18.9</td>
<td>44.2</td>
<td>12.6</td>
</tr>
<tr>
<td>C-8</td>
<td>2.3</td>
<td>5.7</td>
<td>8.0</td>
<td>42.0</td>
<td>42.0</td>
</tr>
</tbody>
</table>

*Note. Numbers indicate percentage of respondents. SCI = spinal cord injury.*
cost (36.6%), lack of reimbursement (32.7%), and contractures (20.8%). Other reasons given were lack of a qualified orthotist (5%), unsuitable patient population (5%), and lack of family acceptance (5%).

Hand Function Evaluation

Regarding evaluation of hand function, four standardized tests, the Nine Hole Peg Test (Mathiowetz, Weber, Khashman, & Volland, 1985), the Minnesota Rate of Manipulation Test (American Guidance Service, 1969), the Jebsen-Taylor Hand Function Test (Jebsen, Taylor, Treischmann, Trotter, & Howard, 1969), and the Perdue Pegboard Test (Tiffin & Asher, 1948), were used by between 34% and 44% of the respondents. However, most respondents (61%) expressed their preference for observations of the patients engaged in functional activities as the most appropriate assessment of hand function in this population.

Reasons cited for not using standardized assessments were concern about the validity of such tests for spinal cord injury (cited by 59.5% of respondents); time constraints, priority conflicts, or both (e.g., treatment time was needed for other things or the therapists had to treat more than 1 patient at a time precluding individual attention required for test administration) (26.2%); patient issues (e.g., the patient became bored or frustrated) (19.0%); and therapist or department limitations or both (e.g., test not available or therapist lacked knowledge of how to administer the test) (14.3%).

To determine if there was any relationship between the respondents’ characteristics and the choices they made, we calculated Spearman correlation coefficients for several of the questions. The results were inconclusive and did not indicate consistently meaningful relationships.

Discussion

The results of this study suggest that the application of static splints to patients with quadriplegia is common practice among occupational therapists. However, such splints are used less frequently than the literature indicates they should be. This discrepancy may be attributed in part to the reasons respondents gave for not splinting, as listed earlier.

The fact that patients with lesions at C-5 and C-6 were more likely to be fitted with static splints than those with C-7 or C-8 lesions makes intuitive sense, because the former patients have less active musculature to support the hand structure. However, patients with C-7 and C-8 lesions have a potential muscle imbalance, whereby the extrinsic muscles can overpower the weak or absent intrinsic muscles, thus putting them at risk for claw hand deformity. This suggests that splinting should be considered for these patients.

The literature review revealed much discrepancy in defining optimal functional positioning for the quadriplegic hand. We did not ask our respondents to define it because functional position can vary according to the specific clinical picture presented by individual patients with quadriplegia. For example, if there is finger flexor tone, one might want to splint with the wrist in neutral to open the hand and decrease the tone. Conversely, if there is no finger flexor tone, one might want to splint with the wrist in 30° to 45° of extension to encourage tightening of the flexors to allow future tenodesis grasp. Clearly, specific concepts regarding hand function need to be defined. For example, a flowchart could be created for decision making concerning splinting options for specific hand variables.

Recent work by Ditunno, Stover, Donovan, Waters, and Sniezek (1989) indicates a steady increase in the occurrence of incomplete lesions and concomitant decrease in complete lesions over the past 10 years. This suggests that early splinting to preserve the architecture of the hand will be even more important in the future, because ultimate hand function is more difficult to predict in persons with incomplete lesions.

There was a fair degree of consistency regarding the clinical reasoning pertaining to static splints. We found that the reasons that respondents elected to apply static splints were similar to those identified in the literature. Regarding the selection of a specific splint design, muscle strength was the main criterion cited by the respondents; almost half of them checked this item. It is interesting to note that the patient’s and family’s acceptance was the third-ranked splint design selection criterion, although it was cited by few respondents. However, patient noncompliance was the primary reason that respondents gave for electing not to apply static splints. This suggests that there is a screening process in place that is applied to patients to determine suitability for splinting.

The results of the study indicate that dynamic splints are more likely to be applied to patients with C-6 and C-7 lesions. Summing the responses for always, most of the time, and often for each lesion level, we found the following: C-5 = 31%, C-6 = 69%, C-7 = 43%, and C-8 = 15%. Although people with C-8 lesions are not likely to be fitted with dynamic splints, the results suggest that the use of such splints for this level of injury should be considered.

Lack of patient compliance was again the major reason that respondents did not provide dynamic splints to patients. Contradictory findings regarding patient compliance with wearing dynamic splints is reported in the literature. Wise and colleagues (1986) and Shepherd and Ruzicka (1991) found high levels (82% and 53%, respectively) of acceptance of specific dynamic splints as indicated by continued use. However, Garber and Gregorio (1990) found that overall splint use declined to 39% after 2 years. Our results suggest that therapists screen patients for compliance prior to fitting dynamic splints.
Thus, the results of the cited studies should be considered in light of this selection effect.

Our finding that most respondents preferred to evaluate hand function by observing the patient performing functional daily tasks concurs with the literature. However, this method leaves no objective means to document baseline status or ongoing progress. The majority of respondents cited lack of validity for the population with spinal cord injury as their primary reason for not using the available hand function tests. The standardized tests reported in the survey are all timed and have normative data for nondysfunctional persons. Although the person with quadriplegia may perform these tasks in a functional manner, the timed scores will rarely be in line with the available norms. Additionally, a person with quadriplegia will often perform functional tasks using both hands, whereas the tests listed in the survey are administered unilaterally or require the hands to work independent of each other to complete the task.

It is clear from the results of the study that a standardized, valid hand function test for patients with quadriplegia is needed. The assessment might be based on functional activities, not be timed, permit use of both hands, and allow use of adaptive devices.

The effectiveness of static hand splinting remains unaddressed. The results of our study concur with the literature that splinting is an accepted treatment intervention for quadriplegia and therefore cannot ethically be withheld for the purpose of experimental research. Efficacy studies are needed to justify the expense of splinting in terms of time and money.

Acknowledgments

We greatly appreciate the participation of the therapists who responded to the questionnaire.

We gratefully acknowledge the American Occupational Therapy Foundation for funding this study.

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