Development of a tetraplegic hand assessment and splinting protocol

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The occupational therapists at the National Spinal Injuries Centre initiated a survey of national and international spinal units in order to investigate which components of hand assessment and which hand splints were most commonly used on patients who have had a spinal cord injury. One hundred and seven questionnaires were sent, but of the 49 returned, only 44 of the assessment questionnaires and 46 of the splinting questionnaires were fully completed and could be used for this study. The results from this survey, the information gathered from the literature and the experiences of the occupational therapists, were used to develop a tetraplegic hand assessment and splinting protocol. This protocol has helped the occupational therapists to be more thorough in their hand assessments, and more discerning with the splints that they make or supply for patients. The low response would suggest that this study should be viewed as a pilot one and that there is need for more valid and reliable research.

Keywords: tetraplegic; hand assessment; splints; occupational therapy.

Introduction

Hand assessments and static hand splinting are an integral part of occupational therapy for patients who have had a serious cervical spinal cord injury.^{1–7} The information obtained from assessments is invaluable for planning, monitoring and evaluating treatment.^{1,2} Splints are important as a means of preventing deformity and promoting a functional hand position.^{1–3,7–12}

Despite the apparent importance of hand assessments Krajnik & Bridle⁷ found that formal assessments were not done due to a lack of time and staff shortages, the absence of standardised tests available for spinal cord injured patients, limited funding with which to purchase equipment, and/or patient boredom or frustration. They found that therapists considered observation of the patient when involved in functional activities as the most informative assessment. However, these authors suggested that this does not provide an objective means of documenting a patient's status and progress. Krajnik & Bridle⁷ also noted that splinting the tetraplegic hand was an accepted practice amongst occupational therapists, but that there were no studies to validate its

effectiveness. As a result there appears to be a variety of splints made for similar purposes.^{1,2,7,9,12}

The occupational therapists at the National Spinal Injuries Centre (NSIC) had been concerned for some time that they had not been using formal hand assessments, for reasons similar to those identified by Krajnik & Bridle.⁷ Furthermore, they were making very different splints for the same or similar problem.

These concerns resulted in a project to develop a 'tetraplegic hand assessment and splinting protocol' which would be within the scope of the staff to implement, considering their workloads and time limitations. The components included in the assessment were to be those most relevant for planning and monitoring treatment of the hands. The splints included were to be those most effective in preventing deformity and promoting hand function.

Literature review

Hand assessments

When assessing the tetraplegic hand occupational therapists are advised to include tests of physical appearance, range of motion,

muscle strength, muscle tone, sensation and function.^{1–3,5} Physical appearance involves the observation of the hands to identify oedema, scars, atrophy, dryness and other signs of dysfunction and injury.^{4,9,13} Range of motion, whether passive or active, may identify loss of joint movement due to contracture or stiffness.^{1,3,5,13,14} Restrictions of joint movement may affect the functional performance and abilities of the hands. Muscle tone can be assessed when doing range of motion measurements or when testing muscle strength.

Manual muscle testing provides an indication of the strength of muscle groups used to perform hand movements and prehension.^{1–3,5,15} The Oxford Scale is a common method of grading muscle strength.¹⁵ It is an important assessment for prescribing and monitoring hand splints and evaluating functional recovery.^{2,3}

Grip and pinch gauges are another means of evaluating the strength of hand muscles.^{1,2,3} The use of these gauges were appropriate for those patients with an incomplete cervical lesion or with a complete lesion of C8–T1.

Sensation is an important function of the hand.^{16,17} If impaired, the functional abilities of the hand will be affected. As there are a number of different sensory modalities, a variety of tests have been developed. These include tests for hot/cold, sharp/dull, light/deep touch, pain, stereognosis, proprioception, and two-point discrimination.^{1,3,4,13,14} Moberg¹⁸ suggested that two-point discrimination was the most useful sensory test for tetraplegic patients, as it not only indicated the degree of functional sensation in a person's hands but also correlated with proprioception.

Hand function tests are arguably the most important assessments used by occupational therapists. They measure the prehensile ability of the hand. There are a large number of different tests available, including the Jebson-Taylor hand function test,¹⁹ nine hole pegboard, test,²⁰ Purdue pegboard,²¹ physical capacities evaluation of hand skill,²² Carroll's hand function test,²³ Smith's hand function test²⁴ and the Sollerman test.²⁵ None of these has been standardised for tetraplegic patients.⁷

Initial assessment should be done while the patient is on bedrest, as it is during this phase that treatment begins.^{2,5,26} Reassessments are required to monitor progress and to adjust intervention accordingly.^{2,5,26} However few papers or reports indicate the frequency of timing of reassessments. Hill² suggested that a full assessment should be done on admission and discharge and parts of this assessment should be redone during rehabilitation. However, she did not indicate which parts of the full assessment should be redone in this way.

Static hand splinting

The hands of a tetraplegic patient may be prone to overstretching, contracture, stiffness, tightening of soft tissues, and instability of the joints, due to loss of muscle function.^{2,8,27} Static splints are considered to be an important means of controlling and preventing these deformities of the tetraplegic hand^{1,2,7,16,27–29} and they do this in several ways.

Firstly, splints may support the wrist in neutral to 30° dorsiflexion, the MP joints in 45°–90° flexion, the PIP joints in 45° flexion and the DIP joints in neutral. This is called the functional position^{1,2,10,30,31} and resembles the normal resting position of the hand, where the muscles and soft tissues are neither stretched nor contracted.

Hand splints may maintain the integrity of the joints.^{1,2,7,10,11,31} By supporting the joints and maintaining their alignment, splints compensate for weak or paralysed muscles and joint laxity, thus reducing any potential damage to soft tissues.

Splints may assist with maintaining the normal appearance of the hands by supporting the arches.^{1,2,7} To do this, they should be moulded to conform to the arches and creases of the hands.^{1,10,11}

By positioning the hand so that the muscles are not held in elongation, splints may prevent muscle overstretching.^{2,7,31} Furthermore they can maintain an adequate web space, which is important for retaining the cosmetic appearance of the hand, but more important for maintaining range of motion of the pollicis joints to allow functional grasp.^{1,2,7}

Finally, some splints aim to develop what is commonly called a tenodesis grasp by positioning the wrist and fingers in a position to shorten the long flexors of the fingers and thumb.^{2,29,32,33} When this is achieved, the person can grasp objects using a lateral or pulp to pulp pinch, by actively extending the wrist³⁴ (Fig 1). There does not appear to be any literature suggesting which tenodesis grasp should be achieved, although lateral pinch was the preferred result following tetraplegic hand surgery.^{18,35–38} The most common static hand splints for tetraplegic patients, referred to in the literature, can be separated into four categories:

- 1 *Resting pan or paddle splint (RPS)* (Fig 2): this type of splint supports the whole hand and wrist, and extends up the forearm. It fulfils all the purposes stated previously except that it does not develop tenodesis.^{1–3,7,9–12} It is worn by those patients who have wrist extensors and finger muscles of below grade 3 on the Oxford Scale.^{2,3,7,12}
- 2 *Wrist extension splints (WES)* (Fig 3): these splints support the wrist in exten-

Figure 1 Tenodesis Grasp: (A) Pulp to pulp pinch. (B) Lateral pinch.

Figure 2 Resting pan or paddle splint (RPS).

Figure 3 Wrist extension splints (WES). (A) Futuro-type wrist splint. (B) Long opponens splint. (C) Dorsal cock-up splint. (D) Spiral splint.

sion and are prescribed for patients with wrist extensors of grade 3 or below, but who have elbow flexors.^{1–3} They enable patients to use their hands, and with assistive devices to do such activities as push a manual wheelchair, feed themselves and use a keyboard. The long opponens splint also maintains the web space.^{1–3} Various authors claim that this

splint may assist in developing tenodesis, but this was disputed by Cheshire & Rowe.⁹ There was no evidence in the literature to support either claim.

- 3 *Short hand splints (SHS)* (Fig 4): these are worn to maintain the web space, promote a functional hand position and prevent hyperextension of the MP joints.^{2,3,7} They are worn by patients who have good wrist extension, but an imbalance between the extrinsic and intrinsic finger muscles.^{2,3,7}
- 4 *Tenodesis splints (TS)* (Fig 5): there appears to be a lack of literature on these

Figure 4 Short hand splints (SHS). (A) Short resting pan or paddle splint. (B) Short opponens splint. (C) Thumb post splint. (D) Commercially available MP flexion splint.

Figure 5 Tenodesis splints (TS). (A) Taping. (B) Heidleberg splint. (C) Volar splint.

splints even though several authors mention developing tenodesis grasp as a purpose of splinting.^{2,7,12,28,32} Most of the information on the use of these splints comes from handouts which various departments had written for their own use. These splints would be for those who have wrist extensors of above grade 3 with flickers or no movement of the fingers.^{2,3,7}

The literature failed to identify the frequency and the stages of rehabilitation when each component of the assessment should be done, nor which splint from each category was most effective. Further information was required before a hand protocol could be developed. A survey was conducted to gather information on what happened in practice.

Methods

One hundred and seven questionnaires were sent to occupational therapy departments attached to spinal injury centres in the following countries (the number in the bracket is the number of centres contacted): Britain (12), Ireland (1), Iceland (1), Sweden (8), Finland (3), France (4), India (8), Belgium (1), Norway (2), Italy (1), Denmark (2), Netherlands (7), Austria (3), Zimbabwe (1), Philippines (2), Japan (3), Singapore (2), Malaysia (1), USA (22), Canada (15), Australia (6) and New Zealand (2). The list of spinal units was obtained from the occupational therapy associations of countries affiliated to the World Federation of Occupational Therapists. The first section of the questionnaire referred to hand assessments, and the second section to hand splinting, of tetraplegic patients.

Therapists were asked to indicate the stages of a patient's hospital stay when they used each assessment component. This study separated the hospital stay into four stages: (1) bedrest stage (BR) from admission to when the patient starts to sit up out of bed; (2) bedrest complete stage (BRC) from when the patient first sits out of bed until sitting is tolerated long enough to start going to the therapy departments; (3) rehabilitation stage (Rehab) from when the patient first starts to attend therapy departments until discharge; (4) discharge stage (DC) which is the period prior to when the patient leaves hospital.

In the splinting section, therapists were asked to list the three most common static hand splints they used, the reasons they used them and for which level of lesion each splint was appropriate.

The therapists were asked to send a copy of their assessment forms and splint patterns with the completed questionnaires.

Results

Forty nine (46%) questionnaires were returned. These came from the following countries: Britain (8), Ireland (1), Sweden (2), France (1), India (1), Norway (2), Denmark (2), Netherlands (1), Zimbabwe (1), Philippines (1), USA (13), Canada (10),

Australia (5) and New Zealand (1). A low return rate is often associated with postal surveys but the problem may also have been compounded by language (the questionnaires were only written in English), incorrect address of contact or the questionnaires may not have been appropriate to some centres. Of the 49 (46%) replies, only 44 (41%) of the assessment section and 46 (43%) of the splinting section were completed fully and could be used in the study.

Hand assessments

The number of respondents who used each component is shown in Figure 7. There were some other components mentioned such as oedema, muscle bulk measurements and photographic record, but these were only mentioned by a few respondents and so were not included in the study. Not all respondents indicated which tools they used for each component so it was not possible to determine the statistical significance for this.

There does not appear to be any definitely preferred hand function test. Many therapists used their own or a variety of commercially available ones, which may have been adapted, including some of the tests mentioned in the literature review.

Many therapists indicated that they assess several sensory modalities including sharp/dull, light/deep touch, temperature, stereognosis, two-point discrimination and proprioception. Three noted that they only do two-point discrimination.

Although grip strength measurements were used by 98% of respondents, many of them indicated that it is most useful for those with a complete lesion of C8–T1. Most respondents did not comment on how they tested grip strength, but of those that did, a dynameter was preferred. The comments on pinch strength were similar.

None of the respondents indicated how they assessed range of motion; however it is usually done with a goniometer or by Odstock wire tracings.³⁹ It was noted that muscle tone was assessed by observation or when doing another assessment. Some therapists said that it was formally assessed by another department.

The Oxford Scale was the preferred choice of those who indicated which scale they used to record manual muscle testing. Some respondents commented that this test was done by another department.

Except for hand function, all other components were used for an initial assessment during the bedrest stage by a large percentage of respondents (Fig 6). Significantly more reassessments were done during the rehabilitation and discharge stages. A small

majority of respondents indicated they would reassess range of motion and muscle tone during the bedrest complete stage (Fig 6).

Hand splinting

Thirty-nine (85%) of respondents used wrist extension splints, 38 (83%) used resting pan or paddle splints, 26 (51%) used short hand splints and 14 (30%) used tenodesis splints.

Figure 6 Assessment and reassessment.

There was no indication as to which splint in each category was most preferred.

The purposes for each category of splints are shown in Figure 7. Results greater than 50% indicate that the majority of respondents who used that type of splint felt it fulfilled that purpose. Figure 8 shows the levels of lesion for which the respondents felt the splints were appropriate.

Discussion and development of the protocol

The results from this survey can only be considered as an indication of hand assessment and splinting practice, as there was a poor return of questionnaires. Furthermore, the questionnaire structure had two major weaknesses. It did not accurately record which assessment tools were used and it did

Figure 7 Purposes of splints. PFP = promote functional position; MJJ = maintain joint integrity; SA = support arches; PMO = prevent muscle overstretch; PNT = provide natural tenodesis; MWS = maintain web space; WES = wrist extension splints; RPS = resting pan or paddle splints; SHS = short hand splints; TS = tenodesis splints.

Figure 8 Splints for different levels of cord injury. See Figure 7 for key.

not indicate which splints the respondents found to be most effective in each category.

The results and the literature review did, however, highlight that there are gaps in the knowledge of appropriate hand assessment and splinting methods. Possibly as a result of this, there was a lack of consistency of practice between different spinal injury units.

In an attempt to start to close the gaps and to develop consistency, the results of the literature review and the survey were used to develop a tetraplegic hand assessment and splinting protocol, to be used by occupational therapists at NSIC. This protocol would provide a basis for future valid and reliable research.

Hand assessment protocol (Table I)

Both the survey and literature review indicated that a hand assessment should include a test of hand function, sensation, range of motion, muscle strength, and grip and pinch strength. Muscle tone could be assessed informally when doing other tests.

Physical appearance was noted in the literature^{4,9,13} but not in the survey, although some of the 'other assessments' listed by respondents would belong within this component. Like many of the other components, appearance would initially be recorded during the complete bedrest stage and then formally again on discharge. Only informal observation would be required between these stages as the appearance of the hand usually changes gradually. Any significant changes would be noted when doing other assessment components or treatments.

Range of motion measurements should be done on all tetraplegic patients at least once during the bedrest stage, once during the rehabilitation stage and on discharge. If the reassessment is done early during the rehabilitation stage there would be little need to do an assessment during the complete bedrest stage. A manual protractor finger goniometer would be the chosen measuring tool as its use is well documented.^{2,3,5,14}

Manual muscle testing helps to determine the most appropriate splints to be worn.^{2,3,34} The Oxford Scale is a recognised grading system although some authors, such as Pedretti,⁴⁰ adapt it in an attempt to make it more precise. This test would initially be done on all tetraplegic patients during the bedrest stage. Only those who have some returned wrist and hand movements will require reassessment, which would be done at least once during the rehabilitation stage and on discharge.

Identifying intact sensation is important for indicating the functional potential of the hands.¹⁸ Testing all of the sensory modalities would be time consuming. As Moberg's two-point discrimination appears to be quick to administer, reliable and indicates functional sensation of the hands, it is the preferred method of sensory assessment. This would be done on all new tetraplegic patients during the bedrest stage. Only those patients who have some sensation of their hands need to be reassessed.

Grip and pinch strength would be measured using a torsion dynamometer linked to a microprocessor.⁴¹ This provides a visual and reliable tool to measure strength. For patients with a complete tetraplegic injury, only those with a C8–T1

Table I Tetraplegic hand assessment protocol

Component	Bedrest	Rehabilitation	Discharge stage	Lesion level
Appearance	Initial	Informal	Reassess	C1–Ta
Range of motion	Initial	Reassess	Reassess	C1–T1
Manual muscle test	Initial	Reassess	Reassess	C1–T1/C5–T1
Sensation	Initial	Reassess	Reassess	C1–T1/C5–T1
Grip strength	N/A	Initial	Reassess	C8–T1
Pinch	N/A	Initial	Reassess	C8–T1
Hand	N/A	Initial	Reassess	C5–T1

N/A = not applicable.

lesion need do this test as those with a higher lesion usually have insufficient strength and hand movements to register a recording. As manual muscle testing is done during the bedrest stage, grip and pinch strength can be initially assessed during the rehabilitation stage and again on discharge.

None of the commercially available hand function tests have been standardised for tetraplegic patients and this made it difficult to determine which one would be most appropriate. The survey did not highlight a greater preference. The Sollerman hand test (Fig 9)²⁵ appeared to be suitable as it offered a number of activities which require a variety of grips to perform. The scoring procedure and some of the subtests would need to be adapted. As a person has to be sitting to do this test, the initial assessment would be done during the rehabilitation stage with a reassessment on discharge. This test would only be suitable for those patients who have some wrist movement.

Figure 9 Sollerman hand test.

Static hand splinting protocol (Table II)

Unfortunately no specific splints were identified as being the most effective in the literature review or more commonly used in the survey. One splint from each category was chosen for the protocol. Each splint was chosen on the basis of the ease of application, familiarity to the therapists at NSIC, and whether it fulfilled the reasons appropriate to the category that the splint was in.

There was only one splint in the resting pan/paddle category (Fig 2). This splint would be used for those patients with a complete lesion of C5 or above.^{2,3,7,12} For those patients with a complete lesion of

C1–C4 this would be their only splint. It would be worn mainly at night to maintain the hands in a functional position. The hands would be positioned correctly during the day without the splints. For those patients with a complete lesion of C5, wrist extension splints would be worn during the day.¹⁻³

The Futuro-type wrist splint (Fig 3a) appears to be an acceptable wrist extension splint as it is commercially available and quick to apply. Also, after patients have

Table II Splinting protocol

Splint	Muscle grade	Wearing regime
Paddle	Wrist ext: 0–3 Fingers: 0–3	Night and when resting
Futuro	Wrist ext: 0–3 Fingers: 0–3 Elbow flex: 3–5	Daytime when using hands
Short paddle	Wrist ext: 3–5 Fingers: 0–3	Night and when resting
Taping	Wrist ext: 3–5 Fingers: 0–1	Night and use hands during the day

been discharged they can order their own. It is worn as a functional splint for those patients who have weak wrist extensors but some elbow movement, mainly those with a C5 lesion.

The short paddle/resting pan splint (Fig 4a) was chosen as it is a short version of the splint in Figure 2 and hence similar to make. It would only be a temporary splint made for those patients with an imbalance between the extrinsic and intrinsic hand muscles, who have good wrist movement, ie those with a lesion of C7–8.^{2,3,7} It prevents hyperextension of the MP joints and maintains a functional hand position. It would be worn at night as patients are encouraged to actively use their hands during the day.

To achieve a tenodesis grasp, a Futuro-type splint would hold the wrist in extension and the fingers would be taped into 90° flexion of the MP and PIP joints, and neutral position of the DIP joints (Fig 5a). Taping appears to be one of the easiest and quickest methods, especially because the Futuro-type splints are commercially available. Lateral pinch is obtained as it is considered more stable and versatile than pulp to pulp pinch and is preferred following hand surgery.¹⁸ Taping is appropriate for those with a wrist extension grade of above 3 and finger movement of below grade 2, which corresponds to those with a complete lesion of C6–7. This would not be an appropriate splint for those with an incomplete lesion as it may interfere with the recovery of hand movements. This splint would be worn throughout the night and patients encouraged to use their hands during the day.

Tenodesis splints are arguably the most controversial splints made for patients with a tetraplegic lesion because they shorten the flexor tendons. If incorrectly applied or prescribed, patients may develop a fixed flexion contracture of the proximal interphalangeal joints. If contracture should occur, this may limit the functional potential

of specific hand grips, and interfere with future surgical attempts to restore finger movement. However, proponents of this method of splinting maintain that it facilitates the natural shortening of the flexor tendons so that a functional tenodesis grip is achieved more quickly. Fixed flexion contracture and stiffness of the joints are prevented by daily stretching. Splinting would cease once the person developed a functional tenodesis grip.

Conclusions

Through the use of a literature review and a descriptive survey, the occupational therapists at the NSIC were able to develop a tetraplegic hand assessment and splinting protocol. This protocol will assist the occupational therapists to conduct effective hand assessments which will monitor their treatment and to be consistent in the splints they make and the reasons for making them. Unfortunately not all aspects of the protocol are supported by the literature nor this study, and as a result the experience of the therapists was used to select the specific functional hand test and splints. In order to see if these are suitable the protocol will need to be evaluated regularly.

Valid and reliable research needs to be conducted into many aspects of tetraplegic hand assessment and splinting. The development of appropriate assessment tools, particularly for hand function, requires thorough investigation, as does the value of splinting and the effectiveness of specific splints, such as those that develop tenodesis.

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