Occupational Injuries and Illnesses

CHAPTER 17A
Segmental (Hand-Arm) Vibration Injuries (Raynaud's Syndrome)

EXCERPT

Synopsis

SCOPE

Raynaud's syndrome is a characteristic pattern of cold-induced vasospasm marked by blanching of the fingers and hands. When it occurs in workers who use vibrating tools for prolonged periods, it is known as Raynaud's phenomenon of occupational origin and is associated with sensory impairment, pain and paresthesias, and loss of hand and forearm strength. A common cause is use of chain saws, drills and pneumatic hammers. The pathogenesis of vibration-induced injury is not fully understood, but permanent impairment may result. The most important risk factors are high doses of vibration, long duration of exposure and chronic exposure to cold. Diagnosis is based on the presence of vasospasm induced by cold, an occupational or a recreational history of vibrating tool use and the exclusion of the many other disorders that can cause digital vasospasm and peripheral neuropathy. There is no cure other than removing the worker from exposure to vibration; treatment is palliative. It may involve educating the patient about measures for keeping warm, various behavioral conditioning therapies or therapy with vasodilating drugs. Prevention includes education of workers regarding appropriate work practices, control of daily exposure to vibration, redesign of tools to reduce vibration, use of protective clothing and medical surveillance of workers in occupations with risk for development of the syndrome.

§ 17A.01 Introduction

Vibration is a widespread hazard in industry. When it is transmitted from a machine to the human body over a long period of time, vibration can cause discomfort, diminished performance and injury. Prolonged use of manual tools that transmit vibration to the hand and arm can lead to damage to the circulatory system and the nerves of the upper extremities.

Raynaud's syndrome is a characteristic pattern of cold-induced vasospasm (contraction and relaxation of blood vessels) marked by a blanching of the fingers and hands. When it occurs in workers who are or have been exposed to hand-arm vibration, it is known as Raynaud's phenomenon of occupational origin[1] and is associated with sensory impairment, pain and paresthesias (numbness and tingling), and loss of hand and forearm strength (Letz, et al., 1992).

Although the machines that produce vibration are often also a source of noise that causes hearing impairment, the relationship between levels of exposure to vibration and the resulting effects on health has not been as clearly defined as it has been for noise (Taylor and Wasserman, 1988). Neither is the pathogenesis of vibration-induced injuries fully understood, although some of the effects are irreversible and cause permanent impairment (Kakosy, 1989).

As a consequence, considerable controversy exists with respect to identification of workers at risk, pathophysiology, diagnosis--especially quantitative assessment--and treatment (Letz, et al., 1992).

[1] History

A syndrome of color change in the fingers--whitening in response to exposure to cold or emotional distress, followed by the skin becoming blue (cyanosis) and then red as blood returns to the capillaries--was first described by Maurice Raynaud in 1862. In

1883, Sir Thomas Barlow named the syndrome Raynaud's disease. In 1901, the name Raynaud's phenomenon was suggested by Hutchinson, who considered that more than one condition might cause these symptoms. In 1932, Allen and Brown proposed criteria to differentiate the idiopathic (of unknown cause), benign form of the syndrome from the form that is associated with possibly severe underlying disease. They termed this benign form Raynaud's disease (Marcus, et al., 1991; Cleophas and Niemeyer, 1993).

In industry, the use of hand-held vibrating tools goes back to around 1840 in France. By 1900, jack-leg drills were in use for drilling rock; in the 1930s, pneumatic drills were used for chipping and grinding in foundries; and in the 1950s, chain saws were used for felling, debranching and cross-cutting trees in the forestry industry. High levels of vibration of the chain-saw handles and new techniques for the use of these tools resulted in an increasing incidence of vibration effects being reported among forestry workers (Taylor and Wasserman, 1988).

The first report of Raynaud's phenomenon being caused by vibration was made in 1911 by Loriga, who had observed the effect of pneumatic drills on Italian rock miners. In 1918, Dr. Alice Hamilton described a syndrome of ''vibration white finger'' or ''dead man's hand'' among stonecutters in Indiana, where the mallet and hammer were replaced by pneumatic tools around 1900. The cause in both cases was accurately said to be spasm of the arteries of the fingers, brought on by the vibration of the drills. The investigators recognized the resemblance of the signs and symptoms to the syndrome described by Raynaud.

As the use of air-driven and electric-powered hand tools increased, further outbreaks of ''white finger'' were reported, and the term ''vibration-induced white finger'' was adopted. However, in time, investigators recognized that other systems in the hand and arm besides the blood vessels of the fingers were being affected, and eventually the term ''hand-arm vibration syndrome'' was adopted (Taylor and Wasserman, 1988).

Despite a survey in 1982 by the National Institute for Occupational Safety and Health (NIOSH), which found that 1.2 million U.S. workers were exposed to hand-arm vibration (Taylor and Wasserman, 1988), little research on vibration-induced disease has been done in the United States. Consequently most of the available information is based on data obtained in other countries, especially northern and eastern Europe and Japan. A major effect of this lack of attention by American investigators is that clinicians faced with patients who have signs and symptoms of Raynaud's syndrome find few treatment options or prevention measures available (Cherniack, 1990).

[2] Definition

Raynaud's syndrome is one of a group of occupational injuries known as cumulative trauma disorders, which are associated with risk factors such as repetition, forceful exertion, exposure to cold and extreme postures as well as to vibration. Other examples are carpal tunnel syndrome and thoracic outlet syndrome[2] (Frederick, 1992). The importance of these disorders for industrial hygiene is indicated by a government estimate that over half the costs of industrial injury during the 1990s will be due to cumulative trauma disorders (Cherniack, 1990).[3]

Because the complex of symptoms described by Raynaud can be caused by a variety of conditions or may arise spontaneously, it is referred to by several different names that are used by different writers somewhat inconsistently. In general, however, a distinction is made between the benign primary disorder and a more serious condition that is secondary to another disease (Davis, 1993).

[a] Primary Raynaud's Disease

Primary Raynaud's disease is a clinical condition in which there is no disease or abnormality to which the digital vasospasm is secondary. It has no recognized cause and is associated with no physical stimulus other than exposure to cold (Marcus, et al., 1991; Taylor and Wasserman, 1988).

[b] Secondary Raynaud's Phenomenon

The term secondary Raynaud's phenomenon is used to refer to the digital vasospasm (blood vessel contraction) when it is known to be associated with an underlying condition. A large number of diseases and drugs can be underlying causes of Raynaud's phenomenon.[4] This chapter deals with Raynaud's phenomenon induced by vibration, which is known as Raynaud's phenomenon of occupational origin. It has also been called traumatic vasospastic disease, vibration white finger and, most recently, hand-arm vibration syndrome (HAVS) (Marcus, et al., 1991; Taylor and Wasserman, 1988).

[c] Raynaud's Syndrome

The uses of this term are not clearly defined. Some authors use it to refer to the conditions described as primary and secondary Raynaud's syndrome (Cleophas and Niemeyer, 1993). In other cases, the term refers to Raynaud's phenomenon in which associated illness may be present but has not been definitively established. Some writers use ''Raynaud's syndrome'' to refer generally to the characteristic constellation of symptoms that are involved. The term will be so used here (Marcus, et al., 1991).

FOOTNOTES:

Footnote 1. *See* § 17A.01[1] *infra*.

Footnote 2. *See also* ch. 17.

Footnote 3. *See also* Courtroom Medicine--Pain and Suffering, ch. 53 (Matthew Bender).

Footnote 4. *See* § 17A.21 *infra*.

§ 17A.02 Measurement of Vibration

That vibration can cause injury has been recognized only fairly recently, and methods of defining and measuring it are still subject to controversy.

Generally, for the purposes of research, vibration reduction and establishment of regulatory standards, vibration exposure and effects have been categorized as either whole-body or segmental (hand-arm). Raynaud's phenomenon is caused by segmental vibration, the traumatic effects of which are more severe and more clearly understood than those of whole-body vibration (Taylor and Wasserman, 1988).

[1] Defining Vibration

Vibration is defined in terms of several parameters:

- frequency in Hertz (Hz; a measurement of cycles per second);

- amplitude (displacement in meters);

- acceleration (rate of change in velocity, expressed in meters per second squared--m/s[2]--and in gravitational units such that 1 g = 9.8 m/s[2]);

- direction along an axis; and

- state of being continuous or interrupted.

Three internationally agreed upon axes are used in standardized measurement: the X axis (front to back), the Y axis (side to side) and the Z axis (vertical) (Taylor and Wasserman, 1988).

To measure vibration along all three axes, three accelerometers are used, mounted perpendicular each to the others on a tool such as a chain-saw handle. The accelerometers may also be attached to the glove on the hand holding the tool (Letz, et al., 1992). The accelerometer uses a piezoelectric crystal, in which electricity is generated as a result of pressure applied by the vibratory force.

Since a worker's actual experience of vibration involves forces composed of many frequencies at different accelerations, techniques must be employed to analyze the spectrum of vibrations and average them. Thus the signal from the accelerometers is fed into a computer that performs the analysis. In order to provide a single-figure unit to represent a single weighted vibration level for a given tool or to express a regulatory standard, the vibration level may be expressed in decibels.

For general measurement purposes, vibration meters have been developed that read out acceleration, velocity, displacement, the root mean square of a given spectrum of frequencies and the decibel level. Some of these machines can also calculate and display the percentage of permitted exposure that the dose being measured represents, according to international draft standards (Taylor and Wasserman, 1988).

[2] Resonance

In addition to the factors already described, the response of the human body to vibration depends on a factor of resonance. The body's response to vibration is frequency dependent, and different structures within the body resonate to different, specific bands in the frequency spectrum. When a part of the body resonates to a particular vibration frequency, the body amplifies the vibrational energy, exacerbating its effects.

The principal resonance of the lower arm occurs at 16 to 30 Hz; that of the hand occurs between 50 and 150 Hz. The vibration frequencies of commonly used tools, such as chipping hammers, pneumatic drills, impulse drills and rock drills, range between 30 and 60 Hz (Taylor and Wasserman, 1988).

[3] Difficulty of Assessing Vibration Exposure

A variety of difficulties are involved in evaluating and measuring vibration. One problem is that using different techniques of assessment has been found to produce considerable variability in results, leaving a question as to which techniques are more accurate. Another problem involves controversy over appropriate methods for summarizing the various parameters into a single unit measurement figure.

For example, three studies of pneumatic tools at the same shipyard were performed in 1987 and 1988; two were privately funded, and one was performed by NIOSH. All three studies were carried out in accordance with American National Standard Institute guidelines, using comparable equipment. However, whereas the private studies were performed in controlled settings that simulated the workplace but allowed for more quantitative definition of jobs and work surfaces, the NIOSH study was performed at the work site itself. The acceleration values were weighted in all three studies, and unweighted values were also presented in two studies.

Despite these similarities, there was considerable variability in the results. The NIOSH study reported much higher acceleration values than the two proprietary studies, raising the possibility that measurements made in a simulated work site setting may underestimate the actual vibration level experienced by workers on the job. What is more, there was only poor correspondence between weighted and unweighted acceleration values; and there was also extreme variation between the measures of acceleration reported for the same types of tools in different studies and even within studies. Consequently the data from these studies could not be integrated with the reported hours of exposure to create a cumulative exposure index for each worker; neither could they be used to develop regulatory standards based on exposure (Letz, et al., 1992).

§ 17A.03 Causes of Raynaud's Syndrome

The digital vasospasm and decrease of blood flow to the skin that results in the characteristic whitening of the fingers of Raynaud's syndrome may have any of a large number of causes, which may be occupational or nonoccupational. The condition may also be idiopathic (of unknown origin).

[1] Nonvibrational Causes

A large number of diseases may underlie secondary Raynaud's phenomenon. These include connective tissue diseases (e.g., scleroderma, systemic lupus erythematosus and rheumatoid arthritis);[5] occlusive arterial diseases (e.g., arteriosclerosis obliterans, primary pulmonary hypertension and thrombocytosis); hematologic disorders (e.g., polycythemia);[6] neoplasms (e.g., leukemia);[7] neurologic lesions (e.g., causalgia);[8] mononucleosis; Lyme disease;[9] fibrositis;[10] chronic hepatitis and primary biliary cirrhosis.[11]

Raynaud's syndrome can also be caused by certain medications, including beta-blockers, preparations containing ergot, cold and diet pills, cytotoxic drugs and oral contraceptives.

Occupational causes other than vibration include repetitive motion disorders (carpal tunnel syndrome, thoracic outlet syndrome) and exposure to toxic chemicals, including lead, mercury, polyvinyl chloride and arsenic.[12] Constant repetitive trauma to the digits has caused Raynaud's syndrome in typists, telephone operators, pianists and meat cutters.

Finally, Raynaud's syndrome has been associated with psychiatric disorders, including anorexia nervosa,[13] schizophrenia and aggressive states; hormonal disorders, such as hypothyroidism; and with use of caffeine and tobacco (Davis, 1993; Marcus, et al., 1991; Cleophas and Niemeyer, 1993; Coffman, 1989).

[2] Vibrational Causes

Raynaud's syndrome is caused by industrial work processes in which vibration enters the body through the hands, wrists and arms of the worker (Taylor and Wasserman, 1988). Gasoline-powered chain saws, rock drills, riveting machines, grinders, jackhammers and pneumatic hammers are among the tools most commonly reported to cause the syndrome. A study in one shipyard reported the vibration levels of 51 different tools, including various grinding and burring tools, different types of drills (air drills, pistol drills), air hammers, air saws, needle guns, bolt guns, thread tappers, sheet metal cutters and offset wheels (Letz, et al., 1992). Small tools such as metal burring wheels that have little inertial force are nevertheless especially harmful. They are used in occupations such as painting, sheet-metal work and welding (Cherniack, 1990).

Raynaud's syndrome has also been reported in workers who operate pounding and lasting machines, brush saws and sewing machines, as well as in caulkers and machinery platers (Coffman, 1989; Allen, et al., 1992; Letz, et al., 1992). Farmers, farm workers and ranch hands are exposed to segmental vibration through gripping the steering wheel of tractors (Donham and Horvath, 1988). Outdoor workers are particularly at risk, since the painful vasospasms occur in the cold. Thus many studies have been done of tree fellers, most of whom develop symptoms within 10 years of exposure (Cherniack, 1990).

FOOTNOTES:

Footnote 5. *See also* Courtroom Medicine--Pain and Suffering, ch. 14A (Matthew Bender).

Footnote 6. *See also* ch. 42.

Footnote 7. *See also* Courtroom Medicine--Cancer, ch. 8 (Matthew Bender).

Footnote 8. *See also* Courtroom Medicine--Pain and Suffering, ch. 17 (Matthew Bender).

Footnote 9. *See also* Courtroom Medicine--Skin, ch. 48A (Matthew Bender).

Footnote 10. *See also* Courtroom Medicine--Pain and Suffering, ch. 13 (Matthew Bender).

Footnote 11. *See also* Courtroom Medicine, chs. 2 and 3, respectively (Matthew Bender).

Footnote 12. *See also* ch. 36.

Footnote 13. *See also* Courtroom Medicine--Psychic Injuries, ch. 13B (Matthew Bender).

§ 17A.04 Epidemiology

The overall incidence of primary and secondary Raynaud's syndrome is difficult to estimate, since there is no objective diagnostic test for these conditions[14] (Grigg and Wolfe, 1991). Generally, however, Raynaud's syndrome is said to occur as often as hypertension or diabetes (Cleophas and Niemeyer, 1993); the vast majority of patients with this syndrome are women. The most common origin of Raynaud's syndrome in men appears to be vibrational trauma (Coffman, 1989).

[1] Overall Incidence

About 10 percent of the entire female population manifests symptoms of primary Raynaud's disease. The condition is particularly prevalent in young women, with estimates as high as 30 percent for this group (Marcus, et al., 1991). About 90 percent of all patients are women, who often experience mild symptoms beginning during the teen years and tapering off around menopause (Grigg and Wolfe, 1991). About 95 percent of patients with scleroderma, 91 percent with mixed connective tissue disease and 40 percent with lupus have associated Raynaud's syndrome (Marcus, et al., 1991).

The prevalence of Raynaud's syndrome is influenced by climate. In South Carolina, for example, prevalence is about 4 percent, while in London, it is as high as 20 percent (Cleophas and Niameyer, 1993).

[2] Occupational Incidence

In 1982, a survey of workers at shipyards and foundries conducted by NIOSH estimated that 1.2 million American workers were exposed to significantly high levels of vibration. The study also found that the prevalence of hand-arm vibration syndrome (HAVS) in foundries that used pneumatic chipping hammers was around 47 percent, and that among certain groups of workers, up to 89 percent were clinically affected by vibration (Taylor and Wasserman, 1988; Cherniack, 1990).

Despite the fact that HAVS has one of the highest attack rates of occupational diseases, since then, there has been little epidemiologic study of Raynaud's syndrome in the United States (Letz, et al., 1992). However, a disturbing increase in hand-arm vibration syndrome accompanying the spread of the use of power chain saws in forestry led to studies in other countries, including Australia, Japan, Sweden, the United Kingdom and Finland. These studies found prevalence rates ranging from 40 to 90 percent among chain saw operators (Taylor and Wasserman, 1988).

Recent investigations in Japan found a hand-arm vibration syndrome (HAVS) prevalence rate of 9.6 percent among 447 chain saw workers. Workers with 30 years or more of exposure to vibration had a significantly higher prevalence of vibration white finger (29.9 percent) and of hand numbness (25.4 percent) than other groups with less exposure (Mirbod, et al., 1992a).

The prevalence of vibration white finger in another series of groups of workers exposed to vibration (other than chain saw operators) ranged from 2.2 to 4.8

percent. This result did not differ significantly from the prevalence of primary Raynaud's syndrome in the general population of Japan (0.5 to 4.6 percent), which is a somewhat lower prevalence than is found in the general populations of other countries (Mirbod, et al., 1992b).

One study performed in the United States used random samples of workers drawn from different departments of a large shipyard, who experienced a range of exposures to vibration. The investigators found prevalence of white finger symptoms of 71 percent among full-time dedicated pneumatic grinders; 33 percent among workers with part-time exposure; and 6 percent among workers not exposed to vibrating tools. The prevalence of numbness and tingling in the hands and fingers in the same three groups was 84 percent, 50 percent and 17 percent respectively (Letz, et al., 1992).

FOOTNOTES:
Footnote 14. *See* § 17A.08 *infra*.

§ 17A.05 Nature of Injury

Since 1950, it has been evident that in addition to the vascular abnormality induced by exposure to cold, Raynaud's syndrome is associated with neurologic and musculoskeletal abnormalities that become manifest in the following ways (Taylor and Wasserman, 1988; Letz, et al., 1992):

- pain;
- paresthesias;
- impairment of pain and temperature sensation;
- decrease in manual dexterity; and
- loss of grip strength.

Consequently some investigators consider Raynaud's phenomenon of occupational origin to be part of a syndrome involving peripheral nerves, muscles and joints (Coffman, 1989).

Authorities in the Soviet Union and Japan have suggested further that the central nervous system is involved, in the form of damage to the autonomic centers of the brain that is induced by hand-arm vibration; they report a high incidence of the following symptoms:

- fatigue;
- headaches;
- sleep disturbances;
- irritability;
- forgetfulness; and
- dizziness.

Advanced cases are referred to as the diencephalic syndrome. However, a 1983 symposium concluded that no data confirmed this view (Taylor and Wasserman, 1988; Coffman, 1989).

[1] Clinical Manifestations

The earliest symptoms of hand-arm vibration syndrome are numbness and tingling (paresthesias) that occur within a few minutes of beginning to use a vibrating tool. This is followed by a variable amount of swelling of the fingers. As exposure to vibration continues, whitening of the fingertips develops; it is most intense in those fingers that sustain the greatest vibration exposure, although in some cases, the opposite hand is reported to be more severely affected. Initially these episodes last only a few minutes, and symptoms may disappear completely during weekends and vacations.

Symptoms can be relieved by warming the hands. As time goes on, episodes of vasospasm may last up to two hours and can be triggered not only by vibration but also by exposure to cold (Mathias, 1988; Donham and Horvath, 1988; Davis, 1993).

Workers also frequently experience pain, loss of grip strength, loss of dexterity, decrease in ability to manipulate objects and easy fatigue in the forearm and elbow (Cherniack, 1990; Letz, et al., 1992). Although emotional stimuli are said to trigger vasospasm in other forms of Raynaud's syndrome, this factor has not been implicated in the vibration-induced form (Coffman, 1989).

Uncommonly, the blanching of the fingers is followed by cyanosis (bluish discoloration of the skin) and hyperemia (excessive blood in a part; the fingers become red and throbbing). Rarely, there is persistent cyanosis and ischemic (pertaining to inadequate blood supply) ulcerations of the fingertips. The severest cases appear among forestry workers who are exposed to damp cold as well as vibration. However, hand-arm vibration syndrome does not lead to gangrene (death of a large mass of tissue due to loss of blood supply, leading to putrefaction) or loss of fingers, and workers with the syndrome often continue in their occupation for years (Mathias, 1988; Coffman, 1989; Davis, 1993).

[2] Pathophysiology

Exactly how vasospastic attacks result from using vibrating tools is unknown (Coffman, 1989). Neither is it clear why some workers develop Raynaud's syndrome after a fairly short exposure period (slightly over 4 years in one study) (Letz, et al., 1992), but others do not develop it even after as much as 30 years of exposure (Allen, et al., 1992).

The basic mechanism of Raynaud's syndrome is an interruption of the blood flow in the fingers caused by a spasm of the arteries in the palms and fingers (Davis, 1993). Whereas in a normal person, exposure to cold will result in vasoconstriction (contraction of blood vessels) followed by rapid rewarming once the cold ceases, it seems that individuals with Raynaud's syndrome go through a latent period in which there is failure to recover immediately from the cold (Grigg and Wolfe, 1991).

In most cases, the pathology can be reversed through use of a local sympathetic nerve block.[15] In some chronic cases, however, structural changes occur in the vasculature, including local atherosclerosis (a common form of arteriosclerosis--hardening and thickening of artery walls, along with a loss of elasticity--that involves the formation of deposits of yellowish fatty plaques within arterial walls) (Cherniack, 1990).

Some studies have indicated that the sensorineural symptoms in Raynaud's syndrome result from a slowing of nerve conduction velocity in the fingers and palm. Deficits in sensitivity to specific frequencies have been found, suggesting that vibration damages specific types of sensory receptors in the skin. One study also found a deficit in thermal sensitivity, supporting workers' subjective reports of decreased sensitivity to temperature (Cherniack, 1992).

Other investigators have noted that the predominant vibrational frequency of chain saws is 125 Hz, which lies in the frequency range where the pacinian corpuscles (nerve endings involved in the perception of pressure) are most sensitive to vibration. These researchers therefore suggested that chronic overstimulation of these corpuscles may be the cause of the vasospastic reaction, by means of a reflex linkage to the sympathetic innervation of the blood vessels in the skin of the hand. Since the hand that is not exposed to vibration also experiences the syndrome, it is possible that the linkage occurs through the central nervous system (Mathias, 1988; Coffman, 1989).

Finally, some evidence suggests a causal relationship between exposure to vibration and the development of collagen disease such as systemic sclerosis (Matsumoto, et al., 1992; Lau, et al., 1992). This is somewhat controversial, however, and it has not been scientifically established.

FOOTNOTES:
Footnote 15. *See* § 17A.09 [3] *infra*.

§ 17A.06 Risk Factors

Several risk factors play a role in the development of Raynaud's syndrome and in determining the severity of the symptoms.

[1] Intensity of Vibration

The frequency range in which vibration can be harmful lies between 6 and 1000 Hz (Taylor and Wasserman, 1988). The length of the so-called latent interval--the time between the worker's initial exposure to vibration and the first appearance of a white fingertip--is inversely related to the acceleration value of the tool and the cumulative hours of exposure. At frequencies greater than 60 Hz, the threshold acceleration value for causing vasospasm is around 75 meters per second squared (Mathias, 1988).

[2] Duration of Exposure

There is a clear correlation between the severity of symptoms and the duration of exposure to vibration. This relationship was found in both the study of American shipyard workers and that of Japanese chain saw operators[16] (Letz, et al., 1992; Mirbod, et al., 1992a). A study of workers who had made compensation claims for vibration white finger in the United Kingdom, however, found that the severity of vasospasm, as measured in the laboratory, did not correlate with the duration of exposure (Allen, et al., 1992).

[3] Continuous versus Intermittent Exposure

Continuous vibration is more harmful than vibration interrupted by rest periods. A rest period of ten minutes per hour of continuous exposure time is recommended (Taylor and Wasserman, 1988).

[4] Work Practices

Specific work practices increase the risk of developing Raynaud's syndrome. The muscular contractions and paresthesia caused by vibration may lead the worker to grip the tool with excessive force. Since a tighter interface between the hand and the tool results in more efficient transmission of vibration energy to the hand, the damage to the hand tissues is increased.

Similarly, the lighter the tool, the less its mass has a damping effect on its vibration, and the more vibrational energy is transferred to the hand. Thus although a lighter tool results in less wear and tear on arm joints, it increases the dose of vibration received by the worker (Frederick, 1992; Taylor and Wasserman, 1988).

Another work practice found by the study of American shipyard workers to be correlated with more severe vascular and sensorineural symptoms was working with tools held above the head for more than five hours a week (Letz, et al., 1992).

[5] Exposure to Cold

Chronic exposure to cold is another risk factor for Raynaud's syndrome. People who work outdoors in low temperatures are the ones most likely to develop the condition, especially those who also ride bicycles or motorcycles to work in the early morning hours (Taylor and Wasserman, 1988; Coffman, 1989).

[6] Individual Susceptibility

A number of individual factors may also predispose to Raynaud's syndrome. Some individuals have shorter latent intervals than others (Taylor and Wasserman, 1988). Smokers are at greater risk (Coffman, 1989), since smoking has a strong vasoconstrictive effect and therefore exacerbates the effects of the vibration (Davis, 1993).

Other predisposing factors that have been reported are family history of Raynaud's phenomenon, previous arm injuries and pre-existing vascular disease (Coffman, 1989; Mathias, 1988).

FOOTNOTES:
Footnote 16. *See* § 17A.04[2] *supra.*

§ 17A.07 Classification Systems

Occupational physicians have found it difficult not only to measure vibration but to evaluate the disability it produces. Early systems of classifying the effects of vibration in terms of qualitatively described stages were based on symptoms, and therefore these systems used the more easily visualized vascular symptoms, such as the number of fingers that whitened during an attack, the number of attacks and the effect on grip force. These systems also considered the effects of Raynaud's syndrome on a worker's outdoors hobbies and other activities, such as fishing, golfing, swimming and external house maintenance.

Several classification systems were developed, based on the worker's subjective report of disability, of which the two most often used for research and legal purposes are the Taylor-Pelmear system of stage assessment and the system based on work by Andreeva-Galanina in the former Soviet Union.

Subsequently, as it became recognized that the vascular and neurologic symptoms occur independently of each other, a revised scale was developed, known as the Stockholm workshop scale, which grades the stages of the vascular and sensorineural symptoms separately (Cherniack, 1990; Taylor and Wasserman, 1988).

[1] Taylor-Pelmear System

This classification system grades Raynaud's syndrome into stages according to clinical symptoms. It has been widely used since 1968 in the United Kingdom, since 1978 in the United States and also in other countries. This scale assesses functional interference with both work and leisure activities in a semiquantitative manner, based primarily on visible vascular changes (Taylor and Wasserman, 1988; Letz, et al., 1992).

The scale's eight stages include four involving no blanching of the digits and four in which various degrees of blanching are present. In the first four stages (denoted 0, 0T, 0N and 0TN), there may be intermittent tingling (T) or numbness (N) or both tingling or numbness, but no interference with activities. The second four stages (denoted 1 through 4) range from blanching of one or more fingertips with or without tingling and numbness to extensive blanching of most fingers beyond the tips, which occurs in summer as well as winter. In stages 1 to 4, interference with activities ranges from slight to severe, from restriction of social and home activities but no interference with work to the need to change occupation to avoid further vibration exposure (Taylor and Wasserman, 1988).

[2] Andreeva-Galanina System

This system classifies Raynaud's syndrome according to levels, again based on the worker's report of signs and symptoms. It is used in Japan, the former Soviet Union and in Eastern European countries. The levels as defined reflect the view in these countries that hand-arm vibration syndrome constitutes a systemic disease involving a central nervous system component.[17]

In level I, there is numbness, intermittent finger and forearm pain, and light sweating of the palms. Subsequent levels involve increasing degrees of secondary Raynaud's phenomenon, numbness, pain, joint stiffness, decline in muscle power, headache, symptoms of neurosis, nausea and vertigo. The most severe level--IV--involves frequent and prominent secondary Raynaud's phenomenon, sometimes in the legs as well as the hands, together with muscle contracture (permanent contraction often amounting to deformity), peripheral nerve paralysis, changes in the bones of the elbow and further nervous instability as well as neurotic symptoms (Taylor and Wasserman, 1988).

[3] Stockholm Workshop Scale

This system, introduced in 1986, does not grade the disease by its effects on social and occupational functioning but instead is based entirely on symptoms, both vascular and neurologic. The sensorineural symptoms are graded in three stages according to their progressive severity, with stage III involving numbness, decreased tactile discrimination and decreased manipulative dexterity. The vascular symptoms are graded in four stages, ranging from occasional blanching of the fingertips to trophic changes in the skin (ulceration due to insufficient blood supply). The Stockholm workshop scale (Letz, et al., 1992) is summarized in *Table 17A-1.*

Table 17A-1
Stockholm Workshop Scale
Sensorineural stages
0 No symptoms
1 Intermittent numbness, with or without tingling
2 Intermittent or persistent numbness, with decreased sensory perception
3 Intermittent or persistent numbness, with reduced tactile discrimination and/or manipulative dexterity
Vascular stages
0 No attacks
1 Occasional attacks affecting one or more fingertips
2 Occasional attacks affecting distal and middle phalanges of one or more fingers (and, rarely, proximal phalanges)
3 Frequent attacks affecting all phalanges of most fingers
4 Same as stage 3 plus trophic changes in skin of fingertips

§ 17A.08 Diagnosis

The diagnosis of Raynaud's phenomenon of occupational origin can be problematic, especially since it relies heavily on patients' subjective report of symptoms. Diagnosis requires differentiation from the many other disorders that can cause digital vasospasm and peripheral neuropathy, including other occupational disorders, such as carpal tunnel syndrome. In general, however, the presence of vasospasm induced by cold, together with an occupational or a recreational history of vibrating tool use, is the critical combination for the diagnosis. Exclusion of other conditions that cause secondary Raynaud's phenomenon is also required (Cleophas and Niemeyer, 1993; Allen, et al., 1992; Cherniack, 1990).

[1] Objective Tests for Raynaud's Syndrome

In order to standardize the classification of the stages of Raynaud's syndrome and to make possible diagnoses that do not depend on the worker's subjective history of symptoms, a number of objective tests have been developed for the three body systems that are harmed by vibration: the circulatory, sensory and motor-musculoskeletal systems. None of these tests, however, has been shown to have high sensitivity and specificity. Although objective tests successfully show the differences between groups of subjects exposed to vibration and matched control groups, these tests have generally not been useful for clinical assessment of individual patients (Coffman, 1989; Taylor and Wasserman, 1988). It should also be noted that functional symptoms can be present even when test results are normal (Cherniack, 1990).

The early tests devised to assess vibration white finger, which measured sensitivity to light touch (with cotton wool), to temperature (using probes) and to pain (with a sharp pin) were inexact and subject to observer bias. Recently developed tests are more sophisticated and sensitive (Taylor and Wasserman, 1988).

[a] Circulatory System Tests

Many techniques have been devised to detect vasospasm and to measure the ability of the circulation to recover after exposure to cold (Allen, et al., 1992). After provocative cooling of the hands--done classically by immersing them in cold water--abnormally low finger systolic blood pressure, temperature and blood flow indicate the presence of Raynaud's syndrome (Coffman, 1989). Skin blood flow can be assessed by measuring the time required for rewarming after a cold challenge, since there is a direct relationship between blood flow and temperature (Grigg and Wolfe, 1991).

Plethysmography is a technique for registering variations in the volume of a body part and the amount of blood passing through it. This can be done in the finger. The plethysmometer monitors changes in the volume of the finger by the pulsation of the arteries (Grigg and Wolfe, 1991).

Other techniques include Doppler ultrasonography (which can detect whether the arteries are patent--open to the flow of blood--and measure blood pressure[18]); direct capillaroscopy (examination of capillaries with the microscope, to measure the velocity of red blood cells in the circulation of the smallest blood vessels); and thermal entrainment (which assesses changes in blood flow in one hand while the other is exposed to opposite thermal stimuli) (Grigg and Wolfe, 1991).

Another method, the Lewis-Prusik nail bed compression test, involves exerting pressure on the nail bed, thereby compressing the blood vessels in the finger. The time necessary for normal color to return is then measured. The normal time required is 5 seconds; among workers with hand-arm vibration syndrome (HAVS), it is considerably longer (Taylor and Wasserman, 1988).

Another form of testing recently described involves provocative cooling by means of a double-lumen cuff placed over the middle phalange of the finger. Through the cuff's inner chamber flows water whose temperature can be controlled. A laser Doppler probe applied to the skin of the fingertip monitors blood cell flux in the superficial skin blood vessels. The disappearance of this flux indicates the presence of vasospasm (Allen, et al., 1992).

[b] Sensory System Tests

The neurologic component of Raynaud's syndrome is evaluated using electroneuromyographic (EMG) tests of the motor and sensory conduction velocity of the ulnar and median nerves and tests of the conduction velocity of the motor fibers (mixed nerve fibers that transmit impulses to muscle fibers).[19] The worker should not have been exposed to vibration for at least 24 hours before the test, in order to eliminate temporary threshold shifts that may have occurred in response to exposure.

Quantitative tests of sensory performance include esthesiometry (measurement of tactile sensibility) to evaluate two-point discrimination and depth-sense discrimination. Measurement of the vibration perception (vibrotactile) threshold of the finger pulps has also been performed. After a provocative dose of vibration, subjects have manifested temporary shifts in the threshold of vibrotactile perception.

These tests, however, are nonspecific; the neuropathies they detect are also found in workers who are not exposed to vibration (Taylor and Wasserman, 1988).

[c] Motor-Musculoskeletal System Tests

Grip strength may be tested with a dynamometer (instrument for measuring the force of muscular contraction, in this case, by squeezing). Other tests measure the pinching power of the thumb and fourth finger, tapping ability, the tonic vibration reflex (passing of an appreciable period of time after the reflex reaction before relaxation) and excretion of urinary hydroxyproline, which measures breakdown of collagen fiber (Taylor and Wasserman, 1988). Excess collagen fiber in the urine is suggestive of systemic collagen disorders, such as dermatomyositis, scleroderma and so forth.

[2] Clinical Assessment

Following the clinical identification of Raynaud's syndrome, the subsequent assessment should focus on detecting possible underlying disorders and determining how the condition specifically affects the worker, which will guide treatment. Following a history and physical examination, further tests are directed at ruling out other possible diagnoses (Grigg and Wolfe, 1991).

[a] History

A history of vibrating tool use is critical to the diagnosis of Raynaud's phenomenon of occupational origin. It is important to document the type of tool being used, including pneumatic tools used secondarily as well as vibrating tools used recreationally. Workers should also be asked whether they handle ice (as in the food industry), an activity that can cause Raynaud's syndrome (Cherniack, 1990; Coffman, 1989).

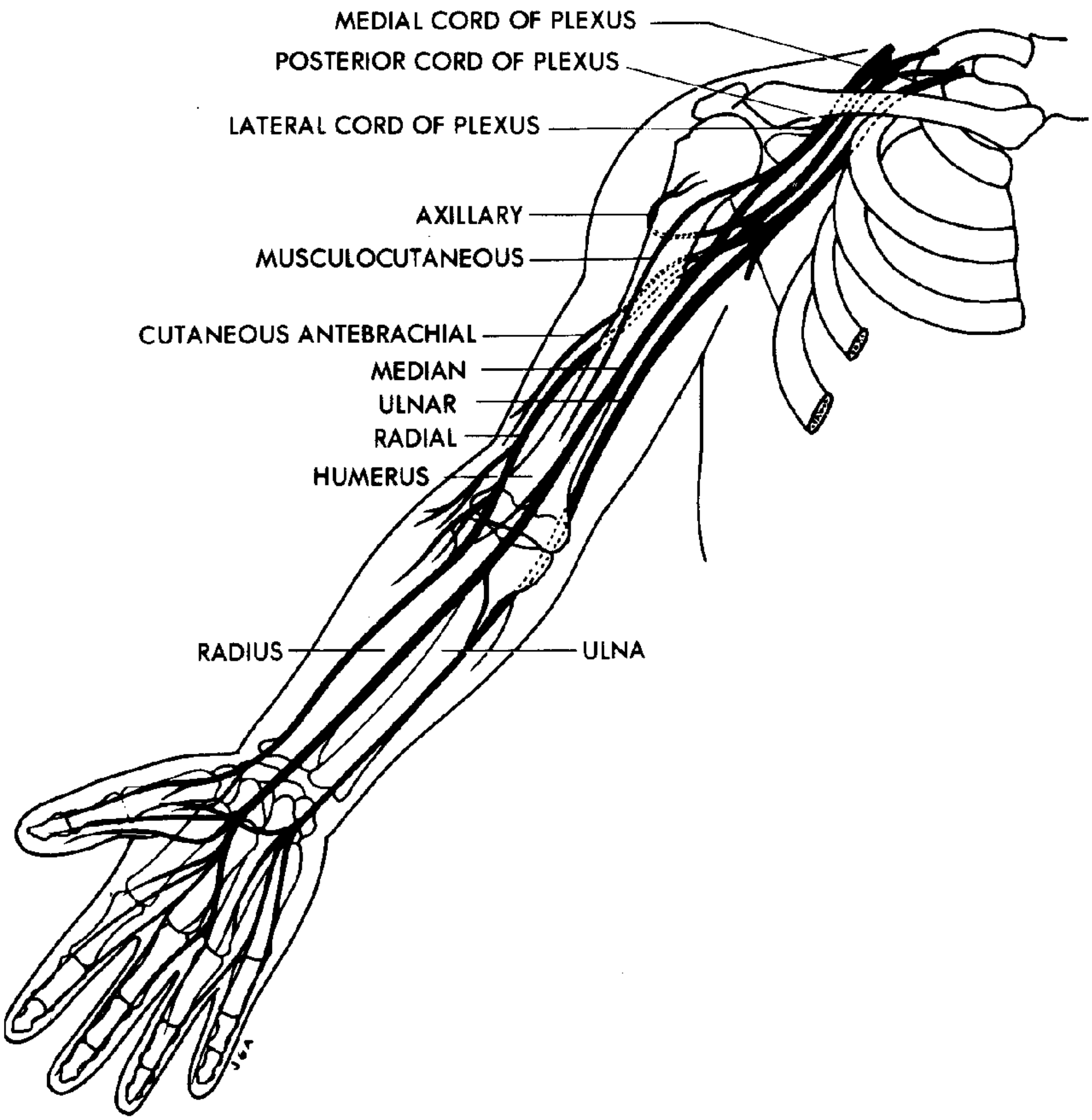
The patient history should further include traumas, such as a crush injury or frostbite of the fingers, both of which can result in intolerance to cold. The patient should be asked about family history and drug taking. In warmer climates, difficulty in tolerating cold water or refrigeration may indicate the presence of disease (Cherniack, 1990; Grigg and Wolfe, 1991).

[b] Physical Examination

During the physical exam, the clinician should look for signs of possible underlying diseases. Such signs may include, among others, weight loss or fatigue (signs of any systemic illness), dry eyes or mouth (sign of Sj"ogren's syndrome), splenomegaly (enlargement of the spleen) and the CREST syndrome (a combination of calcinosis, Raynaud's syndrome, esophageal dysmotility, scleroderma and telangiectasia), which can indicate scleroderma (Davis, 1993).

Assessment of pulses in the upper limbs, together with blood pressure measurement, may reveal an anatomic distortion of the subclavian or axillary artery. If Raynaud's syndrome is asymmetric, this may indicate a surgically correctable lesion, such as atherosclerosis (Grigg and Wolfe, 1991). Cardiac and pulmonary examinations may reveal abnormalities indicating systemic sclerosis (Davis, 1993).

The presence of carpal tunnel syndrome is assessed with Phalen's test (having the patient hyperflex the wrist, or bend it backward; a resulting numbness of the three outside fingers is a positive sign) and with Tinel's test[20] (percussion--light tapping--over the median nerve; a positive sign is a tingling sensation in the hand). (*See Figure 17A-2.*) Thoracic outlet syndrome is assessed by means of Adson's test, in which the examiner palpates both radial pulses (felt over the wrists) as the patient hyperextends the neck and rotates the head on a deep inspiration.[21] The test is positive if the pulse on that side is considerably or completely obliterated (Davis, 1993; Taylor and Wasserman, 1988).



Since the hands appear normal unless the patient is having an attack, Raynaud's syndrome cannot be ruled out if the results of the examination are negative (Davis, 1993).

[c] Laboratory Tests

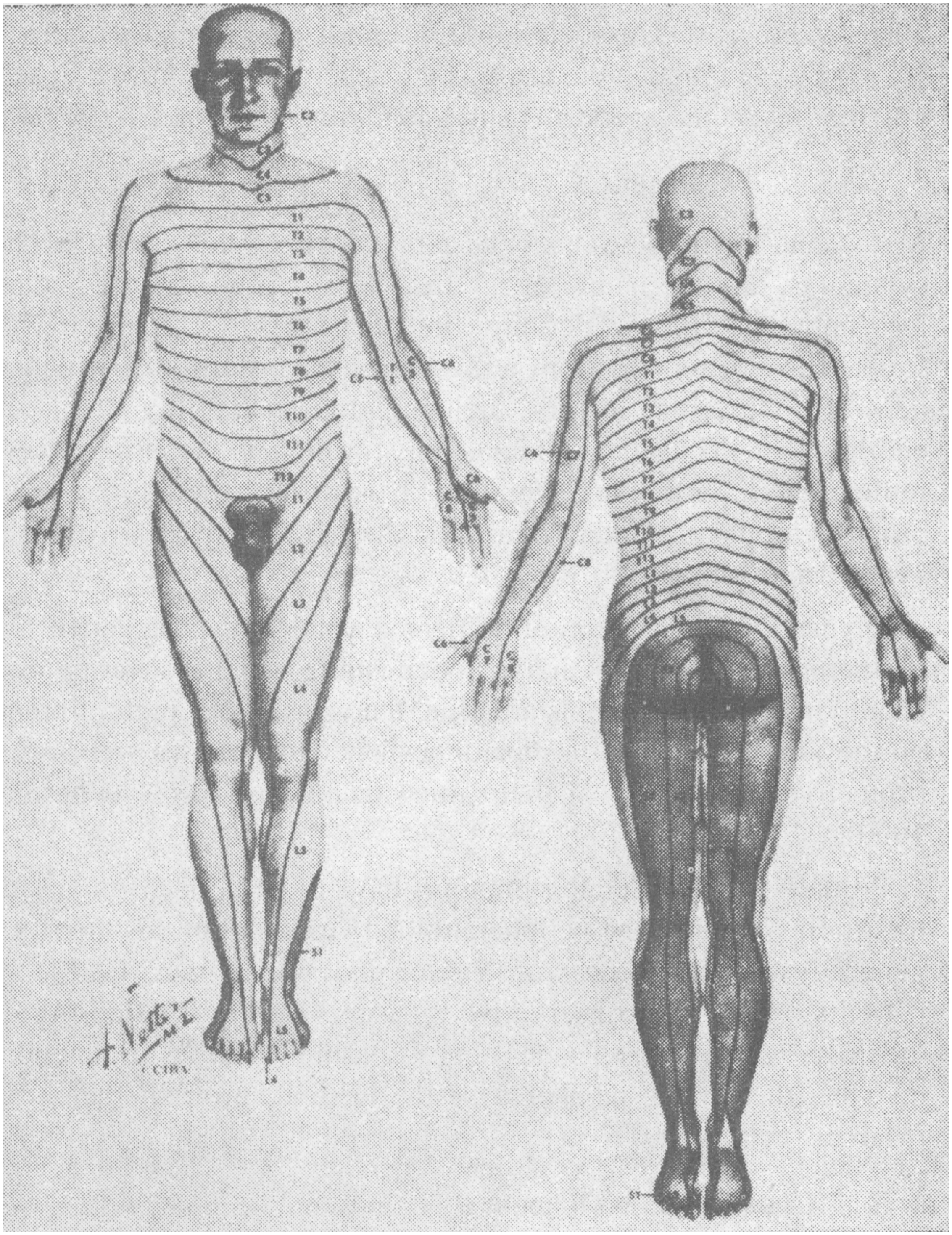
Routine laboratory investigations should include a complete blood count with differential white blood cell count, erythrocyte sedimentation rate (rate at which red blood cells separate out of solution) and measurements of uric acid rheumatoid factor and antinuclear antibody (found in the serum of patients with systemic lupus erythematosus, rheumatoid arthritis and other conditions). Depending on the findings from the history and physical exam, tests for cryoglobulins (abnormal antibodies that appear in the blood upon exposure to cold), cold agglutinins (agglutinins are antibodies that cause clumping, e.g., of cells or bacteria; cold agglutinin acts at low temperatures) and serum protein electrophoresis may also be performed. If the history and physical suggest arthritis or calcinosis, the hands should be x-rayed. If thoracic outlet syndrome is suspected, there should be a chest x-ray. If mononucleosis or Lyme disease is suspected, appropriate tests should be ordered (Cherniack, 1990; Marcus, et al., 1991; Taylor and Wasserman, 1988; Davis, 1993).

[3] Differential Diagnosis

The major diagnoses from which Raynaud's phenomenon of occupational origin must be distinguished are primary Raynaud's disease, systemic diseases such as rheumatoid arthritis and systemic sclerosis, and peripheral obstructive arterial disease. The systemic collagen diseases and vascular diseases can be ruled out by negative results on laboratory tests (Cherniack, 1990; Davis, 1993).

A presumptive diagnosis of primary Raynaud's disease can be made when the history and all physical and laboratory tests are normal. Primary Raynaud's disease characteristically has an early onset (by age 30 in 60 percent of cases); finger whitening is provoked by cold and is bilateral and symmetrical; and there is a familial association (Taylor and Wasserman, 1988; Davis, 1993).

Differential diagnosis of the sensorineural component of Raynaud's syndrome is more complicated, since the signs and symptoms are nonspecific. If the pattern of neuritic pain follows a dermatome (area of skin supplied by a particular nerve), this may indicate a nerve entrapment syndrome or traumatic neuropathy (nerve dysfunction). (*See Figure 17A-3.*) Other conditions that can cause polyneuropathy and nerve compression, such as thyroid disease, rheumatoid arthritis and diabetes mellitus, must also be excluded (Cherniack, 1990). Among factory workers exposed to vibration, secondary Raynaud's phenomenon resulting from a cause other than the vibration may account for between 15 and 17 percent of the reported cases of white finger (Taylor and Wasserman, 1988).



It can also be difficult to differentiate between the harmful effects of vibration and those caused by repetitive movements of the hand and arm that hold the vibrating tool. Sensory deficits and decreased nerve conduction velocity have been found in workers with carpal tunnel syndrome as well as in vibration-exposed workers. Forceful repetitive movement, exposure to vibration and median nerve pain have been associated with one another epidemiologically, but it is not clear whether this association represents coexistent pathologies. However, even though the cause is not specifically identified, it seems possible to diagnose and treat the condition (Cherniack, 1990).

FOOTNOTES:

Footnote 18. *See also* M. Epstein, Common Diagnostic Procedures: Orthopedics and Neurology, ch. 29 (Matthew Bender).

Footnote 19. *See also* M. Epstein, Common Diagnostic Procedures: Othorpedics and Neurology, ch. 11 (Matthew Bender).

Footnote 20. *See also* M. Epstein, Common Diagnostic Procedures: Orthopedics and Neurology, ch. 21 (Matthew Bender).

Footnote 21. *See also* M. Epstein, Common Diagnostic Procedures: Orthopedics and Neurology, ch. 28 (Matthew Bender).

§ 17A.09 Treatment

Raynaud's syndrome cannot be cured. All treatment can do is relieve symptoms, and the nature of the treatment depends on the nature of the symptoms. The only definitive intervention is to remove the worker from exposure to vibration, a measure the feasibility of which will depend on external factors, including the availability of alternate employment. Thus the clinician must weigh the consequences of removing an individual from work against those of the disease progressing if the worker remains on the job (Taylor and Wasserman, 1988; Cherniack, 1990).

Raynaud's syndrome may be treated either by conservative forms of therapy or by drug therapy, depending on the severity of the condition. When symptoms are mild, the worker may prefer to remain on the job, and education regarding work practices, as well as other protective measures, can help minimize symptoms[22] (Cherniack, 1990).

Workers with moderate symptoms have often been given vasodilators (drugs to dilate the peripheral blood vessels), but this therapy has generally been unsuccessful (Taylor and Wasserman, 1988). Most patients should try conservative measures before considering drug therapy, except when episodes of vasospasm interfere with functioning or when they cause pain or dysesthesia (uncomfortable sensations) (Marcus, et al., 1991).

[1] Conservative Therapies

Conservative measures include support and education of the patient and various behavioral conditioning therapies.

[a] Patient Education

An important part of treatment is educating patients about how to control their symptoms.[23] Since cold is the major trigger of vasospasm, patients should be instructed as to why and how to keep warm--and not merely the feet and hands but the whole body. Thick gloves can keep the hands warm and cushion vibration as well. Mittens are even more effective than gloves, and some patients find that electrically heated gloves are helpful on very cold days. Other forms of exposure to cold can be avoided by such tactics as using pot holders to handle frozen food, using glasses with stems or handles for cold drinks and using driving gloves to grip a cold steering wheel.

It is also essential that individuals with Raynaud's syndrome stop smoking as well as avoid inhaling smoke passively. Since caffeine may be a weak precipitating factor, intake of coffee and other caffeinated beverages should be limited (Marcus, et al., 1991; Coffman, 1989; Davis, 1993; Grigg and Wolfe, 1991).

[b] Biofeedback and Relaxation Training

The use of techniques to train the body's autonomic functions (those controlled by the autonomic nervous system, the part of the sympathetic nervous system that is responsible for involuntary actions such as respiration) can be very beneficial to some patients. The techniques help alleviate symptoms by reducing the time required to rewarm the fingers.

Autogenic training teaches patients to concentrate their attention on sensations of warmth and heaviness in the hands. With practice, these sensations can be induced voluntarily. Muscle relaxation training, general relaxation training, meditation, self-hypnosis and visual imagery (such as imagining oneself lying under a hot sun) are other techniques that induce calmness and also help rewarm the digits.

Biofeedback training may be used in conjunction with these techniques. A temperature feedback device provides a visual or an audio display of skin temperature while the patient is doing the relaxation or visual imagery exercise. As the individual monitors the display, which shows when skin temperature increases, he or she becomes able to recognize internally the condition of rewarming, and eventually the person can induce it at will.[24]

Temperature feedback devices are available that can be used in the home. Another form of feedback is electromyographic feedback from the frontalis muscles (over the eyebrows), which may also be used with muscle relaxation training.

Patients who are motivated enough to practice the exercises often get excellent results and can rewarm their fingers at will, reversing the severity of vasospastic attacks as well as the overall number of attacks. Studies have shown that improvement in symptoms often lasts for a year and more (Coffman, 1989; Marcus, et al., 1991; Davis, 1993). In one group of patients, symptomatic improvement using finger temperature biofeedback was retained for three years, and increases in finger temperature were accompanied by increased blood flow in the capillaries (Freedman, 1989).

A typical course of training would be 10 biweekly one-hour sessions. Biofeedback and relaxation training have no known adverse effects, but they do require considerable time from both patient and clinician (Freedman, 1989; Coffman, 1989).

[c] Behavior Modification (Operant Conditioning)

An alternative form of behavioral therapy is Pavlovian or operant conditioning. It aims to interrupt sympathetic nervous system stimuli through counterconditioning. This is done by immersing the patient's hands in warm water (43 degrees C.) while the whole body is exposed to cold (1 to 6 degrees C.). After many sessions, patients' digital temperatures increase during the cold exposure. Sufficiently motivated patients have been able to maintain this increase in skin temperature in reaction to cold for several months to a year.

The conditioning program can be performed at home. However, behavior modification has been reported to be less effective than biofeedback training, especially among individuals with secondary Raynaud's phenomenon (Coffman, 1989; Le Roy, 1989; Marcus, et al., 1991).

[2] Drug Therapy

Some authorities recommend medication only for patients with severe cases of Raynaud's syndrome; others give it for moderate symptoms or when conservative therapy has failed to give relief (Davis, 1993; Coffman, 1989). In any case, the decision to use drug therapy and the choice of a specific agent must involve consideration of risks versus benefits, including side effects (Marcus, et al., 1991).

Several types of vasodilators--drugs that act to dilate blood vessels--have been used to treat Raynaud's syndrome. Calcium-channel blockers, alpha-adrenergic blocking agents and other antihypertensive drugs (medications used to treat high blood pressure) have all been somewhat effective in relieving the vascular symptoms of Raynaud's phenomenon of occupational origin (Cherniack, 1990).

Most workers reporting moderate symptoms of hand-arm vibration syndrome (HAVS) have generally been given some type of vasodilator. However, not only are the results unsatisfactory, but vasodilators affect balance, making them dangerous (Taylor and Wasserman, 1988).

Currently calcium-channel blockers (which reduce vascular tone by preventing calcium ions from crossing the cell membranes of blood vessels) have become the drugs of choice in treating Raynaud's syndrome. The most generally useful agent in this category is nifedipine. If the patient cannot tolerate its side effects, especially headache and lightheadedness, verapamil or diltiazem may be tried (Marcus, et al., 1991; Coffman, 1989).[25]

Alpha-adrenergic blockers inhibit the impulses conveyed by alpha-adrenergic fibers of the sympathetic nervous system. These agents include reserpine, guanethidine and phenoxybenzamine. However, their side effects--nasal congestion, orthostatic hypotension (dizziness upon standing), dyspepsia (indigestion) and inhibition of ejaculation--may make patients unable to tolerate these drugs, particularly phenoxybenzamine (Marcus, et al., 1991; Coffman, 1989).

Prazosin, an antihypertensive drug, has been recommended by some authorities but not by others. Some writers report that combining two drugs that produce vasodilation by different mechanisms may be effective in resistant cases (Grigg and Wolfe, 1991). Others have not found combinations to be more effective than a single drug (Coffman, 1989).

The neurologic and musculoskeletal component of Raynaud's phenomenon of occupational origin may be treated with nonsteroidal anti-inflammatory drugs (NSAIDs) as well as by wrist immobilization (Cherniack, 1990).

Most recently prostaglandins (a group of compounds that can lower blood pressure, inhibit platelet aggregation in the blood and control vascular permeability) have been found effective in some cases. Infusions of prostaglandin E[1] and epoprostenol (prostacyclin) may result in improvement lasting several months (Marcus, et al., 1991; Grigg and Wolfe, 1991).

[3] Sympathectomy

The blood vessels of the fingers may also be dilated by sympathectomy (interruption of part of the sympathetic nervous pathways), either by surgery or by a sympatholytic (opposing the effects of adrenergic impulses) drug that is injected intravenously. The older surgical procedure, in which the thoracic trunk was resected (surgically cut) or the stellate ganglion (a group of nerve cells at the level of the seventh neck vertebra) was partially or completely removed, has been superseded by digital artery sympathectomy, in which the sheath of the artery containing the sympathetic nerve fibers is removed (Coffman, 1989; Marcus, et al., 1991).[26]

Local sympathetic blockade involves injection of the sympatholytic agents guanethidine or reserpine into a peripheral vein (Coffman, 1989).[27] Sympathectomy provides immediate relief. However, the increased blood flow generally lasts only three to six months, and vasospastic attacks recur while the nerve is still severed or blocked (Taylor and Wasserman, 1988). Still there have been reports of good long-term results for digital artery sympathectomy (Marcus, et al., 1991).

[4] Plasmapheresis

In this procedure, blood is drawn, and the plasma (the fluid portion) is removed from it and replaced with new plasma, which is then returned to the body. Some benefit has been reported with plasmapheresis performed serially (Taylor and Wasserman, 1988).

FOOTNOTES:

Footnote 22. *See* § 17A.81 and § 17A.92 *infra* .

Footnote 23. This section discusses general life-style preventive measures. *See* § 17A.11[2] *infra* for specific workplace practices.

Footnote 24. *See also* Courtroom Medicine--Pain and Suffering, ch. 27B (Matthew Bender) for a discussion of various types of self-administered pain relief, including biofeedback.

Footnote 25. *See also* M. Houts, R. Baselt and R. Cravey, Courtroom Toxicology (Matthew Bender), for discussion of drugs and their side effects.

Footnote 26. *See also* Courtroom Medicine--Pain and Suffering, ch. 26 (Matthew Bender), for a discussion of surgical methods of pain relief.

Footnote 27. *See also* Courtroom Medicine--Pain and Suffering, ch. 27 (Matthew Bender) for a discussion of local anesthetic agents.

§ 17A.10 Prognosis

The prognosis for reversal of hand-arm vibration syndrome (HAVS) varies. Mild, sometimes moderate and occasionally even severe cases may remit when exposure to vibration ceases, with the number and severity of vasospastic attacks experienced during the winter, as well as the neurologic symptoms, decreasing (Taylor and Wasserman, 1988; Cherniack, 1990). However, evidence indicates that most cases will not reverse to stage 0 upon termination of exposure, and even when they do, recovery requires several years (Letz, et al., 1992).

In many cases, the hands remain sensitive to cold even after exposure to vibration has ceased. One study found that 50.2 percent of Japanese chain-saw-operator subjects still had Raynaud's syndrome 12 years after tool use had stopped. Another study of Japanese forestry workers found that 13.5 percent recovered from the syndrome while still using chain saws, 12.2 percent recovered within a year of ceasing to use them and 74.3 percent continued to have Raynaud's syndrome 2 years after terminating use. On the other hand, among brush-saw workers, who work during warmer weather, 59 percent recovered within 5 years and 71 percent within 10 years (Coffman, 1989).

In workers older than 45 to 50, reversal of pathologic changes in digital arteries is less likely. Workers with advanced hand-arm vibration syndrome cannot work outdoors in the winter (Taylor and Wasserman, 1988).

§ 17A.11 Prevention

The lack of effective treatment of Raynaud's syndrome makes prevention extremely important, since the condition can result in permanent impairment in occupational abilities and even in unemployment (Kakosy, 1989). Prevention includes several components:

- education of workers regarding appropriate work practices;
- control of daily exposure to vibration;
- redesign of tools to reduce vibration;
- use of protective clothing; and
- medical surveillance of workers.

In addition, standards to protect workers who exhibit symptoms as well as methods of controlling the exposure of all workers may prove helpful.

[1] Proposed Worker Protection Standards

The difficulties in measuring vibration exposure[28] create obstacles to the development of worker protection standards based on exposure. For this reason, NIOSH has recommended worker protection criteria, based on the Stockholm workshop scale, that depend on symptoms instead. These NIOSH criteria mandate that workers with stage 2 vascular or sensorineural symptoms be removed from exposure to vibration, with full pay, until they revert to stage 0.

This symptom-based approach presents several difficulties, however. First, since not all workers do revert to stage 0, as mentioned earlier, this approach does not prevent disease. Second, since some studies have shown that workers may develop symptoms within as short a period as five years, removing them from the job would not be a practical solution. Finally, since objective measures of physiologic abnormalities do not correlate closely with severity of symptoms, workers with a high tolerance of symptoms may remain longer on the job and suffer irreversible impairment as a result (Letz, et al., 1992).

Another standard, which is enforced in northern Europe but not recognized in the United States, limits the weight of tools to be used above the shoulder to a maximum of 10 kilograms (Cherniack, 1990).

[2] Exposure Control Measures

Lacking objective measures that could identify specific physiologic markers to predict disease development, reduction of workers' exposure to vibration assumes added importance (Letz, et al., 1992).

[a] Technical and Administrative Measures

Workers should be trained in ways to use tools that minimize transmission of vibration, such as holding tools as lightly as possible. The number of hours of exposure per day can be limited and broken up by rest periods. Work involving overhead use of vibrating tools can be limited or modified (Frederick, 1992; Letz, et al., 1992; Coffman, 1989).

Workers can also use several layers of warm gloves inside a waterproof glove, and change gloves when they become wet. However, conventional gloves do little to absorb vibration below 500 Hz. Special antivibratory gloves are available that minimize symptoms somewhat (Taylor and Wasserman, 1988; Cherniack, 1990).

Tool redesign, as in the development of antivibratory chain saws, has reduced the incidence of Raynaud's syndrome. Coated handles on tools also help reduce vibration exposure. However, tool redesign has not prevented symptoms from occurring (Cherniack, 1990; Coffman, 1989).

What is more, many tools that cause hazardous levels of vibration continue to be used. The design of pneumatic drills, for example, has not changed since the early part of the century (Taylor and Wasserman, 1988). If exposure guidelines developed by the American Conference of Governmental Industrial Hygienists were applied to many commonly used vibrating tools, use of these tools would either be severely restricted to a very few hours per day or banned entirely (Letz, et al., 1992).

[b] Medical Surveillance

In the absence of reliable objective tests for Raynaud's syndrome, surveillance of workers who are exposed to vibration requires a baseline measurement against which the results of tests performed after a period of exposure can be compared. Thus effective prevention includes a pre-employment physical in which the examiner searches for symptoms of Raynaud's syndrome. Workers with such symptoms should be excluded from using vibrating tools. Such pre-employment tests should include plethysmography,[29] for which a baseline measurement is particularly necessary, since it is difficult to control the variables that influence peripheral blood flow--vasomotor tone, core body temperature and emotional state (Taylor and Wasserman, 1988).

Vibration-exposed workers should then be examined each year. The progression of disease in workers with symptoms of Raynaud's syndrome should be staged,[30] and those who develop stage 2 vascular or sensorineural symptoms should be removed from exposure (if the NIOSH criteria are being followed) (Taylor and Wasserman, 1988; Letz, et al., 1992).

Surveillance may also be carried out by surveying workers about symptoms and by reviewing medical and personnel records, including insurance claims and absentee figures. Information should be collected regarding when and where symptoms occur and what workers believe is causing or aggravating them. Categorizing this information by person, place and time, then calculating rates across jobs or specific work sites, allows managers to detect clusters of cases and determine how effective control measures have been (Frederick, 1992).

FOOTNOTES:

Footnote 28. *See* § 17A.02[3] *supra.*

Footnote 29. *See* § 17A.08[1][a] *supra.*

Footnote 30. *See* § 17A.07 *supra.*

§ 17A.12 Assessment of Disability

As with quantitative measurement of vibration exposure, assessing the disability resulting from Raynaud's syndrome has been problematic for occupational physicians. In particular, the relationship between vasospastic attacks and their effect on the worker's occupational, recreational and social activities has been difficult to establish. Thus the United Kingdom classification Scheme II (Rigby-Cornish) was developed to link clinical signs and symptoms with social disability.

The Scheme II stage assessment of signs and symptoms includes six categories numbered 00 to IV, ranging from no vibration exposure, with no signs or symptoms, to vibration exposure with tissue necrosis of a digit (Taylor and Wasserman, 1988). (*See Table 17A-2.*)

Table 17A-2
Stage Assessment by Signs and Symptoms

	EXPOSURE	SIGNS AND SYMPTOMS
00	None	None
0	Yes	Tingling and/or numbness
I	Yes	Episodic blanching of digits on exposure, tingling and/or numbness
II	Yes	Cyanosis
III	Yes	Permanent circulatory deficiency with sensory impairment
IV	Yes	Necrosis (tissue death) of any digit

The Scheme II assessment of social disability resulting from vibration syndrome includes five categories, ranging from no interference with work or leisure to interference with both that is so severe that the worker's occupation must be changed (Taylor and Wasserman, 1988). (*See Table 17A-3.*)

Table 17A-3
Assessment of Social Disability

DISABILITY	
A	No interference
B	No interference with work; interference with social and recreational activities
C	No interference with work; ceasing of some leisure activities and hobbies; loss of manipulative dexterity
D	Interference with work, social and leisure activities
E	Severe interference with work and social activities, leading worker to request a change in occupation