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Carpal Tunnel Syndrome: Clinical Application

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Carpal Tunnel Syndrome: Clinical Application

by

Amy Schneider
Bachelor Science in Physical Therapy
University of North Dakota, 1996

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of Master of Physical Therapy

Grand Forks, North Dakota
May
1997
This Independent Study, submitted by Amy Schneider in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

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ABSTRACT

Carpal tunnel syndrome (CTS) causes irritation or compression of the median nerve within the carpal tunnel at the wrist. CTS is caused by factors including bony abnormalities, neuropathic conditions, inflammatory conditions, and most commonly, cumulative trauma. The trauma involves excessive repetition, force, bending, vibration, and impact activities performed at home or at work. As a result, the median nerve becomes irritated and intermittent sensory deficits occur initially leading to motor dysfunction with advanced disease. Once CTS is diagnosed, the first line of defense is conservative treatment which may result in operative care if unsuccessful. Modified activity and early postoperative hand therapy is the key to a good prognosis, although no treatment is a reliable cure.

CTS is a growing epidemic with increasing treatment cost demands due to the growing use of computers which lead to repetitive motion. Physical therapists must stay current on the causes, diagnosis, treatment, and prevention of CTS to reduce the incidence. The focus of this paper remains on the therapist’s role in treating CTS conservatively and postoperatively utilizing various clinical techniques with emphasis on preventing CTS using ergonomics in the workplace.
CHAPTER 1

INTRODUCTION

Carpal tunnel syndrome (CTS) falls under the broad category of cumulative trauma disorders. Cumulative trauma disorders are increasing at an alarming rate. In 1983 there were 27,000 reported cases of cumulative trauma disorders, and in 1990 that figure had risen to 224,000 cases. In 1982, the average cost of treatment of cumulative trauma disorders was $29,000 and that figure had elevated to $190,000 by 1990. In 1986 Masear and colleagues studied a meat packing plant which had an excessively high rate of CTS. In this particular plant, days lost from work and compensation claims had amounted to costs in excess of 1 million dollars during the 5 years preceding the study. Lost work days ranged from 7 to 285 with an average of 53.6 days lost per hand. Workers’ compensation ranged from $206 to $4,906 with an average of $1,848 per hand. Settlement costs ranged from $617 to $15,973 with an average of $8,073 per hand. These figures do not include hospital bills and physician fees.

CTS is not a new discovery. Sir James Paget first described CTS in 1853. His description encompassed such symptoms as the loss of sensation to the thumb, middle and index fingers due to compression of the median nerve. His patient was relieved of
pain once the wrist was bound and the palmar aspect of the hand was allowed to relax. However, when the man used his hand the symptoms recurred because of increased pressure on the nerves. In more current literature, CTS has generally been defined as a condition that can limit the use of the hands due to too much pressure on the median nerve as it passes through the carpal tunnel. Phalen has stated that CTS is the primary cause of numbness and tingling in the fingers. In 1966, Phalen described the typical patient as a female (67-75%) between the ages of 40 and 60 years old (50%). According to Phalen, the majority (96%) of patients with CTS have no prior history of injury to their wrists before the onset of the symptoms. The excessive pressure on the median nerve may have a number of causes. Pain and tingling are the primary symptoms caused by the excessive pressure. Unrelieved pressure can cause permanent nerve damage, however CTS is treatable if caught early. Prevention of the problem is easier than correcting it. To aid in prevention, an understanding of the anatomy of the area is crucial.

The anatomy of the wrist and all of its structures is quite intricate (Figure 1). The median nerve runs through the carpal tunnel at the wrist. The carpal tunnel is formed as the transverse carpal ligament stretches from the scaphoid and trapezium, across a groove, and attaches to the pisiform and the hook of the hamate bone. The median nerve passes directly beneath the transverse carpal ligament, superficial to the nine flexor tendons and vasculature, confined within the small tunnel. It is at this level that the median nerve is the most vulnerable to compression by any condition that increases the volume of the structures within the carpal tunnel. Slight swelling of the flexor tendons may be all it takes to force the median nerve up against the firm, inelastic ligament,
1. Median nerve
2. Ulnar nerve
2a. Deep branch of the ulnar nerve
2b. Superficial branch of the ulnar nerve
3. Flexor retinaculum
4. Aponeurosis of the flexor carpi ulnaris muscle
5. Flexor carpi ulnaris muscle
6. Flexor carpi radialis muscle
7. Ulnar artery
8. Palmaris longus muscle
9. Flexor pollicis longus muscle

Figure 1.—Anatomy of the Carpal Tunnel. (Adapted from Pecina et al7)
causing motor and sensory changes experienced in the structures supplied by the distal portion of the median nerve.\textsuperscript{8} This tight space can also disrupt the normal sliding of the nerve, resulting in stretching injuries and microlesions in the already trapped nerve as the extremity moves. An inflammatory reaction and a constricting scar may develop, contributing to permanent entrapment of the nerve.\textsuperscript{9}

Acute CTS is a relatively rare occurrence.\textsuperscript{10} There is a rapid and intense development of symptoms after an individual sustains trauma to the wrist such as a fracture or dislocation of any bones that make up the wrist. Immediate surgical decompression is essential if the symptoms fail to resolve within 6 to 8 hours to prevent further nerve damage. More commonly, however CTS develops in stages.

During the early stages of chronic CTS, swelling and irritation develop, possibly resulting from repetitive wrist movements, vibratory forces, and internal biomechanics fraying the tendons.\textsuperscript{11} At this stage, tingling, numbness, clumsiness, or weakness may be felt in the affected hand, with feeling returning to normal after a rest period. In the intermediate stage, persistent swelling causes constant pressure on the median nerve. Scar tissue also begins to form around the irritated tendons and nerve. Symptoms at this stage include increased incidences of numbness, prickling, burning, and aching in the palmar surface of the hand including the thumb, index and middle fingers (i.e., the sensory distribution of the median nerve). The sufferer often wakes up at night with numbness or tingling fingers (i.e., nocturnal pain) and notices general loss of coordination. The advanced stage of CTS is reached when chronic swelling and scarring cause permanent damage to the blood vessels, tendons, and nerve. Progressive loss in
coordination and strength of some of the muscles within the hand results in difficulties with grip strength and fine movements of the thumb. The abductor pollicis brevis is the muscle most commonly affected, owing to weak thumb abduction and atrophy of the thenar eminence.\textsuperscript{12} The symptoms include advanced loss of hand function, grip strength and muscle girth around the thumb, and the ability to use the involved hand for more than a few minutes or seconds without experiencing numbness, tingling and pain.

The typical patient history involves a gradual onset of the pain and numbness.\textsuperscript{4} However the patient may not be able to determine exactly where these symptoms occur. Burning pain or aching sensations may radiate proximally into the forearm, elbow and possibly the shoulder.\textsuperscript{8} Strenuous use of the hand almost always aggravates the symptoms, however the increase in numbness and pain in the fingers may not be noted until the hand has been at rest for several hours after the activity. Nocturnal pain is characteristic of CTS and it provokes the individual to seek medical attention. This numbness and burning pain is often relieved by hanging the hand over the side of the bed, shaking the hand, or vigorously exercising the fingers. Other symptoms of CTS may include swelling in the hand and volar forearm, and changes in the sweat functions in the hand.

There are variations in the manifestation of the symptoms of CTS. The combination of the classic symptoms discussed previously is common. Patients also may have only one of the classic signs of CTS, which is most commonly nocturnal pain.\textsuperscript{13} The vasodilatation and venostasis which accompanies sleep and inactivity produce swelling of the flexor synovialis, which in turn causes more pressure on the median nerve within the
confines of the carpal tunnel.\textsuperscript{4} Active motion of the fingers will usually relieve the pain by decreasing the venous engorgement.

The onset of a chronic injury, such as CTS, is slow and subtle, giving the worker time to adjust to tasks that cause distress.\textsuperscript{14} In order to complete the tasks that cause distress, employees substitute their usual motions with other movements that elicit less fatigue. Two complications arise with this “symptom march”. First, the multiple symptoms of CTS move from the original site and recruit other areas as the stress is shifted. Second, the symptoms temporally expand so the pain becomes more frequent and longer lasting, eventually becoming constant. This “symptom expansion” is common with chronic injuries and further complicates the management.

Due to the high incidence and cost of CTS it is important for a physical therapist to detect CTS at an early stage. Early detection of CTS is essential for successful non-surgical treatment. Gelberman et al\textsuperscript{15} noted that patients with mild symptoms and the shortest delays on nerve-conduction studies responded most favorably to conservative treatment. Symptoms of less than one year duration, numbness that was intermittent and diffuse, normal two-point discrimination, no evidence of weakness and atrophy, and one to two millisecond prolongations on nerve conduction studies can be considered to be a good prognosis for successful non-surgical treatment. Kaplan and coworkers\textsuperscript{16} noted that the following factors indicate non-surgical treatment: age under 50, symptom duration of less than 10 months, intermittent paraesthesiae, no stenosing flexor tenosynovitis, and a positive Phalen’s test of greater than 30 seconds.
Physical therapists need to stay current on the anatomy, symptoms, causes, and diagnosis of CTS to implement preventative programs in the work environment to finally decrease the incidence of CTS. Prevention is more effective and less expensive than any treatment that can possibly be provided to alleviate the symptoms of CTS. This paper will discuss the causes (chapter 2), assessment (chapter 3), treatment (chapter 4), and prevention (chapter 5) of CTS. The focus will remain on the physical therapist’s role in treating CTS conservatively and postoperatively, utilizing various clinical techniques including ergonomic principles for prevention of CTS.
CHAPTER 2

CAUSES

The direct and indirect causes of carpal tunnel syndrome (CTS) must be explored and identified to ensure proper diagnosis and treatment of the syndrome. Medically untreated disorders such as hypothyroidism, diabetes, and rheumatoid arthritis are underlying causes that may elicit CTS symptoms. These disorders can be considered indirect causes of CTS. The direct causes include trauma to the wrist, overuse activities of the wrist and hand, and abnormalities of the bones or muscles in and around the wrist joints. Immediate management of any indirect disorders may be the key to resolving the secondary, indirect CTS without surgery. In some cases, CTS may result from a combination of factors. For example, an individual can have rheumatoid arthritis and only after starting a job that requires repeated flexion of the wrist does the individual experience symptoms of CTS. This individual may require only treatment for the rheumatoid arthritis to minimize the symptoms of CTS. The causes of CTS must be carefully explored because the true culprit is sometimes hidden in the anatomy, physiology or kinesiology of the body.
Indirect Causes

Symptoms of CTS may result from many diverse conditions, none of which directly cause CTS. Indirect causes of a physiologic origin such as neuropathic conditions, inflammatory conditions, and alterations of fluid balance encourage CTS. Diabetes and alcoholism are neuropathic conditions that cause peripheral neuropathies and numbness. Tenosynovitis, rheumatoid arthritis, infections, and gout encompass the inflammatory disorders that reduce the size of the carpal tunnel. CTS is also associated with other rheumatic diseases including trigger finger and de Quervain’s tenosynovitis. Alterations of fluid balance can occur with pregnancy, hormonal changes, long-term renal dialysis, Raynaud’s disease, and obesity.

According to Phalen in 1970, CTS often accompanies diabetes. In his study, 27% of patients with diabetes or a history of diabetes in the family presented with CTS. Phalen concluded that if the median nerve is mildly affected by the diabetic neuritis, it could be more subject to slight alterations within the carpal tunnel as compared to a normal nerve. In a 1972 study by Phalen, 14.5% of patients with CTS also had diabetes mellitus and an additional 10% gave a family history of diabetes.

If fullness of the soft tissue in the wrist is causing numbness, tenosynovitis is usually the culprit. In a 1975 study by Hybbinette and Mannerfelt, the most common cause of CTS was a combination of tenosynovitis of the flexor tendons and rheumatoid arthritis occurring in approximately 30% of patients with CTS. In Phalen’s study, which supports this theory, 12.8% of the patients in his study had rheumatoid arthritis as well as CTS and 26% presented with chronic nonspecific inflammation. Swelling on the volar
aspect of the forearm just proximal to the wrist was a regular finding in patients with CTS (69 out of 439) and swelling in the entire hand and fingers was noted in 51 patients out of 439.\(^8\)

Fluid retention caused by venous stasis and vasodilatation, both resulting from sleep and inactivity may cause symptoms of CTS to develop.\(^8\) Active motion of the fingers will decrease the venous engorgement in the carpal tunnel and provide relief. Edema is the suspected culprit when CTS manifests with pregnancy.\(^12\) Usually CTS is abated soon after delivery with the decrease in fluid retention, however the patient may later develop tenosynovitis and CTS at menopause.\(^5,12\) Since women at or near menopause make up the majority of CTS patients, hormonal changes may be playing a role in CTS development.\(^5\) In a study by Kasdan and Janes,\(^20\) 13\% of females with CTS were postmenopausal and 42.5\% of the female patients had either a hysterectomy and/or oophorectomy. Patients on renal dialysis had forearm vascular shunts, which may increase the venous stasis pressure and edema in the ipsilateral upper extremity resulting in nerve compression and causing CTS symptoms.\(^18\)

In addition, obesity may be considered a risk factor for CTS. According to Kasdan and Janes,\(^20\) out of 1075 patients in their study, 197 were obese (18.3\%). Phalen\(^8\) noted that an increase in adipose tissue in the carpal tunnel can aggravate CTS symptoms. In a study conducted by Nathan and colleagues,\(^21\) obesity in industrial workers was linked to an increased prevalence of slowing of the sensory nerve conduction of the median nerve which is a characteristic of CTS.
A combination of factors contribute to CTS. Barrer also found that only five percent of cases of CTS are the result of diabetes, pregnancy, thyroid disease, recreational activities, the aging process, bone dislocation and fractures, arthritis, fluid retention, vitamin B₆ deficiency, genetic predilection and psychosocial problems. In a 1986 study by Kulick and associates, 49 out of 100 cases of CTS had predisposing conditions including rheumatoid arthritis, osteoarthritis, diabetes and hypothyroidism.

**Direct Causes**

The direct causes of CTS include local trauma, abnormalities of the actual bones and muscles that either make up the carpal tunnel or reside around the area, and overuse. Anatomic changes such as a reduction in the size of the carpal tunnel or an increase in the contents of the canal can trigger CTS. Bony abnormalities, a thickened transverse ligament, and acromegaly shrink the size of the tunnel, while abnormal muscle bulk, various tumors, and a hypertrophic synovium add to the contents within the tunnel. Bony abnormalities may result from wrist or hand fractures, and scaphiod or lunate dislocations, all of which can cause acute or chronic CTS. Despite all the possible problems that may accompany it, trauma is not considered a common cause of CTS.

Congenital anomalies including distal prolongation of the muscle bellies into the carpal tunnel and unusually large vessels on the median nerve, can contribute to the compression of the median nerve. In addition, Phalen discovered two other abnormalities that can impinge on the carpal tunnel. Phalen found one tumor and two ganglia in three patients of the 212 operative cases. In addition, in the same study, Phalen discovered thickening or fibrosis of the flexor synovium within the carpal tunnel in 202
of the 212 (95.8%) surgical wrists. In a later study, 54.6% of the patients that received a surgical biopsy showed fibrosis or thickening of the flexor synovium. Phalen believed this thickening and fibrosis was associated with some type of rheumatic process in the majority of the patients.

The last and most frequent direct cause of CTS is associated with the position and use of the wrist and hand. If repetition, force, bending, vibration and impact are excessive, the risk of developing CTS is increased. Overuse can be a result of constant, rapid, repetitious activity, forceful gripping and pinching, and excessive wrist flexion and extension. These activities cause tendon irritation and decreased blood flow to the carpal tunnel resulting in microtrauma to the soft tissues. The vibration of power tools, steering wheels, and other equipment irritate the median nerve and other structures in the wrist and hand. Patients exposed to vibratory, handheld power tools have a rapid development of numbness, with symptoms lasting progressively longer with continued exposure. Excessive impact that occurs when the hand or a tool held in the hand is used to hit, move or jerk objects may result in damage to the wrist.

Many common everyday activities can lead to overuse of the wrist and hand:

1. Heavy use of hand tools - construction, woodworking, assembly
2. Repetitive keyboarding - computers, adding machines, stamping tools
3. Sewing - machine sewing, threading, knitting, crocheting, industrial textiles
4. Instruments - violin, piano, heavy brass and flute-like instruments
5. Assembling - assembly line, repair work, manufacturing, hobbies

6. Cutting - meat packing, poultry, kitchen and textile work

Many of the high risk activities listed above can be performed at home or on the job. Strains can occur at home while cleaning, child rearing, doing hobbies and even sleeping. Some people keep their wrists flexed during sleep which can cause or irritate the symptoms of CTS.\(^5\)

There is some discrepancy in the literature whether CTS is a result of activities performed at home or at work or a combination of the two. Studies in the past considered occupation as a rare cause of CTS. Phalen\(^4\) stated in 1972 that CTS is rarely a result of occupational trauma. Tenosynovitis resulting from prolonged, excessive, and forceful grasping movements was not a common finding in industrial workers in 1966.\(^8\) Phalen believed, at that time, that an occupation may aggravate but will rarely produce CTS.

However, more recent studies list occupational activities as the cause of CTS. Maizlish et al\(^26\) studied various employees of one California county in 1987. Twenty-five percent of those employees reported CTS symptoms within one year of hire or starting a new job that the employee characterized as repetitive, excessively forceful, and involving pinch grips and awkward postures. As a result the same study, the survey of health care providers revealed 3,413 work-related cases of CTS were treated in California. In a study by Harter et al\(^27\), out of 265 patients with CTS, 56% of the cases were work-related. In 1986, Kulick et al\(^23\) discovered a significant relationship between cases of CTS and industrial-related occupations they classified as stressful. Kasdan and Janes\(^20\) recorded that 40% of the subjects in their study, all of whom had CTS, had occupations involving
the use of vibratory hand tools or requiring rapid, repetitive hand motions. A study confirmed that exposure to handheld vibrating tools and repetitive wrist movements are closely related to CTS.28

A strong occupational link exists with CTS.20,23,26-28 The highest reported incidence of CTS occurs in word processors, carpenters and employees in the meat packing and fish canning industries.24 In the meat and shellfish packing industries, as many as 15% of workers may be affected.25 In a study conducted at a meat packing plant, 14.8% of employees had carpal tunnel release which is unusually high compared to one percent of carpal tunnel release associated with the general population.2 Most jobs at this meat packing plant involved bimanual repetitive grasping and pulling. A high production rate can also lead to increased cumulative trauma and CTS.

In 1991, Barrer22 reported that complaints of CTS have increased in the last three to four years. The increase may be the result of the widespread industry shift to faster forms of automation. Workers often perform the same motion thousands of times in any given workday. In the past, workers would perform a variety of skilled maneuvers that would allow a rest period for the hand and wrist. The computer or word processor has now reduced the need for a range of tasks for the office worker. As a result, many "break" tasks such as making corrections by hand, rolling the paper in and out, and pausing to look up the spelling of a word; have all been automated. Word processors may perform 23,000 keystrokes in a single work period without rest.

Repetitive motion can be performed at home as well as at work. As a result, there may be some controversy about whether a given case of CTS is work-related.22
Generally, if six of the following conditions are applicable, the worker is a victim of occupational CTS: repetitive trauma at work; no history of prior trauma; inflammation or injury at work; no history of pre-existing conditions; no hormonal abnormalities; normal vitamin B₆; positive nerve conduction study results; no repetitive motion away from work; no significant psychosocial problems; and physician’s judgement that the CTS is work-related.

As a result of the diversity and complexity of the causes of CTS, the physical therapist must be proficient in diagnosing CTS. Chapter 3 discusses the details of certain tests to properly identify the specific signs and symptoms CTS.
CHAPTER 3

ASSESSMENT

To make a diagnosis of CTS, it must be determined that the median nerve is, in fact, entrapped at the wrist. Patients presenting with the classic symptoms of CTS, i.e., pain and paresthesia in the radial three and one-half digits, will have to go through various tests to ensure a correct diagnosis. Szabo and Madison have established a recommended diagnostic protocol consisting of five steps. The first step is to obtain an accurate medical history including a description of work habits and hobbies. The second step is to carefully examine both upper extremities and neck to determine if a more proximal lesion exists. The third step entails the performance of diagnostic tests including Tinel’s sign, Phalen’s test, two-point discrimination, and if the two-point discrimination test is normal, the Semmes-Weinstein monofilament test. In cases where symptoms only appear after certain activities, it would be appropriate to do these tests while the patient is symptomatic. This may require the patient to simulate an activity until symptoms appear. During the fourth step radiographs are taken to check for any anatomical abnormalities. The last step involves testing the patient for any underlying
causative disorders if the patient has a positive family history of such disorders or any abnormal physical findings.

According to Phalen, the diagnosis of CTS can be made when there is present at least two or more of the three major clinical signs, i.e., hypoesthesia, Tinel’s sign, and a positive wrist flexion test (Phalen’s test). The hypoesthesia must be restricted to the sensory distribution of the median nerve in the hand which is either reported by the patient or elicited by the examiner.

Many diagnostic tests and signs are associated with CTS. None of the tests are one hundred percent effective alone, however when the tests are performed in combination, the accuracy increases. The most common tests include Phalen’s test, Tinel’s test, a hand diagram, thenar atrophy, and nerve conduction study (NCS). All of these tests, described in the following paragraphs can be performed or utilized by a physical therapist.

**Phalen’s Test or Wrist Flexion Test**

The patient is instructed to place both elbows on a table with the forearms in a vertical position and allow the wrists to fully flex for approximately sixty seconds. In this position the median nerve is further compressed between the flexor tendons and the transverse carpal ligament. Numbness or tingling within sixty seconds in the sensory distribution of the median nerve in the palmar aspect of the hand (radial three and one-half digits) signifies a positive test. However, if there is an advanced degree of sensory loss already present in the hand due to CTS, the test will fail to be positive. Severe restriction of wrist motion may also result in an inaccurate test.
Tinel’s Sign or Percussion Test

The examiner lightly taps over the median nerve in the flexor retinaculum at the wrist. This test, similar to Phalen’s test, causes an increased compression of the median nerve as the transverse carpal ligament is pushed dorsally with every tap. If the test is positive the patient will experience tingling at the site of the compression with the tingling radiating out into the median nerve distribution in the hand. The examiner, again, must be careful when interpreting the results when advanced sensory loss is present.

Hand Diagram

The patient is asked to mark the areas of pain or numbness or tingling on a diagram of the hand. This test demonstrates the patient’s perception of the areas where sensory disturbances occur. A positive result indicates signs on the palmar side of the radial three and one-half digits. In some cases the patient may insist that “the whole hand gets numb and tingly at night”, but after careful examination and questioning it is discovered that the little finger is spared. In true CTS, the little finger is never involved because its sensory supply comes from the ulnar nerve, not the median nerve.

Thenar Atrophy

The profiles of both of the patient’s thenar eminences are compared simultaneously. This test is used to locate actual thenar muscle atrophy due to long term compression of the median nerve at the wrist. The muscles usually involved include the opponens pollicis, abductor pollicis brevis and the flexor pollicis brevis. Atrophy is present when there is an obvious hollowing of the proximal thenar eminence.
occurs almost always after many months or years of hypoesthesia and median nerve compression. The patient will note weakness and clumsiness in their thumbs, but are unaware of the thenar muscle atrophy until the examiner points it out.

**Nerve Conduction Study**

Orthodromic stimulus and recordings are performed across the wrist, testing the conduction velocities of the motor or sensory fibers of the median nerve. A positive result is reached if the motor latency is greater than 4.5 mm/sec or when there is asymmetry greater that 1.0 mm/sec versus the contralateral side. This test is especially useful when the diagnosis of CTS is questionable. In some cases, a NCS provides the only objective evidence of CTS. Considering about half of CTS patients also have abnormalities of the contralateral median nerve, latency values can be compared with reference values taken from normal individuals. The NCS can also be used to test the sensory fibers of the median nerve. A positive result of a distal sensory latency and conduction velocity test yields a sensory latency greater than 3.5 mm/sec or there is asymmetry greater than 0.5 mm/sec versus the contralateral side.

In 1970, Phalen noted that thenar eminence atrophy will be present in approximately half of the patients with CTS, Tinel’s sign present in 66% of patients, a positive Phalen’s test in 77%, and hypoesthesia in 73% of patients. On the other hand, in 1990, Kaplan et al found that out of 331 hands of patients with CTS, only 22.4% had thenar atrophy, 37% demonstrated a Tinel’s sign, and 78% revealed a positive wrist flexion test. The amount of atrophy presented at the time of evaluation has decreased
over the years possibly due to the fact that the patient population is seeking treatment earlier, before their signs and symptoms become severe.\textsuperscript{19,29}

Many other tests exist to diagnose CTS, such as the tourniquet test, hand volume stress test, direct measurement of carpal tunnel pressure, two-point discrimination, vibrometry and Semmes-Weinstein monofilament test. These tests are either complicated or not as effective as the tests described above.

There is discrepancy in the literature in regard to the accuracy of the various tests in diagnosing CTS. In a study conducted by Gellman et al,\textsuperscript{30} Phalen’s test was found to be the most sensitive. Seventy-one percent of the positive Phalen’s tests resulted in patients with proven CTS. Tinel’s sign, although least sensitive in that only 44% of patients with CTS had a positive result to the test, was the most specific. Only six percent of patients without CTS had a false-positive result on the test. The tourniquet test, in which a pressure cuff is inflated proximal to the elbow to elicit paresthesia in the hand, was found to be insensitive and nonspecific. The most sensitive and specific tests for diagnosing CTS are the NCS tests, however these tests are not infallible. Spinner et al\textsuperscript{18} notes a 95% correlation between NCS tests and a clinical diagnosis of CTS. Another study discovered that a positive Tinel’s sign in combination with a probable or classic hand diagram rating showed a strong specificity (.89) and a high positive predictive value (.71).\textsuperscript{31} Also, a positive Phalen’s test and the same hand diagram proved valuable for the diagnosis of CTS.

No diagnostic test exists that is 100% reliable in detecting the varied and intermittent symptoms of CTS, therefore some cases of CTS may be misclassified,
underdiagnosed, or overdiagnosed. A number of anatomical tunnel structures could be causing nerve entrapment, for example the cubital fossa, intervertebral foramen, or dynamic structures including the pronator or supinator muscles. Many disorders present with sensory or motor symptoms similar to CTS, such as cervical radiculopathies, thoracic outlet syndrome (TOS), syringomyelia, Raynaud’s phenomenon, reflex sympathetic dystrophy, and diabetic neuropathy. Phalen et al advised to take great care in diagnosing CTS. Complete neurological and orthopedic examinations must be conducted to rule out any differential diagnoses.

Mistaken diagnoses commonly occur as demonstrated in a study done by Hybbinette and Mannerfelt. In this study, eight patients did not benefit from carpal tunnel release surgery because they were all misdiagnosed. The correct diagnoses included cervical rhizopathy, syringomyelia, a neurosarcoma of the brachial plexus, post-radiologic damage of the brachial plexus, and an aneurysm of the subclavian artery. In a study by Kasdan and Janes, out of 1095 patients presenting with CTS symptoms for over a twelve year period, a total of 994 had a final diagnosis of CTS after completing a thorough evaluation. Eighty-one patients presented with positive Phalen’s and Tinel’s tests, however a different diagnosis was determined following a thorough evaluation.

Cervical disc disease, thoracic outlet syndrome and CTS all cause pain, paresthesia and muscle wasting in the upper extremities. Cervical disc disease occurs when there is an acute or chronic disk herniation or degenerative changes in the cervical spine creating a spinal cord root compression. The main symptoms that distinguish cervical pathology include radicular neck pain, exacerbated by hyperextension.
turning the head toward the painful side and coughing and sneezing may aggravate the pain.

TOS is the result of an irritation or compression of the brachial plexus and subclavian vessels as they pass between the clavicle and the first rib and through the thoracic outlet. The pain associated with TOS occurs diffusely in the arm or over the posterior and anterior shoulder region and radiates down the arm or up the back of the neck. The numbness and paresthesia are usually restricted to the sensory distribution of the ulnar nerve which includes the little finger. If sensory changes occur in the little finger, the examiner must look proximal to the wrist, usually the elbow or cervical spine, for the problematic structures. If sensory changes occur in the little finger, the examiner must look proximal to the wrist, usually the elbow or cervical spine, for the problematic structures. Ulnar numbness in the forearm indicates TOS or cervical root problems.

An NCS shows where the conduction along a nerve is slow, thereby revealing the carpal tunnel as the site of the compression, differentiating between CTS and the other two disorders. It is possible for cervical disk disease or TOS to coexist with CTS and due to this possibility, Sucher states that it is hard, if not impossible, for a clinician to treat CTS unless the clinician is also skilled in the diagnosis and treatment of TOS.

Reflex sympathetic dystrophy, Raynaud’s phenomenon, and diabetic neuropathy will cause sensory deficits in the extremities. Any one of these diseases can coexist with CTS. CTS could be the primary cause of the abnormal autonomic reflex arc seen in reflex sympathetic dystrophy or it could be secondary to the swelling in the hand due to the reflex sympathetic dystrophy. In Raynaud’s phenomenon the symptoms are more severe in the sensory distribution of the median nerve and may appear to be due to CTS
when actually they are not. If diabetes is present it must be determined if a mechanical lesion of CTS exists separately from the generalized diabetic peripheral neuropathy.

Discrepancies exist in the literature about whether CTS is overdiagnosed or underdiagnosed. If CTS is diagnosed when the patient truly has TOS or cervical pathology, overdiagnosis results. Masear et al² speculated on reasons for an unusually high incidence of CTS in a meat packing plant he studied. An increase in patient awareness caused a high number of people to seek treatment, even though some of those people may not have actually had CTS. Also, the benefits of worker’s compensation may be the culprit because it is equal to approximately 94% of the employee’s spendable earnings when at work. Miller³⁴ notes that CTS research and information in medical journals and health and safety journals has increased public awareness. As a result of the public awareness, individuals with symptoms of CTS may seek early professional assessment, whether they truly have CTS or not. In addition, health professionals may use more specific assessment procedures and physical examinations to make an accurate diagnosis.

Underreporting has also been documented. In a surveillance study conducted by Maizlash and associates²⁶ a significant number of CTS cases were not reported through the legally mandated reporting mechanism. Virtually all employers of 54 health care providers were familiar with the symptoms of CTS and nearly all indicated the presence of other symptomatic workers that were not reported. In reports by workers and providers several reasons exist for underreporting, including avoidance of the worker’s compensation system, excessive paperwork, and fear of investigation. These workers
also reported pressure from employers to not file a claim.\textsuperscript{14,26} Reporting of a chronic injury, such as CTS, is tolerance-driven.\textsuperscript{14} Often, patients delay reporting because they confuse the early symptomatic stages of a chronic injury with "getting used to the job". Also, because CTS manifests itself without dramatic physical changes, workers believe they cannot "prove" that they have a problem until "something" shows. Usually by this time the CTS is in the middle to late stages.

After an accurate diagnosis of CTS has been made, the clinician must consider which treatment is most appropriate. Treatment options are discussed in the following chapter.
CHAPTER 4
TREATMENT

The diagnosis and treatment of carpal tunnel syndrome (CTS) must be prompt and effective to avoid permanent median nerve damage. CTS can be treated either conservatively or surgically. The question is: where does one draw the line to decide which to choose? The ability to predict which patients are likely to respond to conservative, non-surgical treatment for CTS could spare some patients the time and expense of surgical treatment. Soon after onset, CTS may be reversible using conservative measures, however, with time, resolution is less likely without surgery. The first step of any treatment entails establishing the correct diagnosis and treating any underlying conditions. Factors considered in determining the method of treatment include results of nerve conduction studies, severity of the symptoms, duration of the symptoms, prior treatment, and, in some cases, the patient’s age and opportunity for activity change. When these factors were all favorable, two-thirds of patients recovered with conservative therapy. When only one factor was unfavorable 59.6% required surgery, when two factors were unfavorable 83.3% required surgery, and when three factors were unfavorable 93.2% required surgery. No patients with four or five
unfavorable factors were cured without surgical intervention. According to Kaplan et al, non-surgical treatment is usually unsuccessful in patients over 50 years old who have a duration of symptoms greater than 10 months, constant paresthesia, stenosing flexor tenosynovitis, or a positive Phalen’s test within 30 seconds.

Conservative treatment is warranted when there is no nerve conduction study (NCS) evidence of CTS and the symptoms are caused by intermittent ischemia and not a fixed lesion. When NCS evidence of CTS is present in symptomatic patients, surgery is the preferred choice. In this case, conservative therapy would delay definitive treatment, allowing further deterioration of the median nerve. Generally, the higher the latency values obtained during the NCS tests, the greater the percentage of patients who require surgery. Also, patients with advanced CTS who are asymptomatic due to extensive median nerve damage should receive a surgical carpal tunnel release.

Surgical treatment is not required for every patient. Resting the hands or a change in occupation is indicated for patients who have had a recent onset of symptoms after an unusual amount of manual labor. However, if thenar atrophy and a long symptomatic history are present, surgical treatment should be recommended immediately. Sucher recommends surgical treatment in cases of CTS that are severe to very severe or progressive and unresponsive to conservative treatment within two to four weeks.

The first line of defense in treating CTS is diuretics (water pills) and anti-inflammatory medications including aspirin and ibuprofen to reduce excess fluid and inflammation. Injections of steroids should be used in more severe cases. Surgery to cut the transverse carpal ligament (i.e., carpal tunnel release) is the last resort to relieve
symptoms; however, even surgery cannot repair any permanent damage, therefore it must be performed in a timely manner before the damage becomes permanent.

**Surgical Treatment**

Wilson and Summer\textsuperscript{35} regard surgical release as the treatment of choice for CTS because it provides a definitive treatment and has a very low morbidity. Surgery is indicated when conservative therapy yields no response, symptoms are severe, and especially when the patient has clear abnormalities on nerve conduction studies, thenar atrophy, or a decrease in sensibility in the median nerve distribution. The goal of surgery is decompression of the median nerve in the carpal tunnel, usually accomplished by severing the entire transverse carpal ligament.\textsuperscript{8} With this carpal tunnel release the oblique incision extends from the hypothenar eminence laterally across the base of the palm to the distal wrist flexion crease. The entire ligament must be severed because most median nerves are compressed in the proximal third of the carpal tunnel.\textsuperscript{4,8} The ligament should be cut through its medial portion to avoid any possible damage to the recurrent branch of the median nerve.

The new “closed-hand” carpal tunnel release operation is beginning to replace the more traditional “open-hand” procedure.\textsuperscript{22} The latter involved opening both the palm and wrist, and required a lengthy recuperation. The closed-hand procedure (endoscopic release) utilizes a small, three-quarter inch incision through which the carpal ligament is divided using a special tool. A short period of recovery (two to six weeks) is possible because immediate use of the hand after surgery is not only possible, but encouraged. Out of 1200 closed-hand procedures performed, a 90% success rate was obtained.
Similarly, Katz et al\textsuperscript{36} reported that 84\% of patients were satisfied following this type of surgery. Their analysis of predictors for early return to work showed endoscopic release to be the strongest predictor versus open carpal tunnel release.

Routine synovectomy is not advised, but if decompression is not achieved, then partial synovectomy of the flexor synovialis should be performed. The flexor tendon synovitis is a contributing cause of CTS, however it may also represent a reaction of the flexor tendons to a tight carpal tunnel.\textsuperscript{10} If the synovitis is a reaction then it will resolve after releasing the transverse carpal ligament. This procedure is appropriate in cases of rheumatoid arthritis, or other diseases in which the flexor synovium is directly at fault.

The purpose of neurolysis is to remove any fibrotic tissue that may be disturbing fluid mechanisms in vascular and nonvascular compartments of the wrist. Neurolysis is used when chronic compression of the median nerve causes fibrotic changes that restrict normal fluid flow to the structures on the wrist and hand. Phalen\textsuperscript{4,8} does not condone routine neurolysis because even in long-standing lesions the swelling of the nerve proximal to the transverse carpal ligament is not a post-traumatic neuroma. He believes that the swelling is the result of edema proximal to the compression site, therefore the problem will resolve after surgery. Also, if the palmaris longus is pressing on the median nerve, then a section of it should be cut or removed. Prevention of swelling in the wrist and hand two to three days postoperatively, is the most important factor in obtaining a pain-free mobile hand. A pressure dressing is worn for three to four days after surgery and the wrist is immobilized in neutral in a splint for seven to ten days. The surgery can be performed on an outpatient basis.
By using specific indications for surgery, Spinner et al\textsuperscript{18} reported a 95% improvement rate after carpal tunnel release. Spinner also noted that following surgery, if the patient returns to a traumatic environment of repetitive motions and extreme wrist positions, the operation is often unsuccessful in controlling symptoms. These patients require modifications of work activity to decrease trauma to the wrist.

Numerous other studies support the success of surgical release as treatment for CTS. Duncan et al\textsuperscript{37} reported that 50-75\% of all patients with CTS in the United States obtain relief of symptoms with surgery. In a study conducted by Harter et al,\textsuperscript{27} surgical release of the transverse carpal ligament was performed on 95 hands with all the patients reporting satisfactory results. Surgery was performed on patients with severe symptoms, such as atrophy or weakness of the abductor pollicis brevis, who could not change jobs or activities and could not benefit from conservative therapy. No patient experienced any significant post-surgical complications, such as hematoma or infection.

Phalen\textsuperscript{4} reported out of 215 wrists treated surgically, 103 presented with thenar atrophy and out of that 103, approximately 83\% regained normal thenar muscles, 9\% showed improvement and 7\% showed no improvement. Also, 71.8\% of the surgically treated hands regained normal sensation, while 27.6\% showed some improvement but still had impaired sensation in the median nerve distribution.

In addition, in a study performed by Kulick et al,\textsuperscript{23} 100 patients with 130 hands affected with CTS for an average of 30 months, all underwent surgical treatment. The average follow-up period was four years and during that time 25 hands displayed lasting symptoms of CTS (19\% surgical failure rate). The factors associated with failure of
surgery included involvement of the abductor pollicis brevis muscle, failure to benefit from the initial injection, presence of a predisposing condition, an occupation that stressed the involved hand and presence of a postoperative complication. The only variable that was significantly associated with long-term relief of CTS after surgical treatment was relief of CTS from steroid injections for more than 6 months prior to the surgery. Kasdan and Janes reported that 27% of their subjects with CTS underwent surgery with approximately 97% relief of symptoms. A 10.5% recurrence rate was documented. The recurrence rate was linked to aggravating activities and once these activities stopped, the symptoms cleared.

In a study done by Hybbinette and Mannerfelt, 98% of 506 wrists were relieved of pain caused by CTS, after surgery. In addition, 90% of patients with hypoesthesia were relieved after the operation. These authors suggest neurolysis of the thenar motor branch in the patients that present with thenar atrophy. Postoperative care consisted of elevation for 24 hours and early active finger flexion and extension to prevent edema and adhesions of the flexor tendons.

Following surgery, there is an important need for some form of therapy or home exercise program. Nathan et al has identified early hand therapy following surgery as the key component for minimizing the time needed to regain normal hand function and for reducing the time-loss cost to the employee. The average return-to-work interval in their study was 24 days and the average number of therapy sessions was six for the 216 patients in the study. This early intensive hand therapy reduced the return to work days by approximately nine days with attendance at one session of therapy per week. It also
reduced the return to work days by approximately 26 days with attendance at three sessions of therapy per week compared to zero sessions per week. The more frequent the visits for hand therapy, the faster the patient returned to work. The hand therapy paid for itself several times over by decreasing the postoperative time-loss cost. Decreasing the return-to-work interval would save millions of dollars in time-loss costs, which could be better spent on prevention. The hand therapy consisted of active range of motion exercises, ultrasound, stretching exercises, soft tissue mobilization, whirlpool treatments, and a home exercise program. Initially wound healing, and incorporating gentle range of motion exercises were employed leading up to active motion and progressive strengthening for the affected wrist and hand. Since wrist splints interfere with hand and wrist mobilization, they were never used postoperatively. In addition, a primary factor of a shorter return-to-work interval was the patients’ cooperation in the postoperative rehabilitation program, therefore it is important to motivate these patients.

Similarly, Totten and Hunter recommend therapy after surgery. The therapy should focus on controlling edema, enhancing range of motion, preventing adhesion formation with nerve gliding techniques and light use of the hand. Nocturnal splinting and compression techniques may be used to guard against excessive motion and discourage surgical scarring. Activities that enhance nerve gliding at the wrist should be performed three to five times daily in a slow controlled manner and involve active use of the extensor tendons, thus allowing passive excursion of the flexor tendons and the median nerve. The activities include digital extension against either a theraband or through putty. Once the sutures are removed (10-21 days postoperatively), edema can be
controlled with contrast baths in combination with gentle range of motion. To promote mobility, frequent scar massage (three to five times daily) and firm pressure massage are applied to the healed incision site. Scar desensitization can be accomplished by immersion of the affected hand in textures, or tactile stimulation using textures, vibration or using the hand in activities such as pottery making.

Along with the therapist, the patient needs to design a home exercise program that incorporates essential movement patterns and precautions into the patient’s occupation and daily living activities. The therapist must incorporate all sources of motivation, such as the patient’s desires, potential, limitations, and societal expectations to facilitate a successful rehabilitation program after carpal tunnel release.

**Conservative Treatment**

Conservative treatment is most appropriate when the symptoms of CTS are mild or the diagnosis is questionable. Non-surgical treatment does require more effort on the part of the physician, and the patient’s cooperation and understanding is essential. When CTS is caused by external forces, a trial of abstinence from any activity that incites symptoms is necessary. This may require cooperation from an employer who is willing to transfer an affected employee to alternate duties. An analysis of work habits and the tools required may lead to modifications that could reduce exposure to adverse stimuli. During early onset of CTS, patients may find resolution of their symptoms by splinting the wrist in neutral at night or during symptomatic activities and by taking oral non-steroidal, anti-inflammatory medications. In the case of CTS development during pregnancy, wrist splints may offer symptomatic relief until delivery. Phalen has also
recommended the use of night splints to prevent compression of the median nerve for patients who constantly keep their wrists flexed during sleep.

Many studies have been conducted analyzing steroid injections and wrist splinting as the primary treatment method. According to Phalen, if no improvement is seen with the first steroid injection, it is unlikely that further injections will help. Prompt relief after injection of a steroid supports the diagnosis of CTS, however failure to improve does not necessarily indicate a diagnostic error. As a result, all patients with CTS should receive at least one steroid injection to ascertain whether or not this treatment will provide sufficient relief to make surgery unnecessary.

Szabo and Madison has recommended a single injection of dexamethasone and lidocaine with epinephrine into the carpal canal after an unsuccessful trial of splinting and oral anti-inflammatory medication. The injection is followed by three weeks of continuous splinting in neutral and then three weeks of only night splinting. If this is unsuccessful and symptoms recur, operative release is recommended. Kaplan et al reported 18.4% successful treatment with wrist splints and anti-inflammatory medications in 331 hands at the average 15.4 month follow-up exam. In this study successful treatment was defined as the absence of any symptoms for six months.

The combination of steroid injections and wrist splinting was the only treatment used on 76 hands in 57 patients without advanced CTS or any other medical conditions in a study conducted by Weiss et al. Overall, 10 of 76 hands (13%) had complete relief of symptoms at the average 11 month follow-up examination. Forty-five hands that had
incomplete or no relief following injections and splinting underwent surgery, resulting in complete relief of symptoms in 33 hands. In a study conducted by Phalen,8 24% of 210 wrists gave no further report of symptoms after one to five injections, 38% showed some improvement and 10% were not improved. Similarly, Gelberman et al15 conducted a study in which 50 hands in 41 patients were treated with a single injection and three weeks of splinting. At the follow-up examination, averaging 18 months following the injection, eleven (22%) of the 50 hands were completely symptom-free. Satisfactory responses to this conservative therapy were defined as mild symptoms in the hand of less than one year’s duration, normal sensibility, normal thenar strength and mass, and one to two milliseconds or less prolongation of either the distal median motor or sensory latencies.

The rate of relapse was high in hands with severe symptoms of more than one year’s duration and findings of atrophy, weakness, and distal motor latencies greater than six milliseconds or absent sensory responses.15 Kasdan and Janes20 found that 85% to 95% of patients with such symptoms that were injected ultimately had a recurrence of symptoms. In addition, conservative treatment consisting of steroid injections and splinting was deemed a failure by Kulick et al23. The authors of this study reported that steroid injections and splinting frequently provide immediate relief, however this conservative treatment fails to consistently give long-term benefits because of its inability to permanently reverse or alleviate the cause of CTS.

Other studies support the use of various agents to treat CTS non-operatively. In a study by Kasdan and Janes20 satisfactory improvement was obtained in 68% of 494
patients with CTS treated conservatively. Treatment consisted of splinting, anti-inflammatory agents, job or activity change, steroid injections, and vitamin B₆. Harter et al.²⁷ used non-surgical treatment which consisted of patient education, wrist splinting, B vitamins, non-steroidal, anti-inflammatory medications, steroid injections, and job modification. Out of the 188 patients, 50 attained normal nerve conduction, 76 showed improvement and 62 did not show improvement. The symptoms remained the same in the 62 patients that did not show improvements. In a study done by Monsivais et al.,⁴¹ 35 patients with 67 mild to moderately CTS affected hands were treated with night splints, intermittent vitamin B₆, non-steroidal anti-inflammatory medication, and at least three injections. During the study, three patients became worse, one improved, and the rest remained unchanged. This low rate of recovery could be due to the fact that 86% of the patients had one or more associated compressive neuropathies such as thoracic outlet syndrome or ulnar nerve compression in the affected extremity.

Bonebrake et al.⁴² utilizes soft tissue techniques to treat CTS. The treatment program they recommend is designed to reduce muscular and fibrotic restriction. Their treatment consisted of ischemic compression, stripping massage, transverse friction massage, skin rolling, tissue stretching, specific muscle exercise, and joint manipulation. The manipulative techniques were applied to the cervical, thoracic, and lumbar spine, and to various areas of the upper and lower extremities, shoulder girdle, and rib cage. All of the subjects previously using wrist splints were to discontinue use to reduce the amount of disuse atrophy of soft tissue structures. The patients who had used the splints the longest and in the most continuous manner were the ones who required, by far, the most
treatments on average. The results of the study showed that, after six months post-treatment, the 43 subjects with CTS had maintained improvements in grip strength, pinch strength, forearm supination and pronation forces, assembly task performance, and pain and distress scores.

Sucher\textsuperscript{43} described an alternate technique to treat CTS using myofascial release and self-stretching to reduce pain and numbness and improve NCS results after approximately two months of therapy. The myofascial technique releases the transverse carpal ligament to dilate and open the canal. The patient with mild to moderate CTS stretches the wrist, digits and thumb as part of the aggressive, conservative approach. Sucher\textsuperscript{44} did another study on 16 subjects with CTS which revealed at least moderate restriction to wrist or thumb motion. All of the patients treated underwent osteopathic manipulative treatment, including an “opponens roll” maneuver and self-stretching or a similar treatment using a self-treatment appliance. All the subjects demonstrated a decrease of palpatory restriction into the normal range, often before symptoms decreased. Improvement in nerve conduction studies usually appeared within one to three months. Sucher’s technique was based on the likelihood that manipulation and stretching exercises mobilize the nerve by reducing the adhesions in and around the carpal tunnel.

Later, in 1995, Sucher\textsuperscript{43} recommended the use of physical modalities in combination with manipulative treatment directed at the carpal canal. This therapeutic approach for treating CTS includes a combination of manipulation, stretching exercises, medication, orthoses, ultrasound, and iontophoresis. Iontophoresis was used in acute or severe CTS to decrease any associated inflammatory component rendering the tissue more responsive to
treatment. Once the severity or irritability decreased, the patient was able to better tolerate the vigorous stretching maneuvers. Also, ultrasound can be initiated along with more intense manipulation and self-stretch to assist in increasing the extensibility of tight structures.

Physical therapy treatment should focus on decreasing inflammation, increasing rest and protecting the carpal tunnel. Modalities such as heat and cold will affect inflammation that has spread into the hand or forearm. The primary purpose of therapy is to protect the involved wrist and hand from further injury caused by overuse. Exercise is encouraged to stretch, strengthen and relax affected muscles (Figure 2). Custom fit splints are used to ensure rest of the wrist in neutral. The therapist can conduct a worksite and recreation activity analysis to identify and modify CTS risk factors.

The real value of the treatments offered for CTS is in allowing individuals to return to their daily living and work activities with little to no pain or performance restrictions. The study by Bonebrake et al. suggests that treatment can be performed and improvements made with little to no lost work time which is beneficial to the worker and the employer. In addition, ergonomic redesign of work sites should be encouraged to minimize future risk of cumulative trauma. This subject is discussed in Chapter 5.
Stretching the wrist flexor muscles

Clench fist tightly, then release, fanning the fingers.

Figure 2.--Exercises for the Wrist.
CHAPTER 5
INJURY PREVENTION

Wellness, health, sports, and physical activity can be the solution to repetitive strain injuries rather than doctors, hospitals, surgery, and insurance. An athlete’s performance is based on working efficiently, producing the desired movement with minimum force and at the proper time. Sitting at a keyboard all day requires a certain kind of athletic skill. Like the athletes, the employees need the proper equipment and a trainer. Treating the employee as an athlete will enable the therapist and the employee to maximize the employee’s skills to allow the employee to work without pain. A philosophy incorporating injury prevention measures can improve productivity as well as decrease the costs of health benefits and workers’ compensation. Isemhagen concurs with this philosophy and takes it a step further, incorporating a triad consisting of the work, worker, and worksite. Isemhagen’s ideas are reflected in injury prevention programs.

Prevention of carpal tunnel syndrome (CTS) and minimizing the deleterious effects of the disorder on employees appears to be the best solution for long-term, productivity-enhancing results. These two goals will also do the most to prevent
damaged company morale, a hidden cost of worker injury. Workers can become
demoralized in a firm that does little or nothing to correct a deleterious situation. The
workers feel as though they have limited options, either they lose use of their CTS-
afflicted hand, or they lose their livelihood; or they remain on the job and eventually lose
both.

The Occupational Safety and Health Administration (OSHA) has published
guidelines for the management of work injury prevention and much of the literature
concurs with the guidelines.\textsuperscript{17,22,34,45,47-51}

**Management Commitment**

Management commitment is a small part of injury prevention, but it is the first big
step. The health, safety, and management personnel must take interest in employee
welfare and in controlling workers' compensation costs.\textsuperscript{22,48} The heart of a prevention
program is management commitment. A program is doomed to fail if management will
not provide financial backing and visible support. Management must be aware of the
frequency and severity of current cumulative trauma disorder cases, including the number
of workers affected in the past several years and the number of lost workdays. Also,
management should be presented with the current cost of existing cases, their projected
cost at closure, and an estimate of anticipated new cases and their projected cost and
impact on the company. In addition, management must be aware of the prevalence and
serious ramifications of CTS to avoid suspicion that employees are making false workers'
compensation claims.
Supervisors have important roles in monitoring and enforcing company CTS prevention policies. Violations should carry immediate ramifications. The company should monitor the supervisors and keep accurate records for the OSHA inspectors.

Program Elements

The goal is to educate everyone simultaneously, to instill a feeling of team work in overcoming the CTS threat to employees’ livelihood and the company’s productivity. The priority of education is to teach people how to reduce or eliminate environmental risks and activities that lead to CTS. After the education phase is completed, the company will be ready to activate a series of measures that comprise the prevention program. The first action involves investigation of ergonomic principles in the actual worksites the company maintains.

Ergonomics entails the analysis of work design, methods, and environment to achieve maximum productivity with minimal risk of injury. Ross defines ergonomics as an applied science concerned with the design of the workstation, tools, and tasks, to match the workers physiologic capabilities and psychologic characteristics. Ergonomic principles adapt the workstation to the worker’s capabilities while preventing injury and strain. Cumulative trauma results from poor workplace design, repetitive movements, awkward body mechanics or postures, and other hazards. Another source says ergonomics is the study of the relationships between people, work, and the work environment, using biomechanical and engineering principles to improve those relationships. Biomechanics describes the connection between the muscles and joints as they maintain or adjust posture caused by environmental forces. Physical therapists use
their knowledge of body mechanics and ergonomics to examine the work environment of workers to determine the potential for trauma as a result of the worksite design. This examination can be done as a preventive or maintenance tool. An ergonomics consultant is recommended to discover what immediate modifications would be appropriate in tools and station design to modify the high risk areas.22

The ergonomics assessment (i.e., a body mechanics examination) produces information on possible or actual causes of injury during a worker’s performance of essential everyday activities, leisure pursuits and work tasks.49 The assessment will lead to diagnosis, prognosis and determination of appropriate interventions. This type of assessment is needed if physical disability, impaired sensorimotor function, pain, or developmental delay occurs that prevents normal performance of daily activities. It is also needed when the employer is seeking a minimum capacity for performance or there is a need to initiate or change a prevention program.

A workplace assessment is conducted to analyze the specifics of the work population, equipment, and facility.50 The evaluation will compare the compatibility of the worker and the demands of the job. An ergonomics assessment involves examining the following49:

1. Essential functions of the job;
2. Work postures needed to perform the job;
3. Joint range of motion, strength, endurance required for the job;
4. Repetition or work and rest cycles during the job;
5. Sources of potential trauma;
6. Vibration;
7. Tools and equipment used;
8. Assessment of work hardening and conditioning programs;
9. Assessment of dexterity and coordination;
10. Review of safety and accident reports; and

The incidence of CTS can be reduced through job modifications such as lowering the force or vibration, using lightweight tools, lowering the speed or torque setting of the tools, eliminating repetitive tasks, and changing the worker’s posture. Gloves can be designed to reduce transmission of vibrations and forces to the hand, and adding a rubber coating, either to the gloves or the tool, helps decrease the amount of force needed to hold a tool. Also, mechanical aids may be used to support the tool or decrease transmission of torque to the worker. Modifications to the handle design may also be beneficial. Tools with angled handles help keep the wrist in a neutral position, and long handles that conform to the palmar arch distribute force throughout the hand.

Employers have adopted various policies to reduce the risk of employees developing CTS. Mandatory warm-up exercises to decrease sudden injury to “cold” muscles, and splints to reduce repetitive wrist movements are recommended. Properly fitted splints may aid in diminishing the possibility of getting CTS while allowing enough freedom of movement to perform the work required. The splints must be fitted correctly to ensure successful results.
Galloway-Midgette\textsuperscript{51} recommends a slightly different approach for a CTS prevention program. First, basic wrist and hand anatomy is taught. Second, the workers are educated on positions to avoid: wrist flexion, ulnar deviation, supination, and pressure at the base of the palm. Many actions such as pushing heavy doors, holding a telephone at an angle and opening jars are performed with a bent wrist.\textsuperscript{45} Workers need to identify daily living activities that use these adverse positions so that they can modify or minimize the adverse motions made during those activities. Third, a worksite visit should be made by an ergonomics specialist to evaluate the tools, work surface height, reaching angle, and height, posture, and hand motions.\textsuperscript{51} Also, splinting is recommended if the wrist needs to be stabilized. Finally, a follow-up visit was recommended to monitor the outcomes and compliance with the prevention program.

McCue and Mayer\textsuperscript{17} reported that prevention of CTS is always more effective and less expensive than any treatment available. In the past, a company’s main concern was how much work an employee accomplished. However, the high cost of treating workers with CTS has compelled employers to take a hard look at how the work is being done. An aggressive ergonomics approach not only protects key employees, but reduces health care and insurance costs. Certain postures and movements will result in employees reporting pain and discomfort.\textsuperscript{45} A good ergonomics design, with adequate breaks in motion, will allow for more efficient work postures, thereby decreasing symptoms.

The prevention program should focus on cost containment projections.\textsuperscript{48} A proposed budget and projected savings should be prepared to show the impact on corporate profit projections. It is also important to emphasize the improved employee
morale, healthier work force, and decreased absenteeism that can occur. Statistics should be taken quarterly to monitor the program and report back to management. In addition, talking with employees will identify whether they are experiencing pain or any other difficulties while performing their jobs. Workers, have a natural resistance to change, so positive reinforcement and support must be given as modifications are introduced. Some changes may fail to solve a worker’s problem or can create new problems, so re-evaluation is important as changes are instituted.

Ergonomic specialists can minimize the stressful aspects of work and help organizations achieve optimal performance. Two common occupations associated with CTS are meat cutters and office workers. The remainder of this chapter will outline programs to specifically address these two occupations.

**Ergonomics for Meat Cutters**

Masear et al\(^2\) described an abnormally high incidence of CTS in meat packing plant workers. Fourteen percent of the employees at this plant have had carpal tunnel release. In the Masear et al\(^2\) study, preemployment nerve conduction study (NCS) screenings were used to detect persons who already had increased motor or sensory latencies. At least one in seven of asymptomatic individuals had results consistent with at least a mild CTS. The NCS screenings were used to help detect persons susceptible to developing CTS.

Following an ergonomics assessment, several preventative measures were instituted to prevent further injury in this particular plant.\(^2\) Masear et al\(^2\) reported what changes were implemented, however they do not report the outcome of the changes in
this plant. Proper stoning to keep the knives sharp should help decrease the force needed for cutting. Also, the amount of grip needed should be reduced by using cotton gloves to take up moisture, and a knife handle with a grain pattern to decrease friction. Adjusting the height of the conveyor or table should also minimize the amount of wrist deviation needed when using the knife. However, if the cutting surface is too high, wrist deviation will again increase. Adjusting the conveyor belt pace so that workers maintain a more steady pace throughout the day should decrease fatigue later in the day.

In addition, other means of prevention included job rotation to minimize the amount of strenuous activity each employee was performing, decreasing the production rate or reducing the number of cuts made be each person per shift, and the designing of a mandatory wrist support to limit wrist deviation. The first two modifications mentioned are usually not feasible in an industrial setting because of the seniority needed to obtain a job change and the need for a high production rate to make a profit. The meat packing plant in this study is planning on implementing a wrist splint.

Office Ergonomics

The population of video display terminal (VDT) operators is growing at an incredible rate as the result of their increased function in the workplace.\textsuperscript{50} By 1990, experts predict that 40 million people will be using VDT's on a daily basis. As a result, the health, safety and optimal productivity of these workers has become a concern. The new technology has increased the incidence of cumulative trauma disorders, including carpal tunnel syndrome (CTS), because VDT work involves chronic repetitive motion and static and constrained postures. In 1986, OSHA was the first to instruct its
compliance officers to detect, evaluate, and recommend solutions regarding musculoskeletal and visual stress in the office environment. Due to the growing concerns of labor unions and the government, management will have to comply with a new set of standards to improve conditions in the workplace.

Four areas of VDT-related health concerns include visual dysfunction, musculoskeletal problems, emotional disturbances, and psychological disturbances. The most common health problem reported by VDT operators is visual dysfunction which can range from temporary acute effects, such as eye irritation and headaches, to chronic visual disorders like cataracts or glaucoma. Musculoskeletal disorders causing pain in VDT operators encompass the shoulders, neck, back, arms, wrists, and fingers.

The seated VDT operator spends most of the time in a stationary position with relatively rigid head and neck positions. This static loading can lead to neck and back pain. VDT workers are less likely than other workers to exchange comments with others, get up to get files, take notes, and in general, divert their attention and change their postures. These factors may be compounded by poor workstation ergonomics.

Office work entails prolonged sitting while using the hands, arms, or eyes to perform tasks that are for the most part stationary. Thus, the muscles are in a fairly continuous state of contraction, called static loading. In this state, the muscles are not provided a proper rest period, resulting in reduced circulation, which impedes waste product elimination and influx of proper nutrients. The decrease in nutrition and increase in waste products combine to produce muscle soreness. This soreness does not cause true injury to the muscle because blood flow is increased with rhythmic contraction and
relaxation. Mechanical wear and fatigue caused by excessive movement and poor posture can lead to other discomforts. Individual differences such as obesity and habits such as leg-crossing may play a role in causing discomfort. Even though most of the discomfort does not lead to major injury, it does result in significant loss in work time productivity and worker health.

An ergonomics training program in the form of educational self-instruction should be implemented to improve data processing accuracy and reduce any musculoskeletal stressors. Postural training, ergonomics exercises, and workstation assessments are used to teach trainers and operators how to manage VDT-related health problems and improve work performance. Postural skills training teaches basic anatomy and how to adjust the workstation and chair to reduce muscle tension and fatigue. Ergonomic exercises are used to encourage range of motion and to relax overworked or strained body parts.

An office ergonomic assessment is concerned with studying the employee in relation to the employee’s workstation, environment, chair, keyboard and other accessories or equipment. Adjustable settings in the workstation are preferred to fixed height workstations to accommodate different sized workers. Desirable features of a workstation include height and tilt adjustments for the monitor, a flat work space area for source documents, and a separate, adjustable platform for the keyboard.

The workstation environment should support the worker’s feeling of well-being and productivity. Temperature control is especially important because VDT’s produce heat. The temperature should be between 70 and 75 degrees in the winter and 78 to 82
degrees in the summer. Humidity should be around 50% and needs to be monitored because VDT's can dry out the air. If the humidity is too high, it will reduce static which can cause problems with electronic equipment. Also, proper air ventilation and lighting is important; air ventilation promotes comfort and proper lighting reduces glare.

The typical office workers spend more time in their chairs than in any other piece of furniture except their own beds. The chair should allow freedom of motion to permit the user to easily change positions without losing good support. The chair that is improperly designed or not adjustable can restrict blood flow in the legs, provide inadequate support to the back, or force the user to maintain a static position. If the chair is designed ergonomically correct, it should have four degrees of freedom: seat pan tilt, backrest angle, seat height, and backrest height. Using this type of chair, the VDT operator will be able to adjust the chair according to the task being performed. The seat pan or backrest should allow some "give" when pressure is exerted. The front seat tilt of the chair allows the worker to lean forward to read documents and then lean backward to rest. Repeating this movement throughout the day will provide breaks in motion to help avoid CTS. The base of the chair must provide stability to protect the user from tipping. A base with at least five projections is recommended. The chair must provide easy height adjustability to accommodate the wide range of users. In the office, maintaining a straight wrist can be done be simply adjusting the chair height. The seat edge must not put excess pressure against the posterior thigh. The edge of the seat pan should curve down, away from the legs. The backrest needs to provide lumbar support, therefore height adjustability is desirable. The height of the armrests should be adjustable and should
allow the chair to be moved under the worktable. At the same time, the arm rests must be high enough to properly support the arms. Low arm rests promote poor body posture. \(^{45}\) The more flexible and adjustable the chair, the more likely the worker will be able to properly orient the body to the workstation.

When considering the keyboard, it is important to remember that excessive strain of the hands, arms, and wrists can lead to more chronic problems associated with VDT work. \(^{52}\) Several things can be done to eliminate strain. The operators should be able to perform tasks with the elbows at the side without excessive wrist movement. Many times people using a keyboard rest their wrists on the edge of the work surface, sometimes while angling the hand upward. This motion brings structures close to the surface and the sharp edge of the table can begin to irritate those structures. Padded wrist rests can help keep the wrist in neutral and support the weight of the arms. \(^{45}\) The operator should take brief movement breaks and intersperse non-VDT tasks with use of the VDT. \(^{52}\) When selecting a keyboard, one should consider a keyboard that is not attached to the monitor and that has a matte finish to reduce glare. Also, the keyboard should be slim with adjustable tilt, and the keys should be slightly concave.

Chapnik et al, \(^{50}\) recommends using pivoting footrests, wrist rests, document holders, glare shields and exercises to aid VDT operators. The footrests provide support and ensure frequent movement of the lower extremities to stimulate blood circulation. Wrist rests help keep the wrist in neutral to reduce stress to the joint. Document holders are used to support source material and allow the worker to maintain healthy head and neck alignment. Glare shields enhance visibility of the computer monitors by blocking...
out reflections. A complete set of warm-up exercises for the back, neck, shoulders, arms, and hands increases flexibility, strength, endurance, and comfort.

The employer should follow certain recommendations to provide the employee with an optimal office workstation environment. The employer should provide an adjustable chair, properly designed workstation, and any appropriate accessories. Alternate jobs need to be incorporated to reduce repetition and increase freedom of motion. Training should be provided in the use of adjustable components which should be encouraged to be used throughout the work day. Also, the employer must allow frequent rest breaks and encourage workers to change positions frequently. A comfortable indoor temperature is needed with as few drafts as possible. VDT operators should avoid excessive twisting, turning and tilting. Finally the operators must be aware of the importance of a personal exercise program to improve muscle tone and circulation.

In conclusion, employees should be encouraged to listen to their bodies and make themselves comfortable by adjusting their workstations. Body positions should be changed frequently while maintaining support of the feet and neutralization of the wrists. No matter what treatment method is used, most individuals will require some sort of job or activity modification. The design of tools, workstations, production techniques, and production schedules must take into consideration proper body position and human tolerance to the effects of vibration and repetition. Keeping tools in good repair and using dampening devices, such as rubber to minimize vibration. Tools should be modified to avoid sharp wrist flexion. Workstations should be adjustable to allow for neutral positioning for prolonged keyboard use. Production engineers should incorporate
rest periods and modify assembly line speed into the workday to minimize the effects of cumulative trauma.

In closing, knowledge of the anatomy of the carpal tunnel is the basis for complete understanding of CTS. The symptoms of CTS may be diverse, leading to difficulty in identifying the correct diagnosis. In addition, the causes of CTS are numerable, however the culprit must be determined to eliminate the possibility of recurrence after treatment has been administered. Various diagnostic tests for CTS exist, however the tests must be used in combination to accurately distinguish CTS from other diseases. The best tests to use include Phalen’s test, Tinel’s test, the hand diagram, thenar atrophy, and nerve conduction study tests. Physical therapists must have the knowledge of the anatomy, symptoms, causes, and diagnostic tests to determine the correct diagnosis and treatment for CTS.

Physical therapy treatment for CTS includes conservative treatment, and preoperative and postoperative care. The therapist must be very selective in determining which patients may benefit from conservative treatment because delaying surgery when CTS is in its advanced stages is likely to cause further median nerve damage. Prevention of CTS is crucial because once symptoms of CTS have emerged, the progression of CTS may be difficult to arrest. Injury prevention programs need to be established in industries where there is a high risk of developing CTS. Such programs require management support and include an ergonomics assessment. Any changes that need to be made as a result of the ergonomics assessment should be done in cooperation with the employees. The effects should be monitored to determine which changes are most beneficial in
reducing CTS. Physical therapists can help minimize CTS by supporting the use of injury prevention programs.
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