Upper Extremity and Hand Therapy-Module 1: Fundamentals-Part 1

Course Description:
This course is derived from the textbook by Cynthia Cooper “Fundamentals of Hand Therapy: Clinical Reasoning and Treatment Guidelines for Common Diagnoses of the Upper Extremity” © 2007. This illustrated text and reference emphasizes the fundamentals of hand therapy – for both specialists and non-specialists who encounter clients with hand issues. It provides a consistent format with tips and guidelines for hand therapy treatment. Coverage includes hand anatomy, key terms and concepts, and the evaluation process. A focus on professional issues includes clients with functional somatic syndromes and challenging behavior, client-therapist rapport, and the roles of therapy assistants. Providing many case studies, this text helps therapists think critically about clients' individual needs.

Module 1: Fundamentals-Part 1 covers chapters 1 through 3.

Chapter 1: Fundamentals of Clinical Reasoning: Hand Therapy Concepts and Treatment Techniques
Chapter 2: Upper Extremity Anatomy
Chapter 3: Edema Reduction Techniques: A Biologic Rationale for Selection

Methods of Instruction:
Online course available via internet

Target Audience:
Physical Therapists, Physical Therapy Assistants, Occupational Therapists, and Occupational Therapy Assistants

Educational Level:
Intermediate

Prerequisites:
None

Course Goals and Objectives:
At the completion of this course, participants should be able to:
1. Recognize general hand therapy concepts
2. Identify positioning to counteract deforming forces
3. Identify intrinsic and extrinsic extensor muscle tightness
4. List several adjunct treatments
5. Identify cervical injuries and disorders and resulting impairment
6. Recognize neurovascular symptoms associated with upper body movement
7. List and differentiate between the muscles originating from the lateral epicondyle and the medical epicondyle
8. Identify the interstitial, venous and lymphatic capillaries
9. Identify reduction techniques for acute edema
10. List indications for manual edema mobilization
11. Identify reduction techniques for subacute and chronic edema based on the lymphatic system
12. Identify other types of edema an appropriate treatment
13. Recognize edematous tissue
14. Identify MEM massage, drainage, and term definitions

Criteria for Obtaining Continuing Education Credits:
A score of 70% or greater on the written post-test
DIRECTIONS FOR COMPLETING
THE COURSE:

1. This course is offered in conjunction with and with written permission of Elsevier Science Publishing.
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Fundamentals of Clinical Reasoning: Hand Therapy Concepts and Treatment Techniques

CYNTHIA COOPER

“The more you know about something in detail, the less you know about it in general.”


KEY TERMS

- Antideformity (intrinsic-plus) position
- Blocking exercises
- Chip bag
- Composite motions
- Differential flexor tendon gliding exercise
- Dynamic splints
- Dyscoordinate co-contraction
- Edema
- Elastic mobilization splints
- Extensor habitus
- Extrinsic extensor tightness
- Extrinsic muscles
- Fibroplasia phase
- Hard end-feel
- Inflammation phase
- Interosseous muscle tightness
- Intrinsic muscles
- Joint contracture
- Joint tightness
- Lag
- Maturation (remodeling) phase
- Mobilization splints
- Multiarticular
- Musculotendinous tightness
- Outrigger
Part one: Fundamentals

Hand therapy concepts

The anatomy of the hand is complex. Many structures are multiarticular (i.e., they cross multiple joints), and little room is available for scar tissue or edema to develop without affecting function. Injury in one area of the hand can result in stiffness in other, uninjured parts. A good demonstration of this is the quadriga effect, which illustrates the interconnectedness of the digits. If you passively hold your ring finger extended with your other hand and then try to make a fist, you will notice how limited the whole hand feel when just one finger is held stiff. In this example, the flexor digitorum profundus (FDP) tendons to multiple digits have a shared muscle belly. Restricting movement at one finger restricts the other fingers when they try to flex. This example reminds us that clients can be limited in motion in areas not originally injured. Therefore the therapist needs to evaluate beyond the isolated area of injury when treating clients with hand problems.

To be competent in hand therapy, therapists must be able to do more than just note decreased range of motion (ROM). They must be able to figure out what structures are restricted and how these restrictions affect function (e.g., The client has decreased digital flexion due to FDP adherence, preventing him from holding the steering wheel); they then must be able to target treatment to those particular tissues. These three elements are part of all the decisions we make as hand therapists. As treatment continues, re-evaluation reveals new findings with different tissues to target, and appropriate modifications and upgrades are made. This chapter addresses treatment concepts and techniques of hand therapy and concludes with some provocative thoughts to stimulate clinical reasoning.

Timelines and Healing

Tissues heal in predictable phases. However, the length of these phases varies depending on client variables, such as age and health. The three phases of healing are inflammation, fibroplasia, and maturation (also called remodeling). In the inflammation phase, vasodilation occurs, followed by vasodilation, with migration of white blood cells to promote phagocytosis in preparation for further healing. In this stage, which lasts a few days, immobilization often is advised, depending on the specifics of the diagnosis. If wound contamination or delayed healing is a factor, this phase can last longer.

The fibroplasia phase begins about 4 days after injury and lasts 2 to 6 weeks. In this phase, fibroblasts begin the formation of scar tissue. The fibroblasts lay down new collagen, on which capillary buds grow, leading to a gradual increase in the tissue’s tensile strength. In this stage, active range of motion (AROM) and splints typically are used to promote balance in the hand and to protect the healing structures.

The timeline for the maturation (remodeling) phase varies; this phase may even last years. In the maturation phase, the tissue’s architecture changes, reflecting improved organization of the collagen fibers and a further increase in tensile strength. The tissue is more responsive (i.e., reorganizes better) if appropriate therapy is started sooner rather than later. In this stage, gentle resistive exercises may be appropriate, and the client should be monitored for any inflammatory responses (also known as a flare response). Dynamic or static splinting may also be helpful.

Positioning to Counteract Deforming Forces

Predictable deforming forces act on an injured upper extremity (UE). Edema (swelling) routinely occurs after injury, creating tension on the tissues. The resulting predictable deformity posture is one of wrist flexion, metacarpophalangeal (MP) hyperextension, proximal interphalangeal (PIP) and distal interphalangeal (DIP)
flexion, and thumb adduction. This deformity position occurs as a result of tension on the extrinsic muscles caused by dorsal edema.

Use of the antideformity (intrinsic-plus) position is recommended after injury unless it is contraindicated by the diagnosis (e.g., it is not used after flexor tendon repair). The antideformity position consists of the wrist in neutral position or extension, the MP's in flexion, the IP's in extension (IP's refers to the PIP and DIP joints collectively), and the thumb in abduction with opposition (Fig. 1-1). The antideformity position maintains length in the collateral ligaments, which are vulnerable to shortening, and counteracts deforming forces.

Joint and Musculotendinous Tightness

Joint tightness is confirmed if the passive range of motion (PROM) of a joint does not change despite repositioning of proximal or distal joints. Musculotendinous tightness is confirmed if the PROM of a joint changes with repositioning of adjacent joints that are crossed by that particular muscle-tendon (musculotendinous) unit.

Joint tightness and musculotendinous tightness can be treated with serial casting, dynamic splinting, static progressive splinting, or serial static splinting (see section on splinting later in this chapter). With joint tightness, splinting can focus on the stiff joint, and less consideration is needed for the position of proximal joints. With musculotendinous tightness, because the tightness occurs in a structure that crosses multiple joints, the splint must carefully control the position of proximal (and possibly distal) joints to remodel tightness effectively along that musculotendinous unit.

The client in Fig. 1-2, A, had an infected PIP joint in the index finger. He was treated with hospitalization, intravenous administration of antibiotics, and joint debridement. He arrived for therapy 2 weeks later than his physician had ordered; he had no splint, significant edema, and a severe flexion contracture of the PIP joint. Because the stiffness was localized to the PIP joint, he needed only a digit-based extension splint for that joint. Fig. 1-2, B, shows his progress after 2 weeks of edema control and serial static digit-based splinting.

Musculotendinous tightness can be a cause of joint tightness. Clients with tightness of the extrinsic flexors (i.e., lacking passive composite digital extension with the wrist extended) are at risk of developing IP flexion contractures. Instruct these clients to passively place the MP in flexion and then to gently, passively extend the IP's to maintain PIP and DIP joint motion. In these cases, although you should consider night splinting in composite extension to lengthen the extrinsic flexors, the better course may be to splint in a modified intrinsic-plus posi-
tion with the MPs flexed as needed to support the IPs in full extension. This helps prevent IP flexion contractures.

**Intrinsic or Extrinsic Extensor Muscle Tightness**

Intrinsic muscles are the small muscles in the hand. Extrinsic muscles are longer musculotendinous units that originate proximal to the hand. Intrinsic tightness and extrinsic extensor tightness are tested by putting these muscles on stretch. This is accomplished by comparing the PROM of digital PIP and DIP flexion when the MP joint is passively extended and then passively flexed. With interosseous muscle tightness, passive PIP and DIP flexion is limited when the MP joint is passively extended or hyperextended (Fig. 1-3). With extrinsic extensor tightness, PIP and DIP flexion is limited when the MP joint is passively flexed (Fig. 1-4).

To treat intrinsic tightness, perform PIP and DIP flexion with MP hyperextension. Functional splints (see splinting section) are very helpful for isolating specific exercises to restore length to the intrinsics while performing daily activities. To treat extrinsic extensor tightness, promote composite motions (i.e., combined flexion motions of the wrist, MPs and IPs) with splinting, gentle stretch, and exercise. Instruct the client that performing these exercises with the wrist in a variety of positions is helpful.

**Extrinsic Extensor or Flexor Tightness**

Extrinsic tightness can involve the flexors or the extensors. To test for tightness, put the structure on stretch by positioning the proximal joint crossed by that structure. With extrinsic extensor tightness, passive composite digital flexion is more limited with the wrist flexed than with the wrist extended. With extrinsic flexor tightness, passive composite digital extension is more limited with the wrist extended than with the wrist flexed.

**Lag or Contracture**

**CLINICAL Pearl**

When PROM is greater than AROM at a joint, the active limitation is called a lag.

A client with a PIP extensor lag is unable to actively extend the PIP joint as far as is possible passively (which may not necessarily be full extension). Lags may be caused by adhesions, disruption of the musculotendinous unit, or weakness.

**CLINICAL Pearl**

When passive limitation of joint motion exists, that limitation is called a joint contracture.

Joint contractures can be caused by collateral ligament tightness, adhesions, or a mechanical block. A joint flexion contracture is characterized by a stiff joint in a flexed position that lacks active and passive extension. A person with a joint flexion contracture whose passive extension improves may progress from having a flexion contracture to having an extensor lag. In your treatment communications and documentation, it is important to identify such changes, to use these terms correctly, and...
to be joint specific and motion specific. For example, you should note, “The client has full PIP passive extension but demonstrates a 30-degree PIP extensor lag.”

When a lag is present (PROM exceeds AROM), treatment should focus on promoting active movement. Blocking exercises (Fig. 1-5), differential tendon gliding exercises (see Fig. 1-18), place and hold exercises (see Fig. 1-19), and dynamic or static functional splints can be helpful (Fig. 1-6). If a contracture is present, promote both PROM and AROM with the same exercises and with corrective splinting, which may be the dynamic, static progressive, serial static, or casting type.

**Joint End-Feel**

A joint with a soft end-feel has a spongy quality at the end-range. This is a favorable quality that indicates a potential for remodeling. Splinting for soft end-feel may be the static type or the low-load, long duration type (see splinting section).

A joint with a hard end-feel has an unyielding quality at end-range. This is a stiffer joint, and correcting it may require serial casting or static progressive splinting with longer periods of splint wear.7

Documenting the end-feel and explaining the implications of your findings to the client are very important.

**Preventing Pain**

**Precaution.** Pain with therapy is a signal that injury is occurring. Irreversible damage can result when clients or their families or, worse, therapists injure tissue by using painful force and PROM. Avoid pain in your hand therapy treatment. Being overzealous and ignoring objective signs of tissue intolerance is inexcusable.

Teaching clients and their families that painful therapy is counterproductive can be a challenge. Often clients come to therapy with a “no pain, no gain” mentality. To make matters worse, this philosophy frequently is reinforced by their physicians and friends. Therapists have a duty to explain to their clients that imposing, prolonging, or aggravating pain slows the healing process, fosters more scarring and stiffness, and delays or eliminates opportunities to upgrade therapy.

**CLINICAL Pearl**

Never tell your clients, “Exercise to pain tolerance” or “Go to pain.” Instead, say, “Avoid pain when you exercise. It’s okay to feel a stretch that isn’t painful, but it’s not okay to feel pain when you exercise.”

**Taking Care with PROM**

PROM of the hand should be performed gently and with care.

**Precaution.** PROM can injure swollen and inflamed joints and tissues.

Colditz8 cautions that the only joints for which manual PROM is safe are joints with a soft end-feel. Nevertheless, clients may request more aggressive therapy. They may even be passively stressing their swollen, stiff hands at
home. It is very important that the therapist inquire about this and put a stop to it. Explain to your client how injurious and counterproductive it is, emphasizing that delicate hand tissues are all too easily injured (see Chapter 18).

**Precaution.** PROM can trigger inflammatory responses, causing additional scar production, pain, and stiffness. PROM used inappropriately or painfully can incite complex regional pain syndrome (CRPS or RSD).

### What to Say to Clients if the Doctor Orders “Aggressive Therapy”

When a physician orders aggressive therapy for a client, I tell the client, “Your doctor wants you to make excellent progress. But the reality is that tissues in the hand are delicate and can easily be injured by too much force or pressure. We will assertively correct the restricted or injured tissues, and you will make the best progress by providing controlled stress to the proper structures. Painful, injurious treatment or exercise will only delay or even derail your progress. What we will do aggressively is to upgrade your program and encourage maximum results.”

Hopefully, physicians soon will realize the wisdom of replacing the term aggressive with progressive. Until that happens, explain to your clients that pain-free, controlled stretching and remodeling have proved to be the best course of treatment for the fragile hand tissues.

### Quality of Movement and Dyscoordinate Co-contraction

**Dyscoordinate co-contraction** is a poor quality of movement that can result from co-contraction of antagonist muscles. Clients may demonstrate dyscoordinate co-contraction when they use excessive effort with exercise or when they fear pain with exercise or PROM, or it may be habitual. The resulting motion looks unpleasant and awkward. For example, you may feel the extensors contract as the client tries to activate the flexors. It is important not to ignore dyscoordinate co-contraction. Instead, teach the client pain-free, smooth movements that feel pleasant to perform. Replace isolated exercises with purposeful or functional activities and try proximal oscillations (small, gentle, rhythmic motions) to facilitate a more effective quality of movement. Biofeedback or electrical stimulation may also be helpful. Imagery offers additional possibilities (e.g., have your client pretend to move the extremity through gelatin or water). Do not bark at the client to “Relax!” Instead, be gentle with your voice and your verbal cues.

### Adjunct Treatments

Superficial heating agents can have beneficial effects on analgesic, vascular, metabolic, and connective tissue responses. Analgesic effects are seen in diminished pain and elevated pain tolerance. Vascular effects are evidenced by reduced muscle spasms and improved pain relief. Metabolic effects are related to an increased flow of blood and oxygen to the tissues, with improved provision of nutrients and removal of byproducts associated with inflammation. Connective tissue effects are seen as reduced stiffness with improved extensibility of tissues.

Many clients feel that heat helps prepare the tissue for exercise and activity. The safest way to warm the tissues of hand therapy clients is aerobic exercise, unless this is contraindicated for medical reasons. Tai chi, for example, provides multijoint ROM, relaxation, and cardioc effects.

Application of external heat (e.g., hot packs) is a popular method in many clinics. Although the use of heat is fine if it is not contraindicated, be mindful that heat increases edema, which acts like glue, and this may contribute to stiffness. Heat can degrade collagen and may contribute to microscopic tears in soft tissue. For these reasons, be very gentle and cautious if you perform PROM after heat application. Monitor the situation to make sure that the overall benefits of heat outweigh any possible negative responses. Measuring edema is a good way to objectify these responses.

Cold therapy (also called cryotherapy) traditionally has been used to relieve pain and to reduce inflammation and edema after injury (and sometimes after overly aggressive therapy). Cryotherapy typically is used after acute injury to reduce bleeding by means of vasoconstriction. Cold therapy reduces postinjury edema and inflammation and raises the pain threshold. However, remember: cold therapy can be harmful to tissues; be cautious with this modality.

**Precaution.** Do not use cryotherapy on clients with nerve injury or repair, sensory impairment, peripheral vascular disease, Raynaud’s phenomenon, lupus, leukemia, multiple myeloma, neuropathy, other rheumatic disease, or cold intolerance.

Other modalities used in hand therapy include therapeutic ultrasound, electrical stimulation, and iontophoresis (provision of an agent such as an anti-inflammatory medication into tissue through use of low-voltage direct current). Therapists should study these topics further. However, they also must abide by their practice acts and the regulations of their state licensing agencies regarding the use of modalities. Never use a modality for which you cannot demonstrate proper education and training.
Scar Management

Scar can take many months to heal fully. Treat scar sensitivity with desensitization. If the sensitivity causes functional limitations, provide protection, such as padding or silicone gel. Scars are mature when they are pale, supple, flatter, and no longer sensitive. Scar maturation can be facilitated by light compression (e.g., with Coban, Tubigrip [an elastic support sleeve], or edema gloves).

Precaution. Always check to make sure the compression on the scar is not excessive (i.e., the wrap, sleeve, or glove are not too tight).

Inserts made of padded materials or silicone gel pads also help facilitate scar maturation. This padding is thought to promote neutral warmth of the area and may decrease oxygen to the collagen, thus promoting collagen maturation. Evans advocates scar management using micropore paper tape applied longitudinally along the incision line once epithelialization has occurred.

Instruct your clients to avoid sun exposure while the scar is still immature (i.e., pink or red, thick, itchy, or sensitive). Sunlight can burn the fragile scar and darken its color, affecting the cosmetic result when the scar is mature. Frequent use of sunscreen is highly recommended (see Chapter 19).

Although scar massage is often performed, it is important to monitor the client’s tissue response.

Precaution. If scar massage is too aggressive, it may cause inflammation and contribute to more extensive development or thickening of scar tissue.

Do not encourage aggressive massage; instead, teach the client to perform gentler massage that does not cause a flare of tissues. Further research on this topic is needed.

TREATMENT TECHNIQUES

Splinting

Splinting is a mainstay of therapy for UE problems. Splints can provide immobilization or selective mobilization. They can be used with exercise or to promote function. The topic of splinting exceeds the scope of this book. I strongly advise readers to study more comprehensive resources on this subject. In addition to learning about splint fabrication, readers should learn about strap placement for mechanical advantage and comfort.

Static Splints are used to immobilize tissues, to prevent deformity, to prevent contracture of soft tissue, and to provide substitution for lost motor function. Serial static splints position the tissue for lengthening and are remolded at intervals. Static splints contribute to disuse, stiffness, and atrophy, therefore they should not be used more than necessary. Static progressive splints (also called inelastic mobilization splints) apply mobilizing force using nonmoving parts such as monofilament, Velcro, or screws. Dynamic splints (also called mobilization splints or elastic mobilization splints) use moving parts such as rubber bands or spring wires to apply a gentle force. These splints are used to correct deformity, to substitute for absent or impaired motor function, to provide controlled movement, and to promote wound healing or help with alignment of fractures.

Forearm-based splints should cover approximately two thirds of the forearm. Have the client bend the arm at the elbow and note the placement where the forearm meets the biceps muscle. The proximal edge of the splint should be 1/4-inch distal to this so that the splint is not pushed distally when the client flexes the elbow. Flaring the proximal edges of the splint is also important to ensure that the splint stays on the arm. Clearing the distal palmar crease is extremely important. If the splint crosses this crease, MP flexion will be impeded. When you construct a dorsal forearm-based splint or a forearm-based ulnar gutter, pad the area of the ulnar head, because this bony prominence can become a pressure area. Always incorporate the padding into the molding of the splint; do not place it inside afterward as an addition.

With mobilization splints, the best approach is to provide a splint your client can tolerate for long periods.

CLINICAL Pearl

Applying low tension that is tolerable and constant over prolonged periods is much better than applying strong forces over shorter periods.

The amount of safe force for the hand is 100 to 300 g. Clients often ask that more force be used in their splint. These clients need repeated education that low load over a long duration is the safest and most effective way to remodel tissues and make clinical progress.

Precaution. Painful splinting can be harmful.

Skin blanching is a sign of high tension or incorrect splint mechanics. The line of pull on the part being mobilized in a static progressive or dynamic splint must be a 90-degree angle from the outrigger (the structure from which the forces are directed). An outrigger can be high profile or low profile (Fig. 1-7). High-profile outriggers have certain mechanical and adjustment advantages but are bulkier and less attractive.
Splints Used with Exercise

A dorsal dropout splint can be used to correct digital flexion or extrinsic extensor tightness. Mold the splint in a position of comfortable stretch. Use strapping as needed to keep it in place. The client should try to gently flex the digits away from the splint as able (Fig. 1-8). Having an object to reach for, such as a dowel in the palm, can be helpful.

Splinting can be used to achieve various differential MP positions. The differential MP splint in Fig. 1-9 positions the long finger MP in greater flexion than the index and ring fingers. In this splint, active MP flexion of the index and ring fingers facilitates long finger flexion. Fig. 1-10 shows the opposite differential MP splint, with the long finger MP more extended than the adjacent fingers. A differential MP splint with the small finger MP more flexed than the ring finger might be useful for a small finger metacarpal fracture with limited MP flexion. Active PIP flexion and extension within this type of splint at various MP positions also promotes PIP joint

**FIGURE 1-7** Examples of the 90-degree angle of pull with high-profile and low-profile outriggers. (From Fess EE: Principles and methods of splinting for mobilization of joints. In Mackin EJ, Callahan AD, Skirven TM et al, editors: Rehabilitation of the hand and upper extremity, ed 5, St Louis, 2002, Mosby.)
ROM and tendon gliding. This splint can be used during a progressive gripping activity (e.g., gripping a handful of dried beans, squeezing some out of the hand, then gripping further).

A scrap of thermoplastic material can be used to create a cylinder to fit the client’s available limited fist position. Sustained gripping of or holding onto this cylinder and “pumping” to flex and extend the digits around the cylinder may enhance composite digital flexion.

**Chip Bags**

Chip bags can be incorporated into splinting regimens to maximize lymphatic flow and minimize the stiffness and adherence that otherwise would worsen as a result of the edema. A chip bag is a cotton stockinette bag filled with small foam pieces of various densities (Fig. 1-11). The foam can be cut from a variety of sources, including foam exercise blocks, padding, and soft Velcro materials. Chip bags traditionally have been used in the treatment of lymphedema; they are positioned over indurated areas.
of edema within external compressive garments or multilayered stretch bandages. Chip bags provide light traction on the skin, facilitate lymphatic stimulation, and promote neutral warmth. All these effects help reduce edema. The increased body heat under the chip bag and the light pressure exerted by the bag help soften thickened or fibrotic tissue.

In some cases chip bags can be used alone, without an accompanying splint. In such cases they can be held in place with stockinette or a soft Velcro strap that is not applied tightly. Sometimes a less technical approach, such as using chip bags with splints, is a very effective option. Chip bags also can be positioned inside or in conjunction with splints to maximize edema control and reduce scar adherence. Clients find chip bags very comfortable. Some refer to the chip bag as their “pillow,” which probably conveys the comfort they experience with it. If the therapist wants less bulk or wants the effect of a chip bag with an existing splint that cannot accommodate the bulk, a product such as the Gore Procel cast liner (Fig. 1-12) can be used instead.

**CASE Studies**

**CASE STUDY 1-1**

A client was in an altercation with a family member, and her hand was closed in a door during the argument. She was seen for malunion of a right distal radius fracture with right ulnar joint dislocation and extensor pollicis longus (EPL) rupture. She underwent open carpal tunnel release, corrective osteotomy of the distal radius fracture with internal fixation and bone grafting, and intercalary tendon grafting of the EPL tendon using the extensor indicis proprius (EIP). When the client was seen in occupational therapy, her hand was extremely swollen and stiff, and she had severe extrinsic extensor tightness that limited full fisting. She developed complex regional pain syndrome and was treated successfully for this with a combination of stellate ganglion blocks and hand therapy. Note the dorsal scars and edema (Fig. 1-13, A). The style of chip bag incorporated into her volar wrist splint is shown in Fig. 1-13, B. This woman was a highly motivated client. At the time her therapy was discontinued, she had regained very good hand function.

**CASE STUDY 1-2**

A client who underwent surgery for release of a Dupuytren’s contracture developed a flare reaction. Note the incisional scar and fullness of the ulnar hand (Fig. 1-14, A), as well as the limitation in composite digital flexion (Fig. 1-14, B). This client used a chip bag inside an exercise splint designed to block the MPJs and promote PIP and DIP flexion exercise; the goals were to resolve intrinsic muscle tightness and promote composite digital flexion. Within 2 weeks, the client had made very good gains (Fig. 1-14, C).
FIGURE 1-14  

A, Flared incisional scar that developed after Dupuytren’s release surgery.  
B, Limited active composite flexion.  
C, Full active composite flexion 2 weeks later.
CASE STUDY 1-3
A woman who fell while hiking sustained a displaced distal radius fracture that required external fixation and percutaneous pin fixation. More than a week passed after her fall before she went to her physician. The woman explained this by noting that she has attention deficit disorder. She came to therapy 1 day after applying an elastic bandage tightly and irregularly around her external fixator. Note the indentations left on her skin by the wrap (Fig. 1-15, A). Chip bags were incorporated into the dressings and splints with external fixator and pins. The client progressed very well in therapy. She had good composite digital extension and flexion at the time of discharge (Fig. 1-15, C and D).

Soft Four-Finger Buddy Strap
A soft four-finger buddy strap can be made from Softstrap Velcro loop to provide transverse support that promotes more efficient primary function of the extrinsic flexors and extensors (see Fig. 1-21 on CD). This strap facilitates AROM for composite flexion and extension and for isolated extensor digitorum communis (EDC) and FDP tendon glide. It also stimulates lymphatic flow over the volar proximal phalanges, similar to chip bags. The soft four-finger buddy strap can relieve pain and promote AROM when hand stiffness is present. It also is helpful for symptom management in clients with lateral epicondylitis (tennis elbow) who have EDC involvement and pain on fisting.21

EXERCISES FOR UPPER EXTREMITY THERAPY
Precaution. Shoulder stiffness can develop insidiously and can be very limiting.

Check the client’s posture and proximal motion initially and then at intervals. Incorporate proximal AROM into all home exercise programs, even if this is only a preventive measure (see Chapter 10).

Shorter, milder sessions of exercise performed more frequently are better than longer, intensive sessions done less often. Some clients do well at first, performing 5 repetitions 5 times a day and gradually building to 10

FIGURE 1-15  A, Indentations made by a tight elastic bandage applied by the client. B, Chip bags incorporated into dressings and splints with external fixator and pins. C and D, Resolution of edema and active digital extension and flexion at discharge.
repetitions hourly during the day. Explain that exercises work well if the process is brief and frequent.

When working on isolated wrist extension, be sure to isolate the extensor carpi radialis brevis (ECRB) and teach clients how to extend the wrist with a soft fist that includes MP flexion. Have them hold an object so that the MPs are flexed. It is critical to retrain the ECRB to perform wrist extension. Without this isolation of motion, the client may learn to extend the wrist with EDC substitution instead of using the ECRB.

Teach the client that one way to do this is to keep a towel roll pressed to the side of the body with the arm used to perform forearm rotation exercises, because this requires that the elbow be kept close to the body.

In some cases, AROM through functional activity and exercise may be all that is needed to enable the client to recover full UE flexibility and function. When more isolated and structure-specific exercises are needed, the exercises discussed in the following sections may be helpful.

Blocking Exercises

Blocking exercises are exercises in which proximal support is provided to promote isolated motion at a particular site. They are helpful for clients with limitation of either AROM or PROM or both. Blocking exercises exert more force than nonblocking exercises.

CLINICAL Pearl

Once established, the habit of extending the wrist with EDC substitution can be very hard to break.

To work on wrist active/active assistive range of motion (A/AAROM), put a towel on the table and then place a coffee can (no bigger than the 3 lb size) on its side on the towel. Teach the client to place the involved hand on the can and to use the other hand to hold the involved hand flat on the can. The client then rolls the can using A/AAROM forward and backward. Clients like the feeling of this exercise, which also promotes proximal ROM and stimulates lymphatic flow.

In contrast to this, if extrinsic flexor tightness is a problem, the client would perform exercises involving wrist extension with simultaneous digital extension. Otherwise, exercises for wrist extension should be done primarily with a fist that includes MP flexion.

Always look at the client’s wrist position when exercising the digits. Do not exercise or coax the digits into flexion with the wrist flexed unless you are deliberately trying to stretch the extrinsic extensors. It is biomechanically easier to achieve digital flexion with the wrist in extension, to achieve PIP joint flexion with the MP extended, and to achieve PIP joint extension with the MP flexed. If the client cannot sustain a position of wrist neutral or extension, use a splint or have the client self-support the wrist using the other hand when digital exercises are performed.

Instruct clients always to keep the upper arm locked at the side of the body when performing forearm rotation exercises.

CLINICAL Pearl

Do not perform forearm rotation exercises with the elbow on a table or even on a pillow; this prevents isolated forearm rotation and allows for substitution with humeral motions.

CLINICAL Pearl

With blocking exercises, instruct the client to hold the position at comfortable end-range for 3 to 5 seconds; this allows remodeling of the tissues.

Blocking exercises can be accomplished in a variety of ways. You can use either commercially available devices or individual devices made from scraps of splinting materials. Digital gutters or cylinders that cross the IPs help isolate MP flexion and extension. If the cylinder is shortened to free the DIP, then DIP blocking exercises can be performed. These exercises can be done with the MP in extension or in varying degrees of flexion. Often a client exerts too strong a contraction, and the PIP tries to flex within the blocking splint. Explain to the client that isolating motion to only the DIP requires a soft quality of effort so that the effort is not overridden by other structures. The biomechanical challenge to the FDP is greater when DIP flexion is performed with MP flexion than with MP extension. This positional progression can be used to upgrade the exercises.

CLINICAL Pearl

When a digital block is used to promote MP flexion of the small finger, it is very helpful to stabilize the small finger metacarpal.

The ring and small finger metacarpals are more mobile at their carpometacarpal (CMC) joints than are the index and long finger metacarpals. If the metacarpal
PART ONE Fundamentals

is supported by your hand or the client’s other hand, more effective isolated motion can occur at the MP joint. This isolation and proximal support can be very helpful for clients trying to recover MP flexion after a small finger metacarpal fracture.

A blocking splint with the MPs flexed helps isolate active PIP flexion (Fig. 1-16). Extending the PIP is easier biomechanically when the MP is flexed, because this position promotes central slip function. This same blocking splint also promotes composite flexion exercise and can be helpful for normalizing extrinsic extensor tightness. Conversely, a blocking splint with the MPs extended (Fig. 1-17) helps to isolate active IP flexion and FDP excursion and to resolve intrinsic tightness. These types of splints can be used with function, or they may be used only for exercise.

A DIP cap or flexion block diverts FDP excursion to the PIP and thus promotes isolated exercise of the FDS muscle with MP and PIP flexion and DIP extension. This blocking device may also help the client exercise the flexor digitorum superficialis (FDS) fist position more easily (see following section).

Differential Flexor Tendon Gliding Exercises

Differential flexor tendon gliding exercises are a mainstay of most home programs because they are easy to perform and they promote motion very effectively (Fig. 1-18). They are a standard exercise for conservative management of carpal tunnel syndrome and are also used after carpal tunnel release. These exercises are an important option for all clients with hand or wrist stiffness. Rolling a thick highlighting pen up and down in the palm is an effective way to perform FDP gliding.

Place and Hold Exercises

Place and hold exercises can be helpful when PROM is greater than AROM (Fig. 1-19). Gently perform AAROM to position the finger (e.g., in composite flexion). Then ask the client to sustain that position comfortably while releasing the assisting hand. The assisting hand may be yours or the client’s other hand. Watch for co-contraction or force that is too strenuous as the client tries to sustain the exercise position. A combination of blocking exercises and place and hold exercises can be very productive. Also, you can try doing place and hold exercises with a blocking splint in place.

When the client releases the sustained contraction, pain sometimes may be felt in the area of a stiff joint. For instance, if the client performs place and hold exercises for composite fisting and then has PIP joint discomfort when releasing the fist, have the client relax the muscle contraction but stay in the same fisted position. While the client stays in that position, gradually provide assistance to gently begin extending the digit or digits (minimal joint distraction mobilization also can be helpful if not contraindicated). Next, ask the client to slowly actively extend the digits the rest of the way. This technique can be helpful for eliminating pain associated with end-ranges and AAROM.

Resistive Exercises

After clients have been medically cleared for them, resistive exercises are used for strengthening and to improve excursion of adherent tissue. Sometimes clients want to use a greater load than is safe for them. Teach clients that, for isolating wrist curls, they should not use as heavy a weight as they would for biceps curls.

Precaution. Think carefully and critically about the status of your client’s wrist if the person is recovering from a fracture, has had tendonitis, or is at risk for degenerative joint changes. Be very careful with wrist radial and ulnar deviation strengthening exercises, because these may provoke tendonitis.
FIGURE 1-18  Differential tendon gliding exercises.  


FIGURE 1-19  

Generally speaking, the safest course in performing resistive exercises is to use more repetitions with a lower load. This approach promotes endurance. (A more detailed discussion of resistive exercise is presented in Chapter 4.)

Resistive exercise can take many forms, including progressive resistive exercises (PREs) and exercises performed with graded grippers, rubber bands, squeeze balls, graded clothespins, and putty. For example, marbles or other objects can be embedded in putty, requiring pinch and dexterity to remove them.

**Functional Activity**

It is essential that the client incorporate the gains made from exercising into functional UE use at home and at work. Practicing or simulating relevant activities in the clinic can reinforce this. Examples of such activities may include tying shoes, folding clothes, manipulating coins, writing with an adapted pen, using the involved hand for handshakes, hammering, using screwdrivers, or lifting. Putty can be used to simulate activities such as turning keys. Adding visualization to the simulation enhances the treatment. The scope of practice for either occupational therapy or physical therapy dictates some of these choices.

Ball rolling can be used for wrist AROM, composite stretching, weight bearing, and closed chain exercise. The ball can be dribbled or thrown for strengthening or sports simulation. Balloons can also be thrown or batted with the hand.

Dried beans can be used for grip and release, for progressive gripping, and for fishing other objects (e.g., marbles) out of the beans. Instruct the client to grip the beans and then to release them with full digital extension. Wrist motions can be varied, and tenodesis can be incorporated. You also can have the client use opposition of the thumb to each finger to pick up one bean and then release it with full digital extension.

Pegs of varying sizes promote tendon gliding, sensory stimulation, and joint ROM. Fine motor activities (e.g., threading beads, in-hand manipulation of marbles, stacking blocks) can be modified with blocking splints to promote isolated ROM or tendon glide.

**TIPS FROM THE FIELD**

- Look at all your clients and their hands with interest and curiosity. For example, what do you see in Fig. 1-20? See the CD for the answer.
- Be tender when you touch your clients. If your hands are cold, try to warm them up a bit before you touch the person.
- Remember that you do not have to evaluate and treat everything on the first visit.

- Never yell at or order a client to “Relax.” Instead, encourage relaxation with a calm, slow voice.
- Working on one area of stiffness sometimes can also resolve stiffness in another area.
  - **Example:** A client who sustained a distal radius fracture had limited AROM and PROM in wrist flexion and extension and decreased ECRB excursion (i.e., passive wrist extension exceeded active wrist extension). Stretching led to improved wrist flexion. It also helped reduce ECRB adherence, which resulted in improved wrist extension.
  - **Example:** A client had extrinsic flexor tightness after a distal radius fracture with edema and decreased wrist and hand AROM. As her extrinsic flexor tightness resolved (she recovered full passive composite extension), the active digital flexion also resolved because she had better mechanical function of the lengthened digital flexors.
- Keep the timeline open for more progress by not performing painful therapy and by avoiding a flare reaction.
- As a hand therapist, you won't be able to resolve every problem in every case. If prolonged, established stiffness is present, if the client has highly fibrotic tissue responses, or if client follow-through has been poor, residual limitations may exist that are beyond our ability to correct.
- Document explicitly if poor client follow-through is a factor. For example, a client was carrying a glass table, which broke; the client received a laceration to his right-dominant forearm. Several flexor tendons and the median and ulnar nerves also were lacerated. The client missed many
therapy visits and did not perform his Duran home program (see Chapter 16). The client returned to therapy with very poor passive digital flexion, severe edema, and skin maceration. In this case, documentation would include the following: “The patient had been instructed to perform hourly protected passive digital flexion within his splint, but he reports that he did not do so. He states he understands the need to exercise as instructed. He also states he understands that if he does not gain passive digital flexion soon, he may lose the opportunity to make maximum clinical gains.” If appropriate, the progress note to this client’s physician should report that the patient now agrees to increase the frequency of home exercise program (HEP) exercises, as he was previously instructed to do.

- If a client is not following through as instructed, it is important to investigate why this is happening and to work with the client to correct the situation. Clients can have a number of reasons for failing to follow their regimen. They may be uninformed about the importance of the HEP; they may think they can catch up and make progress later; they may have a secondary agenda, such as avoiding a return to work; they may be depressed; or they may need help to assimilate the HEP into their daily routine successfully. (See Chapter 7 for more information on functional somatic syndromes and challenging behaviors.)

- Help clients learn to be patient. Encourage them to continue with their home program and to celebrate small improvements. Assist them in finding meaningful ways to use their time (e.g., find new interests and hobbies) if participation in an enjoyable activity has been temporarily disrupted.

- Replenish your own reserves so that you have the resources needed for complicated clinical situations (see Chapter 8). Give yourself a few moments to take some deep breaths and focus on the client as a person. Try to sense what it must be like for the client to have this injury. Carefully check for extensor habitus, which is habitual posturing in digital extension. The index finger is particularly prone to this response. Extensor habitus can occur after an injury as simple as a paper cut. It is important to identify this phenomenon and to correct it as soon as possible so that it does not become permanent and so that joint stiffness does not occur. Buddy straps and splinting may be helpful.

- Take one day at a time with the therapy. Do not presume that you will pick up where your last session left off. Look at your clients with fresh eyes at each visit. Ask them what is better, what they are noticing about their hands, what they are able to do functionally now, and what they are still unable to accomplish functionally.

THINKING OUTSIDE THE (TREATMENT) BOX

When to Mix and Match

Mix and match your treatment repertoire. After reading the rest of this book, try to think outside the treatment box. Be creative and have some fun. For example, why not perform early protective motions (e.g., place and hold tenodesis motions described in Chapter 22) with most of your patients?

When Less is More

Teaching your client the benefits of a “less is more” approach to UE exercises is very important. For example, a 12-year-old girl underwent flexor tendon grafting. In therapy, when trying to isolate FDP motion at the DIP with the PIP blocked, she was co-contracting and eliciting PIP flexion instead. The therapist taught her to contract more softly so as to isolate the FDP more effectively. The therapist used some helpful verbal cues, such as “Don’t try so hard,” “Stop trying altogether,” and “Stop thinking.” The therapist gave these cues in a soft, gentle voice and made sure to compliment the girl and smile when her isolated motion was of better quality. This activity was followed by place and hold exercises, which progressed successfully. Even though this client was very young, she learned the quality of isolated motion well, recognizing that “less is more.” She also could see the improvement in her capabilities.

When to Stop Exercising for a Few Days

Another important lesson to teach clients is when to stop exercising for a short time. For example, a 53-year-old, right-dominant woman sustained a distal radius fracture when she fell while shopping. She developed significant, diffuse edema and stiffness of the shoulder, elbow, forearm, and hand. This client demonstrated objective signs of a flare response after efforts were made to upgrade her exercises gradually. She was at risk for IP flexion contractures of all digits. Her sisters came to visit her, and they all went to a spa for 4 days. During this time, the client stopped performing her assigned UE exercises while she pampered herself at the spa. When she came back to therapy, she had diminished flare responses, decreased edema, and improved ROM throughout the upper extremity. It helped her immensely to stop trying so hard. She was then able to resume “trying,” but with a better sense of her tissue tolerances.
When to Accept a Stiff Hand and Get On with Life

Unfortunately, hand therapists cannot fix everything. In some cases, the client’s injuries may be too severe to permit a full recovery. In other cases, a family crisis may prevent therapy from continuing in a timely manner. Under circumstances such as these, the client’s best course of action is to accept the residual stiffness or limitations and to resume otherwise normal living. In such cases, therapists can perform the important role of identifying and teaching compensatory techniques to maximize the client’s function. Also, sometimes the therapist has the responsibility to identify a clinical plateau and to help clients realize that they may have achieved all that is possible at that time.

SUMMARY

This chapter has identified fundamental hand therapy concepts that foster clinical reasoning. It also has highlighted treatment techniques and provided guidelines to promote interventions that are safe and appropriate. Most treatment techniques are not diagnosis specific, but rather can be applied to a variety of diagnoses. As a hand therapist, the challenge you face is to be tissue specific, to be aware of clinical precautions, and to adapt the appropriate treatment from your toolbox of techniques to a given diagnosis. As you continue with this book, I encourage you to ask yourself what interventions would be most appropriate and why. I also recommend that you return to this chapter and reread it after you have read the rest of the book. Rereading this chapter at that time will help you appreciate what you have learned; that, hopefully, will be how to apply clinical reasoning in selecting safe treatment choices for clients with many different diagnoses.

Acknowledgments

I wish to thank Sandra M. Artzberger, MS, OTR, CHT, CLT, for reviewing this chapter and for providing me the impetus to explore chip bags in conjunction with upper extremity splinting; Patricia Zarbock Fantauzzo, COTA/L, for her creative ideas for using chip bags on clients with upper extremity problems; and Joel Moorhead, MD, MPH, John L. Evans, BS, Lisa Deshaies OTR, CHT, and Sharon Flinn, PhD, OTR/L, CHT, CVE, for reading and critiquing this chapter.

References


An understanding of normal anatomy is essential to the treatment of common upper extremity (UE) disorders. Without the ability to recognize the effects of impairment on the functional demands of our clients, we cannot fully assist them in their recovery efforts. Occupational and physical therapists learn the basic anatomy and neurophysiology of the upper extremity. However, courses in gross anatomy and neurophysiology frequently entail rote memorization of terminology, origins, insertions, nerves, and actions. Hand therapy practitioners need to take the next step in organizing this introductory knowledge of the human body. A presentation of UE anatomy in nontraditional views can assist you in making meaningful connections in the ways the upper limbs operate as a kinematic chain; it also can help you to realize the delicate balance between form and function and to meet the educational needs of your clients.

To further enhance your clinical reasoning skills, this chapter presents a series of scenarios, along with questions and illustrations. These will facilitate your overall reasoning processes with regard to the upper extremity. This line of discovery can help you to appreciate the complexity of the upper extremity and to reflect on the dynamic relationship of various anatomic systems. An anatomic review of the upper extremity begins with the proximal structures and concludes with a review of the distal anatomy. More detailed discussions of specific anatomic features, such as joint function, the lymphatic system, dermatome levels, sensory distributions, and pulley mechanisms for flexor tendons, are provided in other chapters of this book.

**SCENARIO 1**

**How Does Proper Cervical Alignment Facilitate Normal Functioning of Blood Vessels and Nerve Roots?**

Proper cervical alignment is necessary for sound neurologic and vascular function in the shoulder, arm, and hand. Symptoms of cervical misalignment may appear distal to the primary injury site and manifest as sensory, motor, or autonomic dysfunction. A thorough understanding of the workings of the cervical spine is necessary to identify the source of injury in some clients with symptoms along the upper extremity. Educating the client in appropriate cervical posture patterns is part of an effective intervention and improves UE rehabilitation outcomes.

The relationships of bones, ligaments, disks, vasculature, and nerves provide the cervical spine with valuable mobility that other segments of the spinal column do not have. The cervical spine supports motions of the head, which consist of rotation from side to side, flexion and extension, lateral flexion to each side, and all the motions in between. The locations of the spinal components are designed to provide increased mobility at the cervical level; however, their anatomic relationships also make them vulnerable to injury. Disorders arising from misalignment of the cervical spine can result in conditions that impair UE function (Table 2-1).

Proper cervical alignment of vertebrae, muscles, and soft tissue provides for normal conduction and excursion of nervous tissue in nerves C1-C8. Proper alignment of these structures also provides for normal blood flow in
the vertebral artery and the vertebral and deep cervical veins, ensuring adequate blood flow and drainage for the cervical structures related to UE function. The anterior rami of nerves C5-T1 form the brachial plexus, which innervates the entire UE (Fig. 2-1).4

The neurovascular bundle can become frequent or constant and somewhat unrelenting. Fig. 2-2 shows common claviculocostal sites of increased neurovascular pressure with upper body movement. The symptoms that occur at these sites often are referred to as thoracic outlet syndrome.

Therapists must always keep in mind that increased neurovascular tension, over time, can lead to compression. Tension occurs with normal upper body movement. If the movement becomes repetitive over time, long-term compression occurs. The effects of upper body movement on neurovascular structures are presented in Table 2-2. Many other upper body and UE sites are prone to neurovascular compression arising from poor posture, injury, and/or muscle imbalance caused by weakness or malnutrition.

The glenohumeral joint depends on the rotator cuff muscles, rather than bones or ligaments, for its support.5 The rotator cuff muscles include the subscapularis,
**FIGURE 2-1** Diagram of the brachial plexus. The small nerve to the subclavius from the upper trunk is omitted. (From Jenkins DB: Hollinshead's functional anatomy of the limb and back, ed 8, Philadelphia, 2002, WB Saunders.)

**TABLE 2-2** Neurovascular Symptoms Associated with Upper Body Movement

<table>
<thead>
<tr>
<th>BODY PART</th>
<th>MOTION</th>
<th>RESULT</th>
<th>SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td>Depression</td>
<td>Peripheral nerve: Stretching of upper and middle trunks of brachial plexus over scalene muscle; pulling of lower trunks into angle formed by first rib and scalene tendon. Blood vessel: No compression of subclavian artery.</td>
<td>Numbness and pain, particularly over ulnar distribution; pain worse at night because of positioning; intensity fluctuates throughout the day; arm fatigue, weakness, finger cramps, tingling, numbness, cold hand, areas of hyperesthesia, atrophy, tremor; and/or discoloration of hand.</td>
</tr>
<tr>
<td>Retraction</td>
<td></td>
<td>Peripheral nerve: No compression</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abduction and retraction</td>
<td>Blood vessel: Compression of subclavian vein by tendon of subclavian muscle, not by clavicle.</td>
<td></td>
</tr>
<tr>
<td>Scapula</td>
<td>Retraction</td>
<td>Peripheral nerve: Compression of brachial plexus at point where it passes between clavicle and first rib. Blood vessel: Compression of subclavian artery at point where it passes between clavicle and first rib.</td>
<td></td>
</tr>
</tbody>
</table>
The supraspinatus, infraspinatus, and teres minor muscles. The glenohumeral joint is a ball-and-socket synovial joint that moves in multiple axes. The motion of the glenohumeral joint provided by the rotator cuff muscles is related to the angle of pull of each muscle. Table 2-3 presents the locations and motions of the rotator cuff muscles. 

Besides providing the primary motions of the glenohumeral joint, the rotator cuff muscles act as part of force couples. For instance, the deltoid and supraspinatus muscles work as a force couple to produce glenohumeral abduction or flexion. The deltoid and teres minor muscles work as a force couple to produce depression and stabilization of the humeral head. Another force couple, the deltoid muscle and the rotator cuff muscles, produce depression of the humeral head and flexion of the humerus. The therapist also must keep in mind the impact of forces and how the impact may change with different positions or postures. For instance, painting a ceiling requires glenohumeral stabilization and flexion proximally—but how do the forces change when the position is held for an extended period with the cervical spine extended? The therapist must look at the entire system, not just the isolated motion of shoulder flexion, in such cases.

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Scenario 4

If you were to perform a manual muscle test by assessing nerve function, which muscles would be evaluated for the median, the ulnar, and the radial nerve distributions? Why would it be useful to evaluate these muscles by this grouping?

Manual muscle tests frequently are performed by evaluating the synergistic action of muscle groups, such as wrist extension or finger flexion. However, manual muscle testing can be a valuable tool for viewing muscle function from other perspectives. A new therapist may identify unrecognized impairments of the upper extremity caused by muscle imbalances arising from a condition such as peripheral neuropathy.

The findings of a manual muscle test are more precise when the test involves muscles innervated by various nerve distributions. Fig. 2-3, A, shows the distribution of the muscles associated with the axial and radial nerves. It is important to note that more than finger, as well as wrist extension, can be involved in impairments in this area.
area, especially with trauma to the nerve proximal to the elbow, such as in the midhumeral or brachial plexus regions. The muscles evaluated should include wrist and finger extensors and the muscles responsible primarily for elbow extension, elbow flexion with the forearm in mid-position (i.e., forearm in neutral position), supination, and thumb extension/abduction.

The same approach can be used to identify the muscles innervated by the median nerve (Fig. 2-3, B). Note that the pronator teres and several extrinsic muscles (muscles that originate outside the hand and have tendons that cross the wrist) are innervated by the median nerve. In some cases the musculotendinous units can cross the elbow, forearm, wrist, fingers, and thumb. The median nerve also innervates several intrinsic muscles (muscles that originate in the hand). These muscles potentially may provide movement to the thumb, index finger, and middle fingers. Fig. 2-3, C, shows the muscles innervated by the ulnar nerve. Motor function is supplied to a wrist flexor, finger flexors to the ring and little fingers, and to many intrinsic muscles of the fingers and thumb. Delineating patterns of weakness based on nerve distribution presents a picture of function very different from that obtained from a generalized manual muscle test.

**SCENARIO 5**

If You were to Identify the Muscles That Originate on the Lateral and Medial Epicondyles, Which Muscles would They be? Why would it be Useful to Evaluate These Muscles by This Grouping?

Even though all muscles that originate from the lateral epicondyle are innervated by the radial nerve, a different picture of function can be obtained by evaluating each muscle individually. Evaluating each individual muscle in this grouping can be useful because these muscles commonly are overused, and they may require a longer recovery time than muscles surrounded by sheaths that bathe them in cooling lubricants.

When you test the muscles that originate from the lateral epicondyle, keep in mind that full joint motion, muscle and connective tissue pliability, and muscle strength are critical for full function. Muscle insufficiency occurs when the full length of a muscle is compromised; this can result in limited range of motion for many joints and reduced muscle strength. A knowledge of the origin of a muscle and the joints it crosses from origin to insertion is critical to understanding the function of that muscle. For example, to obtain a full passive stretch of the extensor digitorum communis muscle, the elbow must be extended, the forearm must be pronated, the wrist must be flexed, and the fingers must be in a fist.

The muscles that originate from the lateral epicondyle, their origin, their action, and the positions in which full musculotendinous flexibility can be achieved are presented in Table 2-4.7

The muscles that originate from the medial epicondyle present a different picture of function (Table 2-5). These muscles all are innervated by the median nerve except for the flexor carpi ulnaris muscle, which is supplied by the ulnar nerve. Despite the different nerve innervations, the same principles apply for stretching these muscles as were suggested for the muscles originating from the lateral epicondyle. For example, to obtain a full passive stretch of the flexor digitorum superficialis, the elbow must be extended, the forearm must be supinated, the wrist must be extended, and the fingers must be in a fully extended position.

**SCENARIO 6**

If You were to Check the Excursion of the Extensor and Flexor Tendons to the Fingers, You would Find That the Location and the Type of Supportive Structures Affect Movement in What Ways?

You have learned that a muscle, such as the extensor digitorum communis, can cross the elbow, forearm, wrist, and fingers. In addition to these anatomic descriptions, a classification system has been developed to identify the location of the extensor tendons, as well as other structures that can affect tendon gliding. The seven zones of the extensor tendons to the fingers and thumb are presented in Fig. 2-4. In the most proximal zones (zones VI and VII), which is made up of the dorsum of the hand and wrist, the influence of an extensor tendon crossing multiple joints is important. Within this area, other important contributors to the function of extensor tendon gliding are the six compartments created by the deep layers of the dorsal fascia. Fig. 2-5 shows the tendons in each of the numbered dorsal compartments of the wrist. Testing the independent movement of each extensor tendon by compartment provides a picture of the effectiveness of tendon excursion through the dorsal pulley system and can supplement the findings of a more generic range of motion or manual muscle test.

Similarly, an appreciation of the extensor tendons to the fingers in zones I through V provide a different perspective on the way location can affect function. In Fig. 2-6 the extensor mechanism of a finger proximal interphalangeal (PIP) joint is presented in a dorsal view and in a lateral view with digital metacarpophalangeal (MP) joint flexion and extension. This shows the balance that must be achieved between the intrinsic and extrinsic muscle groups to allow full extension of a digit.
## Table 2-4

Muscles Originating from the Lateral Epicondyle

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>ORIGIN</th>
<th>ACTION</th>
<th>POSITION FOR FULL MUSCULOTENDINOUS FLEXIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anconeus</td>
<td>Lateral and posterior surfaces of proximal half of body of humerus, and lateral intermuscular septum</td>
<td>Extends the elbow</td>
<td>Elbow flexion, forearm pronation</td>
</tr>
<tr>
<td>Brachioradialis</td>
<td>Proximal two thirds of lateral supracondylar ridge of humerus and lateral intermuscular septum</td>
<td>Flexes the elbow, assists with pronating and supinating the forearm</td>
<td>Elbow extension, forearm pronation or supination</td>
</tr>
<tr>
<td>Supinator</td>
<td>Lateral epicondyle of humerus, radial collateral ligament of elbow joint, annular ligament of radius, and supinator crest of ulna</td>
<td>Supinates the forearm</td>
<td>Elbow extension, forearm pronation</td>
</tr>
<tr>
<td>Extensor carpi radialis longus</td>
<td>Distal one third of lateral supracondylar ridge of humerus and lateral intermuscular septum</td>
<td>Extends the wrist in a radial direction, assists with elbow flexion</td>
<td>Elbow extension, forearm pronation, wrist flexion in an ulnar direction</td>
</tr>
<tr>
<td>Extensor carpi radialis brevis</td>
<td>Lateral epicondyle of humerus, radial collateraligament of elbow, and deep antebrachial fossa</td>
<td>Extends the wrist, assists with wrist radial deviation</td>
<td>Elbow extension, forearm pronation, wrist flexion</td>
</tr>
<tr>
<td>Extensor carpi ulnaris</td>
<td>Lateral epicondyle of humerus, aponeurosis from posterior border of ulna, and deep antebrachial fossa</td>
<td>Extends the wrist in an ulnar direction</td>
<td>Elbow extension, forearm pronation, wrist flexion in a radial direction</td>
</tr>
<tr>
<td>Extensor digitorum communis</td>
<td>Lateral epicondyle of humerus and deep antebrachial fossa</td>
<td>Extends the metacarpophalangeal (MP) joints of the second through fifth digits; in conjunction with the lumbricals and interossei, extends the proximal interphalangeal (PIP) joints of the second through fifth digits; assists with abduction of the index, ring, and little fingers; and assists with extension of the wrist in a radial direction</td>
<td>Elbow extension; forearm pronation; wrist flexion; and MP, PIP, and distal interphalangeal (DIP) flexion of the fingers</td>
</tr>
<tr>
<td>Extensor digitorum minimi</td>
<td>Lateral epicondyles of humerus and deep antebrachial fossa</td>
<td>Extends the MP joint of the fifth digit; in conjunction with the lumbricals and interossei, extends the PIP joints of the fifth digit; assists with abduction of the fifth finger</td>
<td>Elbow extension; forearm pronation; wrist flexion; and MP, PIP, and DIP flexion of the little finger</td>
</tr>
<tr>
<td>MUSCLE</td>
<td>ORIGIN</td>
<td>ACTION</td>
<td>POSITION FOR FULL MUSCULOTENDINOUS FLEXIBILITY</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Pronator teres</td>
<td>Medial epicondyle of humerus, common flexor tendon, and deep antebrachial fascia</td>
<td>Pronates the forearm, assists with elbow flexion</td>
<td>Elbow extension, forearm supination</td>
</tr>
<tr>
<td>Flexor carpi radialis</td>
<td>Common flexor tendon of medial epicondyle of humerus and deep antebrachial fascia</td>
<td>Flexes the wrist in a radial direction; may assist with pronation of the forearm and elbow flexion</td>
<td>Elbow extension, forearm supination, wrist extension in an ulnar direction</td>
</tr>
<tr>
<td>Flexor carpi ulnaris</td>
<td>Common flexor tendon of medial epicondyle of humerus</td>
<td>Flexes the wrist in an ulnar direction; may assist with elbow flexion</td>
<td>Elbow extension, forearm supination, wrist extension in a radial direction</td>
</tr>
<tr>
<td>Palmaris longus</td>
<td>Common flexor tendon of medial epicondyle of humerus and deep antebrachial fascia</td>
<td>Tenses the palmar fascia, flexes the wrist, and may assist with elbow flexion</td>
<td>Elbow extension, forearm supination, wrist extension</td>
</tr>
<tr>
<td>Flexor digitorum superficialis</td>
<td>Common flexor tendon of medial epicondyle of humerus, ulnar collateral ligament of elbow, and deep antebrachial fascia</td>
<td>Flexes the proximal interphalangeal (PIP) joints of the second through fifth digits; assists with metacarpophalangeal (MP) and wrist flexion</td>
<td>Elbow extension; forearm supination; wrist extension; and MP, PIP, and distal interphalangeal (DIP) extension of the fingers</td>
</tr>
</tbody>
</table>

First dorsal interosseous
Extensor indicis proprius
Extensor pollicis brevis
Extensor pollicis longus
Extensor carpi radialis longus and brevis
Abductor pollicis longus
Extensor digitorum communis
Extensor digiti quinti proprius
Abductor digiti quinti
Extensor carpi ulnaris

**FIGURE 2-5** Arrangement of the extensor tendons in the compartments of the wrist. (From Fess EE et al: Hand and upper extremity splinting: principles and methods, ed 3, St Louis, 2004, Mosby.)

**CLINICAL Pearl**

To assess the contribution of the extrinsic muscles to PIP extension, stabilize the wrist and MP joints in extension; in this position, the power of the intrinsic muscles is minimized.

When the PIP joint is held in extension and the distal interphalangeal (DIP) joint is actively flexed, a passive stretch to the lateral bands is completed; this ultimately facilitates balanced extension between the PIP and DIP joints. A knowledge of the extensor tendon anatomy, the location of these tendons by zone, and the surrounding structures is an important component of the therapist’s skill in assessing conditions of the hand.

The finger flexors have similarities and differences with regard to the extensor tendons. Fig. 2-7 shows the five flexor tendon zones to the fingers and the three flexor tendon zones to the thumb. Flexor tendons located in zone V are located proximal to the carpal canal and are not subject to many of the challenges that affect the excursion of flexor tendons in other zones of the hand. Zone IV includes the structures in the carpal tunnel; Fig. 2-8 provides a cross-sectional view of the carpal tunnel anatomy. To examine the excursion of the flexor tendons at this level, start your assessment with the superficial tendons and progress to the tendons in the deeper compartments of the carpal tunnel. The flexor digitorum superficialis (FDS) to the middle and ring fingers is the most superficial structure, followed by the FDS to the index and little fingers, and finally the flexor digitorum profundus (FDP) to all the fingers. Two other compartments are contained within the carpal tunnel, the flexor pollicis longus and the median nerve, and the synovium that encases and lubricates the flexor tendons. Overall, isolating the excursion of these tendons by compartments can be useful, because more superficial injuries, such as burns, may have a greater effect on the FDS than would a deeper injury, such as a fracture to the distal one third of the radius.

Other considerations become evident in flexor tendon zones I through III. In zone III, the flexor tendons are not encased in a lubricating sheath, and injuries to the area may involve the lumbrical muscle. In zones I and II, the relationship between the FDP and the FDS changes. Before entering zone II, the FDP lies deep to the FDS. In zone II, the FDP passes through the decussation of the FDS (Fig. 2-9). Therefore isolating a tendon is very important to assess its excursion.
FIGURE 2-6  Extensor mechanism of the digits. The figure shows distal movement of the extensor expansion with metacarpophalangeal joint flexion. (From Fess EE et al: Hand and upper extremity splinting: principles and methods, ed 3, St Louis, 2004, Mosby.)
To test the FDP, support the PIP joint in extension to allow only DIP flexion. In this way, isolated range of motion exercises can be performed to facilitate the independent function of these two important flexor tendons to the hand.

**SCENARIO 7**

What are the Major Structures that Support the Wrist, Fingers, and Thumb? How Do They Change in Different Positions of Movement and How Do They Contribute to the Strength of the Wrist and Hand?

The collateral ligaments provide joint stability while functional activities occur within multiple planes of movement. Fig. 2-10 shows the ligamentous anatomy of the wrist. The palmar wrist ligaments provide support between the carpal bones. The dorsal wrist ligaments provide support between the carpal bones and the radius.

**CLINICAL Pearl**

When you test the FDS, eliminate the effects of the FDP by holding the DIPs of the nontested fingers in extension and allowing each individual finger to actively flex at only the PIP joint.
FIGURE 2-9 The flexor digitorum superficialis lies volar to the flexor digitorum profundus as the tendons enter the sheath. (From Schneider LH: Flexor tendon injuries, Boston, 1985, Little, Brown.)

The palmar radioscapophoid lunate ligament provides support for the radius, the scaphoid, and the lunate. The triangular fibrocartilage complex (TFCC) provides support between the carpal bones, the ulna, and the distal radial-ulnar joint. Each of the supporting structures is important for stabilizing the wrist in extreme ranges of wrist extension, flexion, radial deviation, and ulnar deviation. The stability of the joint affects more than just mobility; without adequate support on the ulnar border of the wrist, the amount of pinch strength can be diminished.

The collateral ligament is designed to ensure lateral support. When the MP joint is flexed, the collateral ligament lengthens to accommodate the movement; when the joint is in an extended position, the collateral ligament becomes slack. Essentially the opposite process occurs at the PIP joint. (See Chapters 15 and 23 for splinting implications related to collateral ligament length.)

In addition to the lateral support of a joint, volar reinforcement is provided through strong membranous connections with the collateral ligament. The palmar plates (also called volar plates) are slack in flexion but become taut when the joint is extended, thereby protecting the joint from hyperextension stress or dislocation.

The thumb has ligamentous supports at the interphalangeal (IP) joint, the MP joint, and the carpometacarpal (CMC) joint. The ulnar collateral ligament (UCL) of the MP joint is particularly noteworthy. The location of the UCL suggests the importance of this strong band of tissue in supporting pinch, especially lateral pinch. (See Chapter 15 for treatment implications related to the thumb MP collateral ligaments.)

SUMMARY

It is critical that therapists understand the roles and interrelationships of nerves, vascular systems, muscles, tendons, and ligaments in order to appreciate the mechanisms of hand function. Continuing study and application of knowledge are vital if you are to provide the level of rehabilitation expertise needed to help these clients recover from the devastating effects of injury, disease, and aging.
FIGURE 2-10  Ligamentous anatomy of the wrist. A, Palmar wrist ligaments. B, Dorsal wrist ligaments. C, Dorsal view of the flexed wrist, including the triangular fibrocartilage. 1, Ulnar collateral ligament; 2, retinacular sheath; 3, tendon of extensor carpi ulnaris; 4, ulnolunate ligament; 5, triangular fibrocartilage; 6, ulnocarpal meniscus homologue; 7, palmar radioscaphoid lunate ligament. P, Pisiform; H, hamate; C, capitate; Td, trapezoid; Tm, trapezium; Tq, triquetrum; L, lunate; S, scaphoid. (From Fess EE et al: Hand and upper extremity splinting: principles and methods, ed 3, St Louis, 2004, Mosby.)
CHAPTER 2 Upper Extremity Anatomy

Cord portion of collateral ligaments

Accessory collateral ligament

Palmar fibrocartilaginous plates

Collateral ligament (loose in extension)

Palmar plate

Membranous portion of palmar plate (folds in flexion)

Collateral ligament (tight in flexion)


References

Edema Reduction Techniques: A Biologic Rationale for Selection

SANDRA ARTZBERGER

KEY TERMS

Arteriole
Arteriole hydrostatic pressure
Collector lymphatics
Diaphragmatic breathing
Exudate edema
Filarisis
Hydrophilic
Indurated
Initial lymphatic
Interstitium
Lymph
Lymphatic bundles
Lymphatic capillary
Lymph nodes
Lymphangion
Lymphedema
Lymphorrhea
Lymphovenous anastomoses
Macrophages

Manual edema mobilization (MEM)
Manual lymphatic drainage (MLD)
Manual lymphatic treatment (MLT)
Oncotic pressure
Osmotic pressure
Phagocyte cells
Pump point stimulation
Starling's equilibrium
Thoracic duct
Transudate edema
Venule
Watershed areas

Editors Notes: Before the importance of Sandra Artzberger's work on the treatment of edema was recognized, the edema techniques that hand therapists were taught were not specific to the lymphatic system and sometimes even damaged this delicate and amazing part of the body. Artzberger has done much to delineate the anatomy and physiology of posttraumatic edema. She has changed our thinking and has overhauled the treatment...
repertoire, creating an approach that is based on science. Her technique of manual edema mobilization has resulted in much-improved management of edema in clients with upper extremity injuries.

Unlike in the past, the treatment of hand edema no longer needs to be partly a guessing game. Modern treatment selections are more firmly grounded in anatomic and biologic principles and therefore are more successful. To treat edema effectively, the therapist must know the difference between the lymphatic and venous systems, including the role these systems play in edema reduction. It also is essential that the therapist understand the different types of edema. This chapter describes acute, subacute, and chronic edema. It reviews vascular and lymphatic anatomy and biology, and it describes appropriate interventions for edema, including the technique of manual edema mobilization (MEM). Special emphasis is placed on the clinical reasoning involved in selecting the appropriate treatment.

The lymphatic system originates in the interstitium with the smallest of the lymphatic vessels, called the initial lymphatic or lymphatic capillary, and culminates in the largest lymphatic structure, called the thoracic duct. The venous system has a continuous-loop pump system, but the lymphatic system does not (Fig. 3-2). Therefore the lymphatic system must be stimulated to activate a force pump, creating a vacuum and drawing the lymph proximally. Initial lymphatics, which are larger than venules, are finger-shaped tubes that are closed on the distal end and lined with overlapping, oak leaf–shaped endothelial cells. Anchor filaments extend from the endothelial cells to the connective tissue. Movement of the connective tissue pulls on the anchor filaments. This, in turn, pulls on the overlapping flaps (junctions) of the endothelial cells, and water and large molecules are admitted into the initial lymphatic. Large molecules also enter the initial lymphatic when a change in the interstitial pressure causes the junctions of the endothelial cells to spread apart. The initial lymphatic connection forms a netlike structure (see Fig. 3-1).
The balance between fluid moving into and out of the vascular vessels on a cellular level, first described by Ernest Starling in the early 1900s, is called Starling’s equilibrium. This balanced movement of fluid functions as a gradient system from high to low pressure. On the capillary level, arteriole hydrostatic pressure (the pressure of the blood fluid exerted on the arteriole vessel wall) is 30 to 40 mm Hg, which is enough pressure to cause filtration of electrolytes, fluid, a few small plasma proteins, and other nutrients into the interstitium. The osmotic pressure (also called the oncotic pressure) in the interstitium is determined by the concentration of proteins in this intercellular space; this pressure is approximately 25 mm Hg. Tissue cells in the interstitium absorb the nutrients, electrolytes, and other substances filtered out of the arteriole. Of the remaining substances, 90% diffuse by osmosis into the venous system. The residual 10% of leftover substances are large molecules, which are absorbed by the lymphatic system. These large molecules consist of plasma proteins, minerals, ions, hormone cells, bacteria, fat cells, and fluid. Once the cells enter the initial lymphatic, they make up a substance called lymph (see Fig. 3-1).

**ACUTE EDEMA RELATED TO THE VASCULAR ANATOMY**

The venous and lymphatic systems have many pumplike structures that help propel the blood back to the heart. Because of the descending gradient of hydrostatic pressures from the arteriole capillary to the venule capillary, small-molecule substances diffuse easily and are reabsorbed into the venous capillary through its thin wall. Active muscle contraction acts as a pump as it compresses and empties the large deep venous vessels. As this blood is propelled proximally toward the heart, a negative pressure is created, which draws blood from the periphery into the deep veins.

Edema develops when the descending gradient of Starling’s forces are disrupted by an interruption and an imbalance. The cascade of events that occurs after tissue laceration is a good example. Initially, an outflow of water and electrolytes (transudate edema) into the wound occurs. The mast cells then release histamines, which greatly increase capillary permeability, and plasma proteins, phagocytic cells, and other substances leak into the area. Plasma protein fibrinogen is converted to fibrin, which plugs the endothelial cells lining the lymphatics. This prevents the lymphatics from temporarily removing the large molecules as the various phagocyte cells perform their “cleanup” function. Edema results when excess fluid and plasma proteins are trapped in the interstitium. Starling’s equilibrium is disrupted, because the trapping of excess proteins in the interstitium increases the osmotic pressure.

The immediate goal of treatment by physicians and therapists is to limit the amount of outflow into the wound bed, thereby preventing excessive swelling, accumulation of blood, and further tissue damage. After 2 to 5 days, the swelling begins to subside as the surrounding intact venous capillaries start to absorb the transudate and the lymphatic vessels absorb the large-molecule plasma proteins not phagocytized by the macrophages.

**Reduction Techniques for Acute Edema**

**Bulky Dressing**

Several techniques can be used to reduce excessive fluid outflow (edema). For example, a bulky hand dressing applied at the time of surgery gives counterforce to the outflow (filtration) by changing the tissue pressure. It is composed of appropriate wound care dressing, fluffy
pressure is increased along the lymphatic trunks. Ideally, preventing them from falling. For clients with finger replantation, elevation no higher than the heart is recommended. A pillow or two sets of pillows is pushed up against the wall, together. Also, the bed can be moved against the wall so that a belt can be fastened around the pillows to keep them together. Often clients use pillows on either side of them. A pillow or two can be placed under the involved extremity to support it. A plus 45-degree "ski hill" position; this means that pillows are placed such that the elbow is above the shoulder, and the hand is above the elbow and wrist.

Keeping the arm elevated while sleeping can be difficult. Often clients use pillows on either side of them. A belt can be fastened around the pillows to keep them together. Also, the bed can be moved against the wall so that one set of pillows is pushed up against the wall, preventing them from falling. For clients with finger replantation, elevation no higher than the heart is recommended to avoid compromising arterial blood flow.

Precaution. Extreme elevation of the right arm must be avoided in stroke clients with right-sided heart weakness. Extreme upper extremity elevation may cause fluid to flow too quickly into the right side of the heart, because the right upper quadrant is drained by the right lymphatic duct that empties into the right subclavian vein.

Cold Packs
Cold packs, if not contraindicated for vascular and tissue ischemia reasons, cause vasoconstriction and thus reduce the outflow of fluid in the acute stage. However, the temperature of the cold pack is a consideration. Research shows that when the temperature is lower than 59°F (15°C), proteins leak into the interstitium from lymphatic structures. Excess proteins in the interstitium cause edema.

Precaution. To prevent "ice burn" to tissue, always place a dry towel between the skin and the cold pack. Cold packs should not be used on a client with a replanted hand or digit because of the effect of vascular compromise on tissue viability. A nerve repair may be injured by cold postoperatively. Clients should get explicit care instructions from their physicians, including precautions on the use of cold packs.

Retrograde Massage
Light retrograde massage with elevation facilitates diffusion of small molecules into the venous system. The elevation reduces capillary filtration (outflow) pressure, and the light pressure from the retrograde massage aids in venous absorption of the small molecules.

Precaution. The pressure is kept light to avoid damaging the single-cell initial lymphatic structures in the dermal layer of the skin.

Compression
Light compression, such as from an elastic glove, Coban lightly spiral-layered on a digit (see Fig. 3-6, A, on CD), or low-stretch finger bandage wraps (see Fig. 3-6, B, on CD), facilitates small molecule absorption by the venous system and absorption of large and small molecules by the lymphatic system. A loose but compressive glove generally is one in which the glove material can be pulled away from the hand and fingers at least 1/8 inch (see Figure 3-6, C, on CD).

Precaution. An elastic glove should be fitted to give some compression but should feel loose on the hand and fingers. If the compression is too tight, fluid flow is restricted, which increases edema.

Kinesio Tape also promotes absorption of the large and small molecules in the interstitium because it increases the space between the skin and connective tissue (see Fig. 3-6, D, on CD). Increasing this space creates a pull on the connective tissue anchor filaments attached to the endothelial cells of the initial lymphatics; this separates the planted endothelial junctions, thereby increasing lymph and fluid flow.

Indications for Manual Edema Mobilization
Many wonder why MEM is not started in the acute stage. In 1989, Hutzschteuter and Brummer did a research study on this point using sheep. They compared the...
results in two groups, one in which manual lymphatic drainage (MLD) was performed and one in which it was not, over a defined period (i.e., immediate postoperative to 3 weeks postoperative). They found that both groups showed minimal fluid reduction during the first week after surgery. However, after the first week, the MLD group had a significantly greater increase in fluid movement and edema reduction than the control group. These results are not surprising because initially, acute edema is transudate that is changing to exudate edema as the plasma proteins invade and are contained. Only the lymphatic vessels can remove excess proteins from the interstitium. MEM and manual lymphatic treatment (MLT)* programs are designed to activate lymphatic vessels. A multicenter study compared the results of retrograde massage with those of MEM in clients with subacute edema from a wrist injury 4 weeks after injury. The study found that both groups showed improvement, but the MEM group showed statistically greater improvement in all but one category.

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Remember, edema at 4 weeks is subacute and has a high protein content. To be successful in these cases, reduction treatment must stimulate the lymphatics.

Some physicians prescribe proximal active motion of an extremity or gliding of the involved structures, or both, during the acute stage of wound healing. Proximal trunk and shoulder motion is excellent. It decongests the lymphatic vessels and removes tissue waste products, resulting in better oxygenation to tissue and faster wound healing. However, movement must be balanced with rest of involved structures. This is done by progressively grading the exercise so as not to increase hand inflammation, pain, and swelling. Always respect the fragility of healing tissue and vascular structures. When moving the involved structures, start with limited movement and check for signs of increased pain, swelling, or redness. If edema increases, rest the involved hand for a day (consider applying a static splint). Resume activity, but do less than previously and gradually increase the exercise over the next treatment sessions. I usually begin with the rule of three or five: three (or five) repetitions of an exercise three (or five) times a day. If this does not increase swelling, gradually increase repetitions or frequency, or both. Remember, edema and pain limit motion and retard progress.

*Manual lymphatic treatment is the generic term used to describe the massage principles common to all schools of lymphatic drainage.¹³

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Reducing edema is almost always the first priority; do this, and the client will gain motion.

In the early poststroke stages, hand and arm edema is a transudate swelling because fluid leaks into the interstitium as a result of lack of muscle pumping activity on the vascular vessels. Elevation, light retrograde massage, and light compression from an elastic glove or elasticized arm stockinette are effective treatments that promote diffusion of leaked electrolytes and water back into the venous system.

Precaution. When using an elasticized garment, observe two important precautions: (1) make sure it is not too tight (i.e., it does not cause color or temperature changes in the hand or digit) and (2) with elasticized stockinette, make sure it cannot roll down, causing swelling distally.

A body garment glue can be used to prevent the elastic stockinette from rolling down on itself, which can cause distal swelling. Keep in mind that some body garment glues are latex based, therefore always make sure your client does not have a latex allergy before using such a glue.

Summary of Reduction Treatment for Acute Edema

- Bulky hand dressing (usually applied by the surgeon postoperatively)
- High-voltage pulse current (HVPC) (used only for very acute edema; benefit in humans not yet proven)
- Elevation
  - Lesser degree of elevation is needed for replanted digits and/or hands.  
  - Extreme elevation is contraindicated if right-sided heart weakness is present (i.e., poststroke client).
- Cold packs (used in the first 24 to 48 hours only as directed by physician)
  - Cold packs should not be used for replants because cold causes vasoconstriction.  
  - Precautions should be clarified with physician if a nerve is involved.
- Light retrograde massage
- Loose elastic glove or elastic stockinette
- Coban (loosely placed on digit in spiral, distal-to-proximal pattern)
- Finger bandage wraps
- Limited active motion of uninvolved areas (excessive trunk/shoulder motion increases edema)
- Balance of activity and rest for all structures to prevent inflammation or increase in edema
SUBACUTE AND CHRONIC EDEMA RELATED TO THE LYMPHATIC ANATOMY

As mentioned earlier, the initial lymphatic capillary (initial lymphatic) is the lymphatic system’s smallest structure. The initial lymphatic is not connected to the venous or arterial system. As described previously, the initial lymphatic is composed of finger-shaped tubes that are closed on the distal end and lined with overlapping, oak leaf–shaped endothelial cells; these tubes are connected to each other in a netlike structure in the dermal layer of the skin (see Fig. 3-1).1-4 The lymphatic system is also a negative-pressure pump system that absorbs large molecules out of the interstitium ending in the venous system at either the right or left subclavian vein.

The lymphatic system does not have a continuous pump system, such as the venous system and the heart (see Fig. 3-2). Also, unlike with venous capillaries in the interstitium, molecules do not diffuse into the lymphatic capillary. Rather, large molecules that cannot permeate the venous system are absorbed into the initial lymphatic when pressure changes in the interstitium cause the junctions of the endothelial cells to spread apart.2,3 Then the large molecule substances (plasma proteins, fat cells, bacteria, hormones, tissue waste products, ions), and the small water molecules move into the lymphatic capillary.1,2,8 This arrangement is often called a force pump.8

As lymph enters the initial lymphatic, it causes pressure changes that open the valve connected to the next lymphatic vessels, the three-celled collector lymphatics (Figure 3-3). Clinically, the most important features of the tubelike collector lymphatics are a middle layer of muscle cell and the presence of valves every 6 to 8 mm along the tube.1,5 The chamber between two valves is called a lymphangion.7 As a bolus of lymph enters a lymphangion, the single layer muscle cell contracts against the expanding lymphangion and pushes the bolus proximally into the next lymphangion (Fig. 3-3). This process continues until the bolus reaches the afferent lymphatic pathways of the lymph node.

The pumping movement of the lymphangions resembles the peristaltic movement of the small intestine. The lymphangions pump at a rate of 10 to 20 times per minute,1 and exercise can increase this pumping motion by 10 to 30 times.1 Recent theories hold that peristalsis also creates a negative pressure that opens the junctions of the endothelial cells, enabling large-molecule substances to move from the interstitium into the initial lymphatic.1

Eventually the bolus of lymph moves into the afferent lymphatic pathways of the lymph nodes. Lymph nodes, which perform several immunologic functions, are composed of a series of complex sinuses and therefore often are considered “dams” or “kinks in the hose” in the movement of lymph. Excessive swelling distal to the lymph nodes does not increase their rate of filtration, but rather causes further congestion distally.8 Venous vessels do not connect to lymph nodes and therefore do not

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Exercise moves lymph faster through the collector lymphatics and increases the rate of lymphatic uptake from the interstitium.

reflect this slowing of fluid movement. Also, venous vessels do not carry bacteria or tissue waste products and therefore do not pass these substances through the lymph nodes for cleansing. Lymph nodes present significant resistance to the flow of lymph and must be massaged to facilitate a faster flow of the distal congested lymph. The MEM method of massaging healthy and uninfected nodes or uses MEM pump point stimulation, which is a method of simultaneously massaging two groups of nodes, bundles of lymphatic vessels, or watershed areas, which speeds up the movement of lymph through the nodes.

From the nodes, lymph can enter the venous system directly, through lymphovenous anastomoses (areas where the small vessels of the lymphatic and venous systems join), or it can continue on in the lymphatic vessels and empty into either the right lymphatic duct or the largest lymphatic vessel, the thoracic duct. The thoracic duct lies anterior to and parallel with the spinal cord from approximately L2 and empties into the left subclavian vein. The right lymphatic duct terminates in the right subclavian vein.

The movement of lymph in the thoracic duct is affected by changes in thoracic pressure. Diaphragmatic breathing expands the abdomen, causing changes in thoracic pressure that move the contents of the thoracic duct more proximally. This action creates a vacuum, drawing lymph from the more distal vessels toward the thoracic duct. Treatments such as MEM, therefore, begin with diaphragmatic breathing and trunk exercise. This is analogous to removing the plug from a drain or a clog from a backed-up sink. The clog must be removed before the water can flow out. In terms of clinical application, the vacuum created by diaphragmatic breathing moves lymph more proximal in the thoracic duct, creating a space into which the more distal peripheral edema can move.

"Exercise is key to lymphatic activation"—this is a frequently quoted statement. Yet therapists know that in most cases, simply exercising the edematous hand or arm in the subacute phase does not significantly or permanently reduce edema. Lymphatic structures can exceed 30 times their normal capacity before edema becomes visible; this means that proximal to the visible edema is the beginning of nonvisible edematous congestion.

Exercise and light massage significantly proximal to the visible edema create a negative pressure, drawing lymph proximally and thus removing the "clog." The results of research by Pecking and colleagues present a strong argument for stimulating lymphatic absorption and conduction significantly proximal to visible edema. In these researchers' study, MLD was performed exclusively to the contralateral, normal upper quadrant on 108 women with lymphedema caused by mastectomy; this resulted in a 12% to 38% lymph uptake in the hand, even without massage of the involved area. The contralateral massage created a negative pressure (vacuum), drawing the lymph from the involved to the uninvolved area, where it could be absorbed into the normal system.

If we synthesize these findings with the theory that changes in thoracic pressure move lymph proximally, and add the knowledge that muscle contraction stimulates lymphatic uptake on many levels, we arrive at a very strong rationale for beginning edema reduction at the trunk even if edema is visible only in the hand. Clinically, this means that therapists should not begin edema reduction treatment where edema is visible; rather, they must begin in a normal, uninvolved area significantly proximal to the visible edema. Appropriate treatments include diaphragmatic breathing, trunk stretching and muscle contraction exercises and activities, and MEM massage that begins in the area of the uninvolved axilla. (MEM is discussed in more detail later in the chapter.)

**Reduction Techniques for Subacute and Chronic Edema Based on the Lymphatic Anatomy**

To review, the lymphatic system is an independent pump system that works on a negative pressure gradient. When lymph vessels fill (high pressure is created), lymph moves to an area of lower pressure.

The two keys to activating the lymphatic system are as follows:

**CLINICAL Pearl**

The sooner lymphatic decongestion occurs, even with non-visible edema, the less the chances of developing tissue and scar thickening, fibrosis, and contractures.

Before they reach the thoracic duct, the deep lymphatic trunks share a common vascular sheath with the venous and arterial structures. Therefore exercise increases the rate of arterial flow and passively stimulates the lymphatic vessels, increasing the rate of lymph flow. Also, at least 200 lymph nodes are located centrally and around deep venous and arterial structures. Exercise of the abdominal muscles increases the pumping of blood, which stimulates the lymph nodes, moving lymph through them more rapidly.
1. Proximal, uninvolved lymphatic structures must be stimulated (massaged), creating a lower negative pressure to draw the most proximal edema out of the involved area.

2. Molecules are absorbed into the lymphatics from the interstitium because only changes in the interstitial fluid pressure (low to high) cause the endothelial cells lining the lymphatics to open.

Key 1 is based on the theory that negative pressure causes a suction effect that moves the more distal lymph proximally in the trunk and extremities. Appropriate treatments to achieve this include MEM massage that starts at the uninvolved axilla, diaphragmatic breathing, trunk exercise, trunk exercise combined with breathing, proprioceptive neuromuscular facilitation (PNF) techniques combined with exhaling and inhaling, and easy yoga trunk stretching exercises.

Key 2 facilitates the uptake of lymph from the interstitium by creating changes in the interstitial pressure; by causing stretching of the anchor filaments attached to connective tissue; and by creating negative pressure, which causes the opening of lymphatics through lymphangion pumping. Appropriate treatments to achieve this include MEM, Kinesio Taping, gentle myofascial release (MFR), bombardment of tissue with fluidotherapy particles at a machine temperature no higher than 98° F (36.7° C), continuous passive motion (CPM) machine therapy, and active and passive exercise. The movement and slight compression of a loose elastic glove or elastic stockinette causes interstitial pressure changes and lymphatic absorption. It is critical to absorption that the glove fit loosely. Kinesio tape provides light stimulation of tissue because it increases the space between the skin and connective tissue. Courses providing instruction in the use of Kinesio Tape are available.

Massage or compression on tissue must be light to avoid collapsing the single-cell initial lymphatics in the dermal layer. Miller and Scale reported that the initial lymphatics began to collapse at a pressure of 60 mm Hg and that they closed completely at 70 mm Hg. Eliska and Eliskova found that a 3-minute friction massage on edematous tissue at 75 to 100 mm Hg caused temporary damage to the endothelial linings of both the initial lymphatics and the collector lymphatics.

Contrast Baths
Some therapists use contrast baths to reduce edema, although currently no research is available that supports this practice. If contrast baths are to be used, research findings on temperature need to be considered. Kurz states that lymph flows best at temperatures between 71.6° F (22° C) and 105.8° F (41° C). For therapy purposes, the hot temperature should not exceed 98° F (36.7° C) to avoid increasing capillary permeability (which is enhanced by heat) and thus edema. With regard to the cold temperature, as mentioned earlier, research has shown that the initial lymphatics actually leak protein into the interstitium at temperatures below 59° F (15° C). Therefore, to avoid the leakage of more plasma proteins into the interstitium (potentially increasing edema), the cold temperature should not be lower than 59° F (15° C).

Precaution. To avoid worsening the edema, set the temperatures for contrast baths between 71.6° F (22° C) and 98.6° F (36.7° C).

Therapy with contrast baths commonly is performed by having the client immerse the hand in warm water for 3 minutes and then in cold water for 1 minute. This sequence is repeated four times, ending on cold.

High-Voltage Pulse Current
HVPC is also a consideration for subacute and chronic edema. Griffin and colleagues found that HVPC did not reduce pre-existing edema. However, a subsequent study by Stralka and coworkers on employees with cumulative trauma disorders provided new insights and raised more questions. In this study, both the control and experimental groups used a splint that incorporated HVPC. However, the device was energized only in the experimental group. According to the study’s findings, the experimental group showed a reduction in edema, whereas the control group did not. Considering that there are various types of edema, this raises the question of whether the members of the experimental group had a combination acute and chronic edema and, if so, which type the HVPC affected, or whether it affected both types.

Pneumatic Pump
If a pneumatic pump is used on subacute or chronic edema, two research-based guidelines must be considered. First, the maximum pressure should not exceed 40 mm Hg to avoid collapsing the initial lymphatics. Even though the initial lymphatics do not begin to collapse until 60 mm Hg, the 40 mm Hg level is recommended to account for any calibration or pump errors. Second, high pressure is not necessary, because the pneumatic pump only softens lymph, it does not cause protein uptake.

Continuous Passive Motion
CPM initially was designed to maintain gliding of tendons and joints after surgery. However, the movement of the CPM machine pulls on connective tissue. This means that the anchor filaments running from the initial lymphatics to connective tissue are stretched, which pulls apart the junctions of the endothelial cells lining the
initial lymphatics. In extremely edematous tissue, the motion may or may not stretch the anchor filaments because tissue expansion caused by the edema may already have ripped off the anchor filaments. Giudice used CPM on edematous hands more than 4 weeks after the injurious incident and found that although edema diminished initially, it returned to pretreatment levels once the CPM treatment stopped. I would conclude that because no proximal massage of the lymphatics was performed before the CPM technique was used, the fluid content of the lymph was merely pushed into adjacent areas. The hydrophilic plasma proteins (plasma proteins that attract the water molecule) remained congested in the interstitium and retracted the water molecules, causing edema to return. The CPM treatment might have had a more permanent effect if two full MEM treatment sessions, as well as the MEM pump point technique (discussed later in the chapter), had been done before the CPM was applied. Also, a short MEM home treatment program performed three or four times daily would continue to decongest the edema, aiding the anatomic lymphatic pump. A comparison of the use of CPM with and without MEM on subacute hand edema clients would be a valuable research study.

Summary of Reduction Treatment for Subacute Edema

- Diaphragmatic breathing
- Trunk stretches, trunk exercises, easy (appropriate) yoga trunk stretches
- MEM
- Kinesio Taping
- Gentle myofascial release
- Continuous passive motion machines
- Fluidotherapy machine (set at 98°F [36.7°C] or lower)
- Active and passive exercise (avoid excessive exercise, which can cause reinflammation of tissue)
- Loose elastic glove; loose elastic stockinette; cotton finger wrap bandages; Coban
- Pneumatic pump to soften lymph (set at 40 mm Hg maximum)
- Chip bags (see Fig. 3-7, A and B, on CD)

CLINICAL Pearl

Starting proximal at the trunk is the key to lymphatic decongestion; this is the first technique that must be done so that the other edema reduction techniques are effective.

Reduction Techniques for Chronic Edema

Chronic edema is persistent edema that lasts longer than 3 months and is indurated (hard) and difficult to pit. As a result of the long-term entrapment of plasma proteins in the interstitium, the tissue becomes fibrotic. In part, treatment is the same as for subacute edema, but it includes softening of the fibrotic tissue to facilitate uptake by the initial lymphatics. Softening of indurated tissue can be accomplished with low-stretch bandaging, chip bags (convoluted foam pieces covered with stockinette), foam-lined splints, silicone gel sheets, and elastomer pads (see Fig. 3-7 on CD). Neutral warmth builds up under these inserts, causing an enzymatic reaction that softens the indurated tissue. The varying densities of the foam chips in a chip bag can result in tissue pressure differentiation, stimulating protein uptake.

Low-Stretch Bandaging

Low-stretch bandages are cotton, nonelastic bandages that have a 20% stretch because of the weave of the bandage. These bandages are rolled on rather than stretched on. Because of the low stretch factor, Dr. Judith Casley-Smith and Dr. John Casley-Smith call the bandages “high working, low resting bandages.” When a muscle contracts, it bulks up under the bandages. Because they stretch only 20%, they provide a light counterforce, which is not enough to collapse the initial lymphatics. When the muscle relaxes, the bandages only collapse 20%, again not enough to collapse the initial lymphatics. Thus variation in tissue pressure facilitates lymphatic uptake and prevents refilling of stretched tissue. Research has shown that use of a combination of low-stretch and foam bandages on the forearm, along with exercise, increases protein uptake.

Low-stretch finger wraps also soften lymph and facilitate lymphatic absorption. These are often used when a client’s hand is so edematous that it does not fit into an elastic glove. Low-stretch finger wraps are not used to squeeze the edema out, because that would collapse the delicate lymphatic structures. The distal-to-proximal spiral pattern in which the wraps are applied, the neutral warmth maintained by the finger bandages, and the effect of finger movement all soften the indurated tissue, improving lymphatic flow and edema reduction.

Chip Bags

Chip bags vary in size, depending on the area they are to cover. They consist of stockinette bags filled with various densities and sizes of foam. The ends of the bag are either taped or sewn closed. Chip bags can be worn under low-stretch bandages, loose elastic gloves, or splints (see Fig. 3-7, C and D, on CD). Various types of com-
Coban
Coban is used by many therapists on edematous fingers. When placed on the finger or digit circumferentially, it creates a squeezing effect, pushing fluid distal or proximal, or both. Lightly overlapping spirals of Coban distal to proximal down a digit facilitates the absorption and movement of fluid proximally (see Fig. 3-6, A, on CD). Coban also creates a buildup of neutral warmth. A small stockinette or powder can be put on Coban once it is on the finger so that the wrapped fingers do not stick together.

**CLINICAL Pearl**

For chip bags, Coban, or low-stretch bandaging to be successful, proximal MEM, or at least pump point stimulation (discussed later in the chapter), must be done first to decongest the lymph (“pull the drain plug”) and move it proximal.

**Summary of Reduction Treatment for Chronic Edema**

- All techniques listed for treatment of subacute edema
- Methods to soften indurated tissue (i.e., tissue that is hardening or already hard), including chip bags, convoluted foam in stockinette, elastomer and elastomer-type products, silicone gel sheets, foam-lined splints, low-stretch bandages, cotton finger wraps, and loose elastic stockinette and/or gloves (on CD, see Fig. 3-6, A to C; also Fig. 3-7, A to F).

**OTHER TYPES OF EDEMA AND APPROPRIATE TREATMENT**

**Lymphedema**

Lymphedema is a chronic, high-protein edema that results when a permanent mechanical obstruction of the lymphatic system creates a lymphatic overload. Permanent obstruction can be caused by surgical removal of the lymph nodes, irradiation of the nodes or skin, filariasis (an infestation of worms that destroys the lymph nodes), or a congenital deficit of the lymph nodes and lymphatic vessels. Clients with lymphedema must be treated with a full MLT program performed by a trained therapist. Treatment includes multiple rerouting of lymphatic flow patterns around deficit areas. MEM is not appropriate for these clients.

**Precaution.** MEM is a treatment for clients with an overloaded but intact lymphatic system.

Therapists working with hand clients may see a permanent deficit of the lymphatic system, resulting in persistent, sustained swelling. This is seen with circumferential scars, as with a replanted digit. It may also occur with circumferential skin grafting. Primary (congenital) or secondary lymphedema (e.g., from the removal of diseased nodes) causes lymphatic congestion (slow outflow of lymph) in the subcutaneous, epifascial tissue space; which means that only the superficial lymphatic vessels are affected. Therefore a client whose fingers are edematous as a result of this type of lymphedema does not develop joint contractures (Fig. 3-4). If surgical or traumatic invasion into the deeper lymphatic structures around joints has occurred, joint contractures may develop. Soft tissue contractures are caused by laceration of superficial and deep lymphatic capillaries, high capillary permeability that causes leakage of plasma proteins,
and prolonged congestion of plasma proteins around these joint and tendon structures.

**Complex or Combined Edema**

Complex or combined edema is initially a transudate edema, such as acute flaccid stroke hand edema. With flaccidity, no muscle pump facilitates vascular flow, and water and electrolytes leak into the interstitium, resulting in a transudate edema. The treatment is the same as for acute edema. During this phase, night splinting might be considered to prevent shortening of the extensor tendons. Three months later, the edema may have a viscous feel, but it is relatively fast to rebound and it does not significantly or permanently reduce with elevation and/or the use of an elastic glove. The edema now has an exudate component. At this point, the lymphatic system, which initially was aiding in the removal of the excess fluid (transudate edema), has reached its maximum capacity. The lymphatic system is overloaded and has slowed down, resulting in lymphatic congestion. The congested plasma protein content of the fluid makes the edema feel viscous. The treatment is the same as for subacute and chronic edema. Often a splinting program is needed to prevent or overcome joint contractures.

**Precaution.** Overexercising or forcing joints in a flaccid or hemiparetic hand can cause microscopic rupture of tissue, resulting in inflammation and increased hand edema. Therefore a balance must be attained between gentle, progressive motion and rest of structures.

**Cardiac Edema**

Cardiac edema occurs with a decline in the heart’s ability to pump blood completely through the circulatory system. As a result, fluid accumulates in the extremities, especially around the ankles. Often cardiac edema manifests as bilateral ankle swelling with a slight pinkish tone to the tissue. Hand therapists treating older adults need to look for this type of edema.

**Precaution.** MEM and many of the edema reduction techniques are contraindicated for clients with cardiac edema, because movement of more fluid can further overload the already compromised cardiac system.

**Low-Protein Edema**

Low-protein edema can manifest as extremity swelling caused by liver disease, malnutrition, or kidney failure (e.g., nephrotic syndrome). Edema results because too few plasma proteins are present in the interstitium to bond with the water molecule and bring fluid back into the vascular systems.

**Precaution.** Low-protein edema has a systemic cause and must be treated with medication. MEM and many of the edema reduction techniques are contraindicated because they may overload the kidneys or liver. Also, even if these edema control techniques are used, this type of edema will return because of its systemic cause.

**EVALUATION OF EDEMATOUS TISSUE**

Edema reduces range of motion (ROM) both actively and passively because it increases the size of the fingers or hand. This, in turn, can reduce functional use and coordination of the hand. Once the edema has been reduced, if decreased ROM persists, the therapist can effectively evaluate and treat joint and soft tissue limitations. The sooner the edema is reduced, the less the buildup of plasma proteins in soft tissue, the less the fibrosis of the tissue, and the less the thickening of scar tissue.

**Precaution.** Reducing edema does not reverse existing joint contractures.

By taking circumferential measurements, the therapist can determine where on the hand specifically the edema is prevalent. For consistency, always use the same measuring device; also, take measurements at the same time of day and after the same amount of hand activity.

Edema rebound tests (see Chapter 5) can help determine whether treatment has reduced some of the viscous congested edema. For instance, if the edema rebound time was 65 seconds before treatment and 40 seconds after treatment, this indicates that lymph was moved out. To make this subjective test more consistent, devise a protocol for how much pressure used and for how long it is applied.

Volumeters repeatedly have proved that they provide reliable, valid edema measurements. These measurements indicate whether volume reduction has occurred; they do not specify the location of the reduction.

The criteria for tissue quality assessment, another evaluation method, are as follows:

- **Acute edema:** Tissue pits deeply, rebounds rather quickly, and can be easily moved around.
- **Subacute edema or early stage chronic edema:** Tissue pits, is very slow to rebound, and has a viscous quality.
- **Chronic edema:** Tissue pits minimally and has a hard feeling.
- **Severe edema:** Tissue has no elasticity and is shiny, taut, and cannot be lifted.
- **Lymphorrhea:** Weeping of tissue occurs with an extremely congested edematous hand or arm. Lymph, a clear, yellowish fluid, escapes from the interstitium to the outside of the skin. Techni-
cally, weeping tissue is considered an open wound and must be treated as such. MEM techniques can rapidly decongest the lymph and stop the lymphorrhea.

Note: Always perform the capillary refill test if the client's hand has a bulky dressing or if the client is wearing finger bandages.

Precaution. Color, temperature, and sensory changes may be signs of a problem. A purple color often indicates pooling of venous blood, and a whitish color means that arterial blood flow to the tissue is compromised. Immediately notify the physician of these signs.

**CLINICAL Pearl**

Macrophages are less effective in edematous tissue because it has less oxygen; phagocytic activity therefore is diminished.8

The therapist must be able to distinguish between congestion and infection. With an open wound, the classic signs of infection are redness, warmth, pain to the touch, odor, and/or cloudy drainage. With a closed wound, the signs of a subclinical infection are a pinkish red color and slight warmth; also, the wound may be painful to the touch, odor, and/or cloudy drainage. With a closed wound, the signs of a subclinical infection are a pinkish red color and slight warmth; also, the wound may be painful to the touch and the tissue may be hard.30 This is often seen with a very edematous extremity or hand if the first course of antibiotics hasn't fully resolved the infection. Extremely edematous hands often need a second course of antibiotics.

Precaution. If infection is suspected, MEM should not be started before a full course of antibiotics has been completed and the physician has assessed the status of the infection.

The signs of congestion frequently are the same as those of a subclinical infection. The client's history can help determine whether the condition is congestion or infection (or both). Often congestion (and, possibly, infection) can be prevented if the therapist begins treatment of an uninfeected extremity early, before visible edema is present, with the short version of MEM. Prolonged tissue congestion can lead to infection because congestion reduces oxygen delivery to tissue, diminishing the effectiveness of the phagocytic cells.

Both old and new scars can create a barrier to lymph flow. Check for proximal scars (e.g., on the shoulder, back, or axilla). Soften both old and new scars with gentle myofascial release techniques, silicone gel sheets, and/or Kinesio Taping. Instruct the client in MEM techniques to reroute edema around scars and to soften scars.

Sensory testing is very important for an edematous extremity because edema often reduces sensation. As edema is reduced, the degree of sensation usually improves. Sensory testing therefore becomes an objective test that shows limitations and improvements that can be related to function.

Coordination often is diminished by edema in the hand. A nine-hole peg test can become a repeated, scheduled test for assessing hand function. Reducing hand edema should improve coordination, unless an underlying problem exists.

Pain assessment is very important. As edema declines, pain usually diminishes. Clinically, pain reduction often is noticed before ROM shows improvement. Keep in mind that pain can have many sources. For example, in a client with a Colles fracture, edema reduction can relieve the pain caused by the pressure of edema on the nerve receptors; however, the client still may have chronic pain specifically related to the fracture site. Therefore other, appropriate methods must be used to reduce that pain, which differs from edema-related pain. Even during treatment for a different cause of pain, the client should follow a MEM home program twice daily to eliminate any new, not yet visible congested edema.

**MANUAL EDEMA MOBILIZATION**

MEM is an edema reduction technique for persistent edema in the hand, arm, or leg in which the lymph system is intact but overloaded. MEM specifically activates the lymphatic system to facilitate absorption of the excess and congested large plasma protein molecules, other large molecules, and small water molecules from the interstitium. This technique reduces both visible and not yet visible edema. It is a modification of MLT techniques used for lymphadenectomy and/or lymph node irradiation, primary (congenital) lymphedema, and lymphedema arising from filariasis. For those types of edemas, MLT very appropriately involves extensive rerouting of lymph flow around missing or permanently damaged nodes and lymphatic vessel areas.

I developed MEM after I became certified in lymphedema treatment and learned about the anatomic functioning of the lymphatic system. My study of anatomy and physiology led me to realize that the traditional treatments for upper extremity edema could be improved if they were based on this knowledge. I realized that the subacute edema I struggled to reduce in my surgical, trauma, and stroke clients with hand edema was a lymphatic overload edema. In these cases, because the lymphatic system, although overloaded, was still intact, extensive rerouting wasn’t necessary, just decongestion, starting at the trunk.
MEM is a significant modification of MLT in several ways: (1) it involves only one trunk rerouting technique; (2) it requires exercise after each segment is massaged; (3) it has its own light hand massage patterns; (4) it includes scar rerouting patterns; (5) it relies heavily on client follow through with a self-management program; and (6) it incorporates pump point stimulation, which is unique to MEM.

The full MEM program takes 30 minutes. The short version, consisting of trunk rerouting and pump point stimulation, takes 15 minutes. MEM can be combined with other edema reduction techniques, but it should be done before those techniques are performed. The reason for this is simple: MEM decongests the most proximal edema and moves that edema proximally, creating a space into which the more distal edema can move by means of a proximal negative pressure vacuum. The more traditional edema reduction techniques will be more effective after MEM, after there is space cleared to which the edema can be moved proximally.

Principles and Concepts
MEM is grounded in the following principles and concepts:

1. Light massage is provided, ranging from 10 to 20 mm Hg, to prevent collapse of the lymphatic pathways and arterial capillary reflux.
2. When protocol allows, exercises are performed before and after the MEM session; these exercises are done in a specific sequence, starting proximal to the edematous area or in the contralateral quadrant if possible.
3. Massage is performed in segments, proximal to distal, then distal to proximal. Massage ends in a proximal direction (i.e., toward the trunk).
4. When possible, the technique includes exercise of the muscles in the segment just massaged.
5. Massage follows the flow of lymphatic pathways.
6. Massage reroutes around scar areas.
7. The method of massage and the types of exercise do not cause further inflammation of the involved tissue.
8. A client home self-massage program is devised that is specific to the pathologic condition of the hand.
9. MEM can be adapted to various diagnoses and stages of high plasma protein edema.
10. Guidelines are included for incorporating traditional edema control, soft tissue mobilization, and strengthening exercises without increasing in edema.
11. Specific precautions are observed.
12. When necessary, low-stretch compression bandaging or other compression techniques are used.
13. Pump point stimulation is used extensively.
14. MEM is beneficial in clients whose lymphatic vessels are intact but overloaded from congestion.

Contraindications
The precautions and contraindications for MEM include those that are common to most massage programs and others that are specific to the movement of a large volume of fluid through the system. Always consult a physician if you are concerned about the client's current or past cardiac and/or pulmonary status. For instance, if an 80 mL volumetric difference exists between the client's two extremities, inform the physician that with MEM, that much fluid may be moved through the heart and lungs. Ask whether this would compromise the client's cardiac status.

Therapists should not use MEM in the following circumstances:
- If infection is present, because the infection may be spread by the technique.
- Over areas of inflammation, because inflammation and pain may be increased; MEM should be performed proximal to the inflammation to reduce the amount of congested fluid.
- If a hematoma or blood clot is present in the area, because the clot may be activated (i.e., it may move).
- If active cancer is present. A controversial theory notes the potential for spreading cancerous cells. MEM should absolutely never be done if the cancer is not being medically treated. The therapist should always seek the physician's advice.
- If the client has congestive heart failure, severe cardiac problems, or pulmonary problems, because the cardiac and pulmonary systems may be overloaded.
- In the inflammatory stage of acute wound healing, because theoretically the cellular cleanup process and the invasion of fibroblasts may be disrupted.
- If the client has renal failure or severe kidney disease, because the edema in these cases is a low-protein edema, and the renal system may be overloaded and/or the fluid may be moved to some other undesirable site.
- If the client has primary lymphedema or lymphedema arising from a mastectomy. Successful treatment of this condition requires a knowledge of ways to reroute lymph to other parts of the body, as well as specific techniques beyond the scope of this chapter.

MEM Massage, Drainage, and Term Definitions
U’s Hand Movement Pattern
U's are a pattern of hand movement that involves placing a flat but relaxed hand lightly on the skin. The hand
gently tractions the skin slightly distal and then circles back up and around, ending in the direction of the lymph flow pattern. The movement is consistently a clockwise or counterclockwise motion in a U, or teardrop, configuration. Very light pressure (10 mm Hg or less) is used to move just the skin, thereby stimulating the initial lymphatics. Clinically, this is taught by having the therapist first place the full weight of the hand on the client's arm; then, while the entire palm and the digits remain in contact with the client's skin, the hand is partly lifted so that only half its weight rests on the arm. MEM massage proceeds at this very light pressure, moving in a U while tractioning (pulling), not sliding, the skin. This is a "skin" massage—just enough pressure to make the skin move.

Clearing U’s Skin Tractioning Pattern
Clearing Us is a pattern of skin tractioning performed in segments. It starts proximally and moves to the designated distal part of the trunk or arm segment (i.e., upper arm, forearm, or hand). A minimum of five U’s are done in three sections for each segment. The purpose is to create interstitial pressure changes that cause the initial lymphatics to take up lymph. The direction of “flow” movement follows the lymphatic pathways toward the heart (i.e., flowing proximally, not distally). If not contraindicated by the diagnostic protocol, active muscle contraction is done in each segment after it has been “cleared.” This increases the rate of lymphangion contraction, which moves the lymph out of the area more quickly.

Flowing U’s Lymph Movement Pattern
Flowing Us is a pattern of sequential Us that starts in the distal part of the segment being treated and moves proximally past the nearest set of lymph nodes. This could be described as “waltzing” up the arm. The process of moving one U after another from distal to beyond the node is repeated five times. After the final repetition is completed, the flowing U motion is performed all the way to the contralateral upper quadrant. The purpose is to move the softened lymph out of the entire segment and facilitate its eventual return to the venous system and the heart (Fig. 3-5).

Pump Point Stimulation
Pump point stimulation involves simultaneous, synchronous movement of the therapist’s two hands in a U pattern over areas of lymphatic bundles (groups of initial and collector lymphatics), watershed areas, and/or lymph nodes. Because nodes pose resistance to the flow of lymph, pressure from the full weight of the hand is used. Typically the therapist does 20 to 30 Us in one area before proceeding to the next area of pump points. After pump point stimulation is performed in an area, exercise is done either in that area or proximal to it. Sometimes an MEM flow massage is done before the next area of pump points is stimulated (see Fig. 3-8, B, on CD).

Therapists should not attempt MEM unless they have been trained in the technique. Two- and 3-day courses are available and encouraged for any therapist who would like to use MEM as a course of treatment. The following case study is an example of the short version of MEM, which is presented here to offer the reader a sense of what the MEM program entails (see Fig. 3-8 on CD).

Case Study

This case study, presented by Karin Ronhoj, OTR, CLT, an occupational therapist in Denmark, is offered as a clinical reasoning tool to help readers synthesize the material in this chapter. This case represents the first time Karin used MEM. Her problem-solving approach is valuable for readers not already familiar with MEM. The answers to the six questions posed below can be found at the end of the case study.

HISTORY
An 84-year-old woman fractured the first (thumb) metacarpal bone of her left (L) hand when she hit a door with her hand. The client was treated in the emergency department (ED) with casting of the fracture. After 2 days this cast became too tight. She returned to the ED,
where a new cast was applied. At neither visit was the client instructed in any edema reduction techniques. During her third visit to the ED, 10 days after injury, the ED physician called in a hand surgeon. The surgeon immediately sent the client to Karin in occupational therapy (OT), knowing that she had expertise in edema reduction techniques (see Fig. 3-9, A and B, on CD).

1. What edema reduction techniques could the ED physician or nurse have advised the client to perform for this acute stage while wearing the cast?
   a. Elevation of hand above heart
   b. Use of ice/cold pack for 24 hours
   c. Use of hot pack first 24 hours
   d. Continue all activities, use hand as much as possible
   e. Restrict activities for first 24 hours, rest as much as possible with hand elevated above heart, move shoulder and elbow when arm is elevated

CLINICAL EVALUATION FINDINGS

- Social history: widow, lives alone in large house, responsible for all self-care and household chores; client is ambidextrous but prefers using L hand.
- Hematoma covering two thirds of the dorsum of the hand; multiple bruising of volar surface forearm and fingers; fingers pale and also purplish from bruising.
- Hand girth measured along descending angle of MCPs was 6.5 cm larger than same area on unaffected (R) hand. Proximal phalanges of index-small digits averaged 2 cm greater than on the right. Skin was taut, shiny, couldn’t be lifted, and felt viscous (spongy) when compressed.
- Sixty-second rebound time on index proximal phalanx, the most edematous digit.
- Average of 10 to 15 degrees of active and passive motion of all finger joints; thumb not measured.
- When client actively made a fist, distance to palmar crease ranged from 10 cm on index finger to 11 cm on small finger.
- Client reported extreme pain when the therapist touched her hand or when she moved it actively or passively.
- Client needed a replacement splint, to be made of thermoplastic material, for L thumb; hand surgeon had ordered the splint.
- Slight swelling of both ankles, but no heat or redness.

2. The type of edema the client had was subacute because
   a. The tissue had a viscous feel.
   b. The tissue was slow to rebound when pitted.
   c. The physician had given it that label.

3. The therapist must plan an edema reduction program 10 days after the injury. What types of treatment techniques should be considered?
   a. Ice packs
   b. Light retrograde massage
   c. Vigorous active and passive ROM of the entire upper extremity
   d. Intermittent elevation to reduce dependent edema
   e. Kinesio Taping to reduce the hematoma and swelling
   f. MEM
   g. Elevation of the arm/hand as much as possible
   h. Gentle, progressive active ROM of the arm, including the fingers but not the thumb
   i. Light spiral Coban wrapping of the digits
   j. Elastic glove on all fingers and the hand, including the thumb with the splint

4. Why wouldn’t you consider fluidotherapy for this client, even at 98.6°F (36.7°C)? Why wouldn’t you use contrast baths within the recommended range?

INITIAL TREATMENT

Karin’s treatment of this client for the first session consisted of fabrication of a thumb immobilization splint, MEM treatment to the upper trunk (diaphragmatic breathing, MEM exercises before and after treatment, upper trunk massage, active muscle contraction for the shoulders) and an activities of daily living (ADL) evaluation. The client borrowed appropriate assistive devices for temporary one-handed use.

5. Why didn’t Karin do MEM for the entire extremity or trunk and all pump points at the first session (MEM short version)?
   a. She ran out of time.
   b. It was contraindicated because of the extent of bruising on the arm and the hematoma on the hand.
   c. A potential cardiac problem was a concern because of bilateral ankle swelling.
   d. She wanted to go slowly with the client so that she could watch for contraindications and observe the rate of edema reduction.

CONTINUING CARE

The client was seen for a second therapy treatment 5 days later. Her entire medical chart was obtained and showed no cardiac problems. The bilateral ankle swelling was from venous insufficiency. The bruising was fading on
her arm, the color of the fingers had become more normal (i.e., less congestion), her pain had decreased, and she had some increase in ROM. Karin then did the entire MEM program and put low-stretch bandages on the fingers and forearm (see Fig. 3-9, C to E, on CD).

6. Low-stretch bandages were used to:
   a. Squeeze fluid out of the fingers and hand
   b. Prevent refilling of tissue with fluid after MEM massage
   c. Reduce indurated (hard) tissue

SUBSEQUENT CARE
Four days later, the client returned for her third hand therapy treatment. Edema continued to decrease slowly, pain continued to decrease, active and passive ROM of digits continued to improve, the client was successfully following her self-management exercise program, self-massage, and rebandaging wearing 23 of 24 hours daily. Karin noted that the edema was reducing slower than she had thought it would with the MEM method. At this point, she had done MEM massage only up to the wrist because of the contraindication for doing MEM on the area of a hematoma. Karin contacted me, and I advised her to do the Kinesio Taping hematoma/edema reduction method on the dorsum of the hand. She obtained the proper instruction for Kinesio Taping for hematoma/edema reduction. The Kinesio Tape was applied (see Fig. 3-9, F, on CD).

At the client’s fourth therapy visit, 19 days after the start of treatment, she had reduced hand pain with a resulting increase in ROM, such that a composite fist was only 4 cm from touching the palm. Originally the fingers were 10 to 11 cm from touching the palm. This was 4 days after application of the Kinesio Tape, and the hematoma was almost gone.

RESULT OF CARE
Four weeks after treatment began, the thumb splint was discontinued. The next week Karin discontinued the low-stretch bandages and stopped performing MEM during clinic visits. The client continued her home MEM program for 2 more weeks. The client was discharged 2 months after treatment was initiated with a nonedematous, functional thumb and hand (see Fig. 3-9, G and H, on CD).

DISCUSSION
Q: If Karin had known Kinesio Taping methods for hematoma reduction before treating this client, could she have applied the Kinesio Tape at the first treatment session, 10 days after injury?

A: Yes, this would have reduced the hematoma, and the digit edema would have been reduced more quickly.

Q: If Kinesio Taping for hematoma reduction had been applied during the first treatment, could the same MEM trunk program been performed?

A: Yes. However, this was Karin’s first experience with using both MEM and Kinesio Tape. It is advisable not to do two new techniques at one time. It is best to observe the reaction and extent of edema reduction before applying the second technique. This gives a frame of reference for future application. In this case, it was especially important to do just one technique at a time and gradually add techniques because of the extent of bruising.

Q: Is there edema normally related to a healing fracture?

A: Yes, it is not uncommon to see moderate swelling during the first 2 weeks of the healing process. Usually the secondary edema in the surrounding tissue can be reduced during this time with MEM.

Q: Could two or three different treatment techniques have been used to reduce edema during those first three treatment sessions?

A: No. Currently, with subacute edema, MEM is the only method that follows lymphatic anatomy for proximal decongestion. This proximal decongestion must be done first so that the peripheral edema has a space into which it can move. Other techniques will be more effective after trunk MEM and a home MEM program have been done for a week. If edema isn’t reducing as quickly as you think it should, re-evaluate as Karin did.

CLINICAL PROBLEM SOLVING
What is the effect of the hematoma? Are there scars or old injuries proximal to the edema that are barriers to lymph flow? Does the client have fascial restrictions or ROM restrictions proximally? Is the client following through with an MEM home program and doing a light stroking massage? Add more treatment techniques according to your evaluation findings.

ANSWERS
1. A, B, E
2. A, B
3. D through H
4. Because the client must wear the thumb splint at all times. Also, heat would soften the splint.
5. B, C, D
6. B, C
Acknowledgment

I would like to thank Karin Ronhøj of Denmark for the case study and for her passion for MEM. Her dedication has prompted her to conduct an MEM research study (in progress) and to become an expert in the teaching of MEM. Her efforts doubtless will help to further develop this area of expertise.

References