Hour 4
Section 16: Symptoms of Cervical Acceleration/Deceleration Impact (continued)

**Symptoms (continued):**

**Psychological affects:**

Patients with a preexisting psychological issue prior to the trauma do not experience a greater incidence of psychological problems from their injuries. Physical issues seem to have more effect on psychological issues after injury than any preexisting psychological issues.

**Shoulder pain:**

Shoulder pain after acceleration/deceleration impact is usually concomitant with neck pain and can be due to direct injury such as hitting the door, seat belt injury to the shoulder, or referred pain from the cervical spinal structures or disc. Secondary biomechanical issues can develop from cervical muscular disuse or paresis and cause problems such as impingement syndrome, rotator cuff inflammation. Conditions that were subclinical and muscle imbalance based can become clinical after impact.

**Upper back pain:**

Pain can radiate from the cervical spine to the scapula or upper trapezius. Trigger points can develop in the trapezius from impact injuries to the cervical and cervicodorsal spine. Referred
pain to the upper back and or midscapular region can be from strain, herniated disc or scleratomal pain. Paresthesias can occur from muscle spasms in the scalene group with the most common radiation being the ulnar nerve.

**Chest pain:**

Several conditions can cause chest pain from acceleration/deceleration impact. Seat belt injury can lead to fracture of the ribs or costochondritis of the rib cage from direct impact. Symptoms of costochondritis can take up to several weeks to appear. The air bag can also lead to fracture and rib cage injury. Without seat belt harness, acceleration can lead to severe chest injury with rib and/or sternum fracture as well as pneumothorax which can lead to death. Referred pain from cervical disc can cause chest pain. Thoracic Outlet Syndrome can radiate pain to the chest. Injury to the female breast from the seat belt can cause chest pain. Fibromyalgia sufferers can develop chest pain after myofascial injury which can be from an injured sternalis and can be misinterpreted as a cardiac issue. Patients are urged to go the ER to rule out cardiac causes of chest pain in any instance.

**Dysphagia:**

Dysphagia is characterized by a difficulty swallowing, throat swelling, and/or hoarseness. It can be highly serious with its cause in esophageal injury, pharyngeal hemorrhage or edema, or retropharyngeal hemorrhage. It may also be due to severe muscle spasm of the longus capitis and colli muscles. Hoarseness can be due to injury of the larynx with swelling, or injury to cranial nerves or recurrent laryngeal nerve.

**Visual disturbances:**

Visual disturbances have been recorded after acceleration/deceleration impact. The most common form of disturbance is blurred vision which may be due to blood flow alterations to the brain from the vertebral artery or injury to the sympathetic nervous system. Horner’s syndrome may occur as well as photophobia, dry eye, nystagmus or temporary vision loss.

**Auditory disturbances:**

Tinnitus is a common finding after acceleration/deceleration impact and is found with TMD. Phonophobia is common after a minor head injury.

**Balance disorders:**

Injury of the SCMs can cause dizziness. Damage to the sympathetic chain which approximates the SCMs can compromise vascular structures and lead to dizziness. Decreased blood flow at the vertebrobasilar artery can lead to dizziness and can be from TMD or mild traumatic brain injury.
Fatigue and irritability:

Fatigue and irritability have been found with 90% of acceleration/deceleration impact patients. Fatigue can vary from mild to extreme and can be associated with restlessness or insomnia. Patients suffering from mild traumatic brain disorder have been known to require more sleep. Fibromyalgia can develop after trauma and has been associated with spinal injury. There is a 13 times greater chance of developing FMS after cervical injury than after lumbar injury. Sleep disorders are common with FMS. Sleep issues can develop from the pain keeping the patient up at night or grinding, clenching at night from TMD.

The following is an overview of symptoms that can occur with acceleration/deceleration impact:

Cranial nerve palsies
Peripheral neuropathy
Dizziness
Otoneurological disorders
Thoracic outlet syndrome
Oculomotor disturbances
Other visual disturbances
Posttraumatic stress disorder
Herniation of cervical discs
Rupture of ligaments and muscles
Rim lesions
Spinal cord injury
Retropharyngeal hematoma
Injury to subarachnoid space
Mediastinitis
TMJ disruption
Hypopharyngeal perforation
Tracheal perforation
Esophageal perforation
Brain injury
Hypothalamic-pituitary-thyroid axis disorder
Damage to the posterior cervical sympathetic nerves
Menstrual disorders
Tremor
Occipital neuralgia
Cervical dystonia
FMS

Changes to Soft Tissues:

Ligaments:

Ligaments are commonly injured with acceleration/deceleration impact. The ALL, PLL, disc, joint capsule, ligamentum flavum, interspinous ligament and ligamentum nuchae can all be
injured depending on circumstance, severity, complicating factors, age and gender. There has also been injury reported in the alar, apical and transverse ligaments. Ligament damage has been graded with complete or major tears being a surgical condition. Most ligament tears that occur with most cervical acceleration /deceleration injuries are grades I and II and can be treated conservatively.

**Muscles:**

Muscle tissue can be injured in varying forms of severity grades I and II being the most common. Grade I defines a functional intact muscle. Grade II describes a partially damaged but functionally intact muscle. Grade III is a surgical condition in which the muscle has been completely torn and is usually associated with fracture, dislocation or spinal cord injury.

Myofascial Pain Syndrome is when muscle and related structures are inflamed causing pain either locally or referred from a trigger point. Initially, there is a strain to the tissues. Muscle contractions, loss of range of motion, trigger points with a reference zone and weakness follow. Often these conditions are referred to as chronic strain or chronic pain disorder, both misnomers for myofascial pain disorder.

Trigger points are regions of muscle with microtears. When muscle fibers contract to protect the injured region, the fibers are no longer continuous with one another and in attempting to rejoin form bundles of disassociated muscle tissue. In doing so, the entire muscle shortens altering normal mechanics. These regions produce noxious products of inflammation which can affect nearby nerves referring pain. Pain from trigger points do not follow a dermatome path and can be distant from the region of muscle that has received the microtears and trigger point development.

A reference zone is a region of pain felt when palpating the trigger point and can be local or distant from the region involved. When trigger points are active, they can refer pain in the reference zone as well as the local area of tissue injury.

Both trigger points and reference zones define Myofascial Pain Syndrome. Trauma can lead to the development of trigger points or the conversion of a current trigger point from latent to active usually from a stretch injury. With any trigger point, the muscles ability to stretch is decreased and pain is produced with isometric contraction.

To diagnose myofascitis, there are major and minor criteria developed by Simons, DG.

**Major Criteria:**

1. Localized spontaneous pain
2. Spontaneous pain or altered sensations in the expected referred pain area for a particular trigger point.
3. Taut, palpable band in an accessible muscle.
4. Exquisite, localized tenderness in a precise point in that tender band.
5. Some degree of restricted range of motion when measurable.
Minor Criteria:

1. Reproduction of pain or altered sensation (which is normally present at rest) on palpating the trigger point.
2. Local twitch response in the tender band or trigger point by snapping it with the fingers or by dry needling.
3. Pain relieved by muscle stretching or injection.

Nerves:

Compression injuries may occur during the extension phase of acceleration/deceleration impact usually at the IVF. The nerve root can become contused producing disruption of axons. Symptoms are usually paresis seen days or even weeks after trauma. This crush injury can lead to abnormal tissue function for up to 4 months. Chronic inflammation in nerve root linings can lead to fibroblastic scar formation and may contribute to the symptoms of peripheral neuropathy.

There are various reasons spinal nerve roots produce pain when injured. Nerve roots lack an epineurium lining and are more vulnerable to compression. Larger diameter nerve roots are more susceptible to compression and ischemia than smaller diameter fibers. Pressure over a nerve can lead to a conduction block and prolonged pressure can result in mechanical alteration of blood vessels and nerve fibers. Direct compression on axons can lead to complete or partial block of axoplasmic flow mechanisms.

Dura mater, spinal cord and arachnoid mater may be contused in acceleration/deceleration impact. During ramping, stretch occurs to the meninges and spinal cord causing nerve roots to be exposed to extreme traction forces. The diameters of the intervertebral foramen are reduced during extension and/or rotation compressing the neural structures. During forward flexion of deceleration, stretch to the spinal cord and associated structures compounds the initial injury.

Fat:

Fat necrosis can occur from contusions of breast tissue from the shoulder harness during impact. Nodules can develop around a local region of necrosis and liquefied fat cells and form fibrous scar tissue. There has been a link between this fat necrosis and breast cancer. With patients who have silicone breast implants, acute compression injuries from the seat belt can dislodge the implant from their capsules.

Section 17: Changes to Soft Tissue after Acceleration/Deceleration Impact (continued)

Scleratombol pain:

A sclerotome is a deep somatic track innervated by a particular spinal nerve. When the tissue of a sclerotome (ligament, bones and joints) is irritated by mechanical or chemical stimuli pain is "experienced" as originating from all of the tissues that are innervated by the same nerve, or
along the sclerotome. Sclerotome pain is considered deep, ill defined, dull and achy, and diffuse. Sclerotogenous pain does not follow dermatomes but does follow a sclerotome pain pattern. Tissues included in sclerotogenous pain include ligaments, tendons, discs, periosteum and apophyseal joints. Pain referral is thought to be from the injury to deep skeletal and soft tissue structures.

Studies were performed assessing scleratomal pain and it was determined that the subjects had difficulty localizing the point of pain; the deeper the stimulus, the poorer the ability to localize cause. There was a lag between the time of stimulation and the time that the pain was felt. Different pain thresholds were noted for different tissues. Pain from periosteum or attachments of ligaments and tendons was associated with an extensive radiation of pain. Pain radiation was associated with soreness of muscles and tenderness over bony prominences. Vasomotor disturbances such as sweating and blanching may occur. Peripheral radiation of pain sometime appeared after several minutes or hours. Pain sometimes occurred for several days and was unrelated to the size of the lesion. The pain was so reproducible that charts could be made to demonstrate consistent patterns.

Feinstein et al. also found that stimulation of the first cervical level, evoked pain in the occipital region and/or forehead. Stimulation of a group of muscles innervated by the same roots of the brachial plexus referred pain to the same areas. Deep tenderness and muscle spasm were noted. Hypoalgesia was noted on the skin over areas of referred pain. Autonomic reactions such as pallor, sweating, hypotension, a faint feeling and nausea were most common with thoracic stimulus. The sympathetic nervous system was not responsible for pain referral. Peripheral nerve function was not responsible for referred pain.

Conditions that cause pain and are associated with acceleration /deceleration impact are:

Fracture
Dislocation
Subluxation
Periosteal tear
Ligamentous tear
Facet joint injury
Tendinous tear
Muscular tear
Fascial tear
Disc injury
Hemorrhage
Edema
Ischemia
Spasm
Adhesions
Altered vertebral kinematics
Myofascial inflammation
Trigger points
osteoarthritis

The quality of pain for the particular tissues is as follows:

*Bone* pain is deep, local, burning or dull.
*Joint* pain follows a capsular pattern and is elicited on passive movement.
*Ligament* pain is deep, dull, and achy and elicited on passive movement.
*Muscle* pain is elicited on active movement.
*Tendon* pain is dull and achy but sharp with movement.
*Vascular* issues can cause throbbing pain or paresthesias.
*Bursal* pain is achy and elicited on passive movement.
*Nerve* pain is stabbing or shooting.
*Fascial* pain is achy and does not follow a dermatome pattern.

The most sensitive tissues are listed in order of sensitivity as follows:
Periosteum
Ligament
Fibrous joint capsule
Tendon
Fascia
Muscle

It is common for the pain pattern experienced after acceleration/deceleration impact to be different than most clinicians basing pain patterns exclusively on dermatomes understand. In those cases, MRI or EMG cannot confirm injury to the structures associated with dermatome pain patterns. These patients are misdiagnosed, mistreated or considered malingerers when they are in fact not fabricating their pain patterns. The patterns may be more consistent with scleratomal pain and an untrained eye may miss the true cause. This is common with musculoskeletal injury and has been noted in the treatment protocol of strain/counterstrain. Also, an injury to a particular soft tissue may produce muscle spasm in another segmentally related tissue. This is common with referred organic pain and can also be seen with trigger points and secondary trigger points. This secondary muscle spasm becomes another source of pain which if left untreated results in chronic painful myofascial condition. In fact, it is the initial tissue that
must be treated in order to resolve the secondary muscle spasm and its pain. All too often these patients are not treated properly, their conditions do not resolve and they are misconstrued as malingering. This is common with myofascial conditions after trauma.

Cervical ligaments, facet joints and discs can be the source of neck and shoulder pain; lumbar ligaments, facet joints or discs can be the source of low back pain. The source of pain radiation has been traced to the recurrent meningeal nerves at those particular levels.

**Prognosis for Soft Tissue Injuries in Acceleration/Deceleration Impact:**

Over the years research has been done to determine the outcome of cervical acceleration/deceleration injury. Many studies have been limited in the information that had been collected such as vector, speed, gender, etc. Be wary of those studies. Macnab determined that rear impact injuries had more prolonged symptoms than front or side impact. In rear impact patients, 83% continued to have symptoms for more than 2 years after the incident. Hohl determined that 43% continued to be symptomatic after 5 years. Maimaris et al. determined that 34% remained symptomatic at 2 years with a greater tendency to develop spondylosis with a preexisting cervical kyphosis. Those with preexisting spondylosis prior to the impact had poor prognosis and poor results. Norris and Watt performed a study in which 86% of patients were still symptomatic after 10 years. These patients had preexisting spondylosis prior to impact.

Regarding posttraumatic headaches, Brenner et al. determined that 40 – 60% of posttraumatic headache cases persisted more than 2 months. Denker and Perry found headache symptoms lasting longer than 1 year in 33% of patients and up to 20% in cases after 3 years. Glaser and Shafer determined that 31% of patients continued to experience headaches after 5 years.

There are 3 major studies that are introduced in litigation to negate or limit liability:

The Quebec Task Force or QTF funded by a supplemental insurer based conclusions on less than 1% of information gathered in research regarding acceleration/deceleration impact. Their analysis was limited exclusively to the diagnostic code of 847.0 cervical strain/sprain, all other diagnoses were omitted. Their term for recovery is defined as the patient had returned to work. In fact, QTF determined that “whiplash is not harmful” and “it results in temporary discomfort” and “has a favorable prognosis”. In truth, overall analysis of complex studies as mentioned above have determined that only 35 – 50% of patients make a full recovery.

The Saskatchewan Study funded by the Canadian government auto insurer was vague in their assessment of the injuries or treatment received but taking a position of their study by a predetermined statement that “The elimination of compensation for pain and suffering is associated with a decreased incidence and improved prognosis of whiplash injury” and “An insurance system in which financial compensation is determined by the continued presence of pain and suffering provides barriers to recovery”. The information was gathered by questionnaire of the injured, not examination, history or clinical findings.

The Lithuanian Studies determined that the effects of litigation and insurance compensation affect outcome of injury recovery. The study involved 202 patients who were involved in
acceleration/deceleration impact and a control group of 202 that were not. The two groups were assessed 22 months after their crash or no crash and were found to have the same prevalence of neck pain. Their conclusion was that whiplash injuries do not cause chronic symptoms and that in industrialized countries with insurance settlements somehow use the accident to claim chronic pain. In fact, in this study, only 15% of the 202 acceleration/deceleration impact patients actually had been injured in their accident. Also, 43% of the cars in Lithuania had no head restraint.

In truth, studies funded by insurers or performed haphazardly with no regard to the actual circumstances in acceleration/deceleration impact have been used to hurt your patients in their settlements. Be wary of what is used by an insurer to justify cessation of care or refusal to accept your patient’s real objective findings. In all cases of acceleration/deceleration the best tool for protecting your patient with their case is in the documentation and objective and clinical findings as well as an understanding of the tools used against your proof so that you as their physician advocate can combat any false or unjustified “reason” to call your patient a malingeringer.

Section 18: Temporomandibular Joint and Acceleration/Deceleration Impact

**Temporomandibular Joint:**

For a more complete understanding of the TMJ, its function and associated maladies and treatments, please refer to Soft Tissue Injury 107, Linda Simon, DC.

**Bones:**

*Mandible* and *Temporal bones:*
The mandible is suspended from the skull by muscles and ligaments. Sixteen teeth form the mandibular arch and 135 to 160 contact points at full occlusion. Any alteration of alignment alters stability adding stress to the TMJ. The mandible is dynamic and uneven muscle forces tend to deform it mostly in the condylar head contributing to joint deterioration.

Temporal bones articulate with the mandible and disc at the temporal fossa (a region of four bones; parietal, frontal, sphenoid and temporal). Anterior of the fossa is the articular eminence, posterior to the fossa is the squamotympanic fissure. The fissure allows for the flow of inflammatory products formed by the TMJ. The articular eminence is load bearing. The slope and degree of its convexity is responsible for the pathway of condylar movement. A steep slope can allow for disc slippage whereas a flat slope can allow for more freedom in movement and decreased possibility of internal derangement.

Joints:

Mandible, articular eminence of the temporal bone and articular disc:

The disc is biconcave and fused with the capsule. Thicker medially with greater joint space, it is the thinner lateral region that receives greater stress. It divides the joint into upper and lower compartments and is more firmly attached to the mandible than the temporal bone. The shape is adaptable and corresponds to the joint surfaces and their functional demands. The adaptability of the disc allows for self-correcting over a lifetime. When the disc is loaded, it compresses and a slide of the disc brings the thinner section between the articular surfaces. When it is
decompressed, it rotates and the thicker portion will fill the joint space and maintain articular surface contact. Although this may seem counterintuitive for the integrity of the disc, this is how this mechanism functions. The shape of the disc also prevents sliding in the sagittal plane and allows for rotation which maintains the functional integrity between the disc and condyle. Disc displacement can result in bite alteration.

The TMJ moves as a hinge for 12-15 mm of initial opening, the condyle and disc are not translating. The joint glides for the rest of the opening which can be up to a maximum of 60 mm. Here the condyle and disc are translating.

Behind the disc is the bilaminar zone of retrodiscal tissue comprised of veins and nerves. This tissue fills on forward movement of the condyle to produce synovial fluid. It also provides slight posterior tractional force when the disc moves anteriorly. The retrodiscal tissue is innervated allowing for capsular pain.

The static position of the TMJ is determined by dentition (occlusion position) and mandibular rest position (neuromuscular tone at rest). There is an interocclusal space of 3-5 mm which varies throughout the day and one’s life. Tension, nail biting, body head posture, dental tooth loss and anxiety can all alter the mandibular rest position. Improper dentition combined with abnormal muscle tension can alter condyle movement leading to an increase in disc pressure or stress the ligaments. Either alone or in combination can lead to the deterioration of the TMJ.

Functional movement of the TMJ consists of forward gliding (translation) and hinge-like rotation. As the forward movement occurs, the mandible head rotates on the lower surface of the disc allowing for chewing or grinding. During protraction (protrusion) and retraction of the mandible, the articular head and disc slide back and forth on the articular surface of the temporal bone moving together.
The movement of the TMJ is termed “gait”. There is *mandibular gait* and *disc-condyle gait*.

*Mandibular gait* consists of condylar rotation and translation. With these movements combined, TMJ opening, closing, protrusion, retraction and laterotrusion can occur.

*Opening:* The mandible moves by rotation of the condyle in a horizontal axis. After the first few degrees, the condyle translates anteriorward down the articular eminence of the temporal bone. When the posterior condyle comes to rest in its final anterior/inferior position below the midpoint of the articular crest, full opening has been accomplished.

*Closing* is the exact reverse of opening and ends with the teeth in full contact.

*Protraction or protrusion* occurs by translation of the condyle.

*Retraction* is the opposite function of protraction.

*Laterotrusion or side shifting* involves translation of one condyle and pivoting of the opposite condyle.

*Disc-condyle gait* is secondary to mandibular movement and is most noticeable during translation. The disc moves with the condyle and remains on top of the condylar head throughout. During rotation, however, the disc remains immobile as the condyle spins under it.
**Ligaments:**

*Fibrous Capsule:* Provides stability to the TMJ. The lateral projection of the fibrous capsule is the temporomandibular ligament.

*Temporomandibular ligament:* Consists of two bands; outer oblique and inner bands and reinforces the lateral aspect of the capsular ligament by limiting the opening of the mouth during the rotation of the mandible.

The *discal collateral ligaments* attach to the articular disc and condylar head to divide the TMJ into two separate joint spaces; superior and inferior. The ligaments allow the disc to rotate on the condyle while preventing dislocation of the disc.

The *capsular ligament* surrounds the entire TMJ and resists medial, lateral and inferior displacement of the condyle.

**Muscles:**

**Muscles of mastication:**

*Temporals:* Covers the temporal bone and is a powerful biting muscle. It elevates and retracts the mandible.
Masseter: Covers the lateral ramus and coronoid process of the mandible. It elevates and protracts the mandible and allows for clenching of the teeth.

Medial pterygoid: Two heads (deep and superficial), both embrace the lower lateral pterygoid to elevate and protract the mandible. Unilateral action of both heads pulls the chin to the contralateral side. Bilateral action produces grinding.

Lateral pterygoid: There are two heads; upper and lower. They insert into the mandible neck, articular disc and TMJ capsule. Together, these heads protrude the mandible and depress the chin. Unilaterally, they allow for mandible laterotrusion.

Accessory muscles:

Digastric: There are two bellies; anterior and posterior. Both unite in a common tendon which is connected to the hyoid by a loop of fibrous tissue. They act together to steady and raise the hyoid during swallowing and speaking, and depress the mandible.

Mylohyoid: This muscle forms a sling under the tongue which supports the floor of the mouth. It elevates the hyoid and the tongue during swallowing and speaking and raises the floor of the mouth. It functions during the grinding of food in the mouth.

Geniohyoid: This muscle pulls the hyoid antero-superiorly thus shortening the floor of the mouth. It also widens the pharynx for receiving food during swallowing.
**Infrahyoid:** Called strap muscles, it consists of four muscles which depress the hyoid bone and larynx during swallowing. These are the sternohyoid, sternothyroid, thyrohyoid and omohyoid muscles.

**Platysma:** This muscle originates in the fascia and skin over the pectoralis major and deltoid. It acts to tense the skin of the neck, draw the corners of the mouth down and depress the mandible.

**Buccinator:** This muscle aids mastication by pressing the cheeks against the teeth during chewing.

The following is a quick chart to review the function of the muscles of the TMJ:

<table>
<thead>
<tr>
<th>Open mouth</th>
<th>Close mouth</th>
<th>Protrusion</th>
<th>Laterotrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digastric</td>
<td>Temporalis</td>
<td>Masseter – deep part</td>
<td>Temporalis - ipsilateral</td>
</tr>
<tr>
<td>Mylohyoid</td>
<td>Masseter</td>
<td>Lateral pterygoid</td>
<td>Pterygoids – contralateral</td>
</tr>
<tr>
<td>Geniohyoid</td>
<td>Medial pterygoid</td>
<td>Masseter</td>
<td></td>
</tr>
<tr>
<td>Infrahyoid</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Normal ranges of motion for the TMJ for men and women during the mandibular gait phase of active range of jaw motion are as follows:

<table>
<thead>
<tr>
<th>Full open</th>
<th>Protrusion</th>
<th>Laterotrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-60 mm male</td>
<td>6-11 mm male</td>
<td>4 mm min. (+3 mm) male/female</td>
</tr>
<tr>
<td>40-55 mm female</td>
<td>6-12 mm female</td>
<td>same</td>
</tr>
</tbody>
</table>

**Nerves:**

CNV provides sensory innervation to the face and tongue and motor innervation to the muscles of mastication. Divided into three branches; ophthalmic, maxillary and mandibular, it is the mandibular branch that provides motor input to the masseter, temporalis, and medial and lateral pterygoids.
CNVII or facial nerve provides motor function to the accessory facial muscles; posterior digastric and stylohyoid.

**Blood Vessels:**

The maxillary artery as a branch of the external carotid passes through the lateral pterygoid dividing into three parts. The first branch supplies the inner ear, eardrum, mandible, gums and teeth. The second branch supplies the muscles of mastication. The third branch supplies the palate, orbit and pharynx.

The pterygoid plexus is a venous plexus found between the temporalis and lateral pterygoid.

**Fascia:**

The temporal fascia encompasses the temporalis muscle. Fascia encompassing the platysma is continuous with the inferior border of the mandible.

Section 19: Temporomandibular Joint and Acceleration/Deceleration Impact (continued)

Temporomandibular joint disorder (TMD) has affected 75% of individuals in their lifetime. According to Weinburg and LaPointe, TMD has been classified into 4 mechanisms of injury:
**Classic mandibular whiplash:**

During hyperextension, the head is forced back and jaw forced open causing stretching or tearing of the collateral discal ligaments. During hyperflexion, the head rebounds forward causing the jaw to slam shut crushing the retrodiscal space. Muscle spasm, especially of the lateral pterygoid accentuates the condition.

**Increased vulnerability to injury:**

A preexisting jaw condition or vulnerable position at the time of impact is more likely to injure the jaw during acceleration/deceleration impact. Some preexisting conditions are joint pain, joint, intermittent locking, limited jaw motion, dental issues. Important to discern is if the symptoms worsened or new symptoms and dysfunction appeared.

**Direct trauma to jaw:**

Blunt trauma can occur during acceleration/deceleration impact. This could be from the jaw hitting the dash or steering wheel, a loose object hitting the face or a strike of the airbag.

**Iatrogenic injury:**

Cervical traction can lead to TMD if the sling is not placed properly or if the patient talks or chews gum during traction.

The following conditions should be differentially diagnosed as they could create similar symptoms as TMD:

- Myofascial pain syndrome and trigger points radiating to the face
- Improperly fitting dentures
- Temporal arteritis
- Avascular necrosis
- CSF rhinorhea
- Dental infection
- Middle ear infection
- Sinusitis
- Drug induced headache, muscle ache, sleeplessness or bruxism
The acceleration/deceleration event affects the TMJ via momentum and direction of impact, position of the victim, what the injured was doing at the moment of impact, restraint systems, stature of injured, any loose or flying objects, condition of the patient prior to injury, dental status, bruxating, etc.

**Traumatic injury from acceleration/deceleration impact:**

**Bones:**

*Fracture:* With fracture of the mandible or maxilla, malocclusion may result. Grating sounds could indicate a condyle neck fracture; with pain toward the mandible angle, there could be a styloid process fracture. These are medical emergencies.

*Periostitis* is an inflammation of the periosteum usually from maxillary or mandibular exostoses. Injury can occur from whiplash, tooth brushing, hard objects within food, poor fitting or broken dentures or dental prostheses.
**Teeth:**

*Broken teeth:* Excessive jaw pressure rarely breaks a healthy tooth but can easily break a tooth that was unhealthy, decayed or abscessed. A broken or diseased tooth must be corrected prior to any evaluation or treatment of the TMJ.

*Avulsed teeth:* A “knocked out” tooth is a dental emergency. In most cases, a healthy tooth that was well preserved can be reimplanted. This must be done immediately for it to be affective.

*Intruded teeth:* During an impact, a tooth can be forced deeper into its socket. This can be confused with the TMD. There will be alveolar pain and the tooth will be loose. This is a dental emergency and must be referred immediately.

**Joints:**

*Fibrous ankylosis of the disc:* Disc adhesions can occur after prolonged abnormal loading. Causes are disc derangement, traumatic joint bleeding, or hemarthrosis. Adhesions adhere the disc to the articular eminence leading to alteration in movement. The adhesions, once mature, can be painless. However, a reproducible pop can be heard upon jaw opening.

*Acute closed lock:* Caused by laxicity or trauma, this anterior dislocation of the disc blocks condylar translation. The restriction is 5 – 10 mm open. Patients may be able to reduce the condition themselves by moving the jaw in a specific way. Joint pain, restricted movement without joint sounds, apprehension upon jaw opening, malocclusion, suboccipital pain, dysphagia and tinnitus are symptoms. Initially, there will be no joint sounds but reproducible restrictions during jaw opening.

*Acute open lock:* This anterior dislocation of the condyle prevents its normal return to resting. Acute trauma, excessive joint laxicity or excessive forceful jaw openings are causes. The jaw will be locked open with joint pain, apprehension of jaw movement, a need to close the mouth from muscle strain, suboccipital pain, dysphagia and tinnitus. There are no joint noises.

*Joint capsule injury:* Injury to the capsule occurs with continuous pain that increases with jaw use. Muscle splinting can be secondary especially in the masseter, temporalis and lateral pterygoid.

*Synovitis:* This intracapsular inflammation affects the retrodiscal tissue and is usually caused by a posterior condyle, trauma, bruxism, chronic gum chewing, infections, RA and lupus. The posterior attachment imbibes increasing intracapsular pressure allowing the condyle to anteriorly displace at rest. The joint shifts to the opposite side leading to an ipsilateral malocclusion. Joint pain occurs at full occlusion.

*Capsular contracture:* This painless condition is an inability of the TMJ to passively stretch and can occur following chronic capsulitis or synovitis. Over time, jaw opening is limited and the jaw deviates to the involved side. The patient complains of opposite side jaw pain due to compensation.
**Ligaments:**

*Capsulitis:* Inflammation of the joint capsule from repetitive action is a result of mandibular hyperextension, prolonged dental procedures, endotracheal intubation, and/or wide mouth yawning. Pain increases when the capsule is stretched or jaw translated and is exacerbated by mandible protrusion, contralateral chewing and wide open mouth. There is usually condylar pain and joint swelling.

*Temporomandibular ligament* injury can lead to a lateral condyle and/or disc displacement. Disruption can lead to improper tracking and increased pressure on the retrodiscal tissue.

**Muscles:**

*Contusion:* A blow to the jaw can occur during a motor vehicle accident. Swelling, subcutaneous bleeding, and pain upon palpation are symptoms. Late effects include muscle spasm which can lead to lock jaw.

*Tendinosis:* The temporalis muscle is vulnerable to injury over the zygomatic arch. Pain during chewing radiating to the temporal and mandibular areas is characteristic as well as pain deep to the zygomatic arch, night pain associated with clenching, bruxating or bad side sleeping posture. Chronically, it can present with spasms, jaw deviation and arthrosis.

*Myofascitis:* According to Travell, the most common cause of pain at the head, neck and jaw is inflammation and muscle spasm. Fatigue, spasm, and decreased nutrition and oxygen supply to the muscle can lead to myofascitis and trigger points. Myofascitis of the temporalis and/or masseter can cause sudden jaw pain creating a functional distortion in jaw movement. Tightness, weakness, stiffness, loss of fine motor control, decreased opening and alteration of occlusion points can all be signs of myofascitis. Trigger points in the temporalis, masseter, lateral pterygoid, platysma, digastric as well as the upper trapezius and sternocleidomastoid all refer pain to the jaw. It is important to discern which muscle is radiating the pain for proper treatment.

*Trismus:* This acquired myotonia is due to a chronic spasm of the masseter, lateral pterygoid or temporalis and leads to a decrease in the opening and function of the jaw.

*Myofibrotic contracture:* This painless condition in which fibrosis of muscle fibers leads to resistance of the muscle to passively stretch. Usually caused by trauma or infection, the closing muscles are usually affected thus opening of the jaw becomes limited.

**Nerves:**

*Bell’s palsy:* Trauma, infection, ischemia, viral infection and severe exposure to cold of CNVII can lead to facial paralysis and distortion. Usually unilateral, there may be partial loss of taste. Sometimes it resolves as mysteriously as it arrived.
**Trigeminal neuralgia:** Compression of CNV can be caused by sclerosis, tumors, neuromas and vascular malformations. The condition is recurrent with severe unilateral shock-like pain, burning and radiations. There are no referred pain patterns or secondary muscle spasms with this condition. In initial phases, trigeminal neuralgia can appear as a whiplash related jaw injury.

**Arteries:**

**Temporal arteritis:** Also known as giant cell arteritis, this is an inflammatory disease of the temporal artery. It has been associated with polymyalgia rheumatica, lupus, infection and RA. Symptoms are fever, headache, scalp tenderness, pain upon chewing, blurred vision, and sudden blindness. This condition is definitively diagnosed by biopsy for the identification of giant cells.

**Fascia:**

Lacerations or fascial tears can be found with impact injury especially within the platysma which could affect jaw function.

During acceleration/deceleration impact, TMJ injury can occur when the head is forced back during hyperextension. The jaw forcibly opens beyond the physiological joint limit causing stretching or tearing of the posterior attachments and collateral discal ligaments. When the head is forced forward, the jaw becomes slammed shut causing compression of the retrodiscal tissue. Myospasm of the lateral pterygoid is common and can be due to clenching from cervical pain.

Preexisting conditions, vulnerable jaw position at impact and underlying jaw disease allows for greater vulnerability of injury upon impact. The TMJ should not be evaluated until any bruising subsides.

The following questions need to be asked of the patient to determine if the TMJ has been injured from the impact:
- What are the speed and size of the vehicles?
- Was the vehicle hit from the rear, front or side?
- Where was the patient seated?
- What was the head position?
- Were there restraints?
- What is the patient’s size?
- Was it a direct trauma?
- What is the health of dental structures?
- Does the patient clench, bruxate or chronically chew gum?

The following conditions need to be ruled out before TMJ disorder can be ruled in:
- temporal arteritis
- avascular necrosis
- CNS disorders
- dental issues
- ear nose
- throat issues
drug interactions causing headache
muscle ache
loss of sleep
bruxism
infection
inflammation
thyroid disease
myasthenia gravis
trigeminal neuralgia
depression
RA
acoustic neuroma.

Section 20: Other Regions Commonly Injured During Acceleration/Deceleration Impact

_Upper Extremity:_

**Shoulder:**

For a more complete understanding of the soft tissue function, injuries and treatment of the shoulder please refer to Soft Tissue Injury 104, Linda Simon, DC.

Shoulder injuries are common with acceleration/deceleration impact. There are many means in which the shoulder can be injured; direct impact with the door, seat belt injury to the top of the shoulder, a raised arm can lead to brachial plexus or cervical nerve root injury, the shoulder can be hit by the air bag, a tight hand grip on the steering wheel could lead to severe strain of the forearm myofascia. It is just as important to assess the mechanism of injury and body position when considering the shoulder after an acceleration/deceleration impact as it is to assess the cervical spine and TMJ.
Bones:

Of the shoulder’s 3 bones, the clavicle is the only bone attached to the skeleton. The limited articulation of the shoulder girdle to the frame has the advantage of flexibility and disadvantage of low stability and poor protection from injury. The soft tissue structures highly susceptible to injury and scar tissue formation are primarily responsible for maintaining the association of the shoulder girdle with the body.

Joints:

The glenohumeral joint, a very shallow ball and socket is capable of 120 degrees of motion. A maximum of 30 percent of contact by the humerus occurs at any given time. This joint is mostly stabilized by the tendons and muscles that attach to it as the ligaments are fairly week.

There are two functional joints of the shoulder girdle; the scapulothoracic joint is a functional relationship between the scapula and thorax via muscular associations and articulations with the clavicle and humerus. The scapula rotates in relation to the thorax providing for range of motion. There is a functional joint at the extracapsular space between the coracoacromial arch and greater tuberosity.
Ligaments:

Glenohumeral joint ligaments: superior, medial and inferior run from the scapula to the lesser tuberosity and neck of the humerus and are the weakest support structures of the shoulder.

Coracohumeral ligament connects the coracoid process to the humerus strengthening the capsule during adduction and is the strongest in the shoulder.

Acromioclavicular ligament between the acromion and clavicle.

Ligaments of sternoclavicular joint and interosseous ligaments.

Coracoclavicular ligaments attach the clavicle to the scapula.

Coracoacromial ligament joins the distal coracoid to the acromion.

Transverse humeral ligament between lesser and greater tubercles of the humerus protects the biceps long head tendon.
**Muscles:**

*Anterior shoulder muscles:*

Between humerus and scapula:
- biceps
- coracobrachialis
- anterior deltoid
- subscapularis
Between sternum, clavicle and humerus:
pectoralis major

Between scapula and rib cage:
pectoralis minor
serratus anterior

Between clavicle and rib cage:
subclavius

Between clavicle and cervical spine:
sternocleidomastoid
Posterior muscles of the shoulder: Those with * attach anteriorly.

Between humerus and scapula:
*supraspinatus
infraspinatus
*teres major
teres minor
triceps
posterior deltoid

Between scapula and rib cage:
posterior serratus

Between scapula and cervical spine:
levator scapulae
trapezius

Between scapula and thoracic spine:
rhombooids

Between humerus and thoracolumbar spine:
*latissimus dorsi
Medial muscle of the shoulder:

medial deltoid

Bursa:

There are three bursi in the shoulder that can be injured: subacromial, subcoracoid, and scapulothoracic. Any of these can develop bursitis.

Fascia:

Deltoplectoral fascia is found over the deltoid and anterior pectoralis. Coracoclavicular fascia can be found from the clavicle surrounding the subclavius and the pectoralis minor. These are common regions for myofascitis.

Traumatic injury from acceleration/deceleration impact:

A traumatic event can cause the glenoid labrum to tear, the glenohumeral joint can dislocate, ligaments can sprain or tear (the most common ligament to be injured is the acromioclavicular ligament).

Tears to the fibrous capsule, glenohumeral ligaments, or rotator cuff can lead to glenohumeral joint instability. A fracture of the humerus or glenoid cavity can also lead to instability.
Acute trauma is usually the cause of rotator cuff ruptures but it is the age and condition of the muscle fibers and associated tendons that determine the extent of that injury. Tears to the rotator cuff are likely to be found either superficially nearer to the subacromial or subdeltoid bursa. The most common tear is to the supraspinatus near the long head of the biceps. When torn, the lack of muscle balance will affect the infraspinatus, teres minor and subscapularis. There may be an associated rupture of the long head of the biceps.

Injury to the suprascapular, long thoracic, spinal accessory and axillary nerves is possible. Entrapment can be found along the nerve pathway.

Nerve injury can result in muscle weakness. Muscle weakness leads to instability which in turn leads to degenerative conditions such as tendinosis, bursitis, arthritis, capsule or labrum tear, and ligamentous or tendon tear. The nerves involved are the suprascapular nerve, long thoracic nerve, spinal accessory nerve, and axillary nerve.

Two blood vessel conditions affect the shoulder; Thoracic Outlet Syndrome and Hyperabduction Syndrome.

Myofascitis or myofascial pain syndrome can develop trigger points in the levator scapula, trapezius, sternocleidomastoid, rhomboids, serratus anterior, infraspinatus as well as the pectoralis major.

Elbow, Wrist and Hand:

For a more complete understanding of soft tissue function, injuries and treatment of the elbow, wrist and hand please refer to Soft Tissue Injury 105, Linda Simon, DC.

It is common to injure the elbow, wrist and/or hand from acceleration /deceleration impact. The position and movements of the patient’s arm during impact will determine injury. Hands and wrists are highly vulnerable to fracture from air bag strikes, especially if the hands are placed at “10” and “2” as was taught years ago before air bags as proper steering wheel positions. With air bags, the actual correct position to hold the steering wheel is at “4” and “8”. By keeping the hands on the lower portion of the steering wheel, injury can be prevented from an exploding air bag. Tight grips on the steering wheel during impact can lead to myofascitis and muscle spasms from the hands to the shoulder and upper back. The elbow can be injured by direct trauma as can
the hands and wrists. A preexisting condition in the upper extremity such as carpal tunnel or tenosynovitis of the flexor group can be complicating factors.

Impairment ratings of the elbow give it higher significance in upper extremity impairment than the shoulder. An elbow fixated in extension would be more limiting than an immobile shoulder due to the shoulder’s compensatory scapulothoracic movement. The functional rotational system of the upper extremity allows for the proper dynamics in shoulder, cervical and thoracolumbar spine, and rib cage movement. Injury to this rotational system can have an effect to any or all of these structures.

**Elbow:**

![Elbow Diagram](image)

**Joints:**

There are three joints to the elbow; olecranon-trochlear joint (hinge for flexion/extension), radiocapitellar (hinge for flexion/extension but when combined with the proximal radioulnar joint is a pivot for rotation of the radius about the ulna), and proximal radioulnar joint (pivot for movement of the radius on the ulna). The depth of joint surface and variation of movement allow for this joint to have limited stability but more stability than the shoulder.

**Ligaments:**

![Ligament Diagram](image)
Elbow ligaments provide for the majority of stability. Varus stress or medially directed strain challenges the lateral ligamentous structures. Valgus stress or laterally directed strain challenges the medial ligamentous structures. Medial ligamentous structures provide less support than the lateral ligamentous structures allowing for more injury to occur with valgus stress. Interosseous ligaments connect the radius and ulna allowing for the crossover between the radius and ulna during pronation.

**Muscles:**

Flexors associated with humerus and scapula:
- biceps brachii
- brachialis
- brachioradialis

Flexor associated with humerus/ulna and carpal bone:
- flexor carpi ulnaris

Flexor associated with humerus/ulna and radius:
- pronator teres
Flexor associated with humerus and metacarpal bone:
  flexor carpi radialis

Extensor associated with scapula and ulna:
  triceps (long head)

Extensors associated with humerus and ulna:
  triceps (medial head)
  triceps (lateral head)

Extensor associated with humerus/ulna and metacarpal bone:
  extensor Carpi Ulnaris

Adductor associated with humerus and ulna:
  anconeus

Pronator associated with ulna and the radius:
  pronator quadratus

Supinator associated with humerus/ulna and the radius:
  supinator

The muscles associated with the elbow allow for flexion, extension, pronation and supination and are directly associated with the shoulder, hand and wrist. As they descend into the wrist and hand, tendons separate and travel through sheaths and fascial compartments. This fascial organization allows for hand dexterity and strength. Carpal bones are protected from injury as only one muscle directly articulates with a carpal bone. The retinaculum forms the roof for the palmar and dorsal carpal tunnels. Protection of bones, joints, tendons, nerves and blood vessels; and range of motion and dexterity of the hand are all functions of the soft tissue structures of the hand and wrist.
Upper Extremity (continued):

Elbow, Wrist and Hand (continued):

Wrist:

Bones:

Proximal row consists of four bones: *pisiform, triquetrum, lunate, scaphoid*.
Distal row consists of four bones: *hamate, capitate, trapezoid, trapezium*.
Five *metacarpals* and fourteen *phalanges* as the thumb has two (proximal and distal).
**Joints:**

Distal radioulnar joint is a pivot with an articular disc.

![Diagram of the distal radioulnar joint](image)

Radiocarpal joint is ellipsoid of the radius and proximal row of three carpal bones. Midcarpal joint, a compilation between the proximal and distal carpal bones glides whereas most of the movement (excluding pronation and supination) occurs in this region. Intercarpal, carpal-metacarpal joints glide allowing for flexion/extension, adduction/abduction. First metacarpal-carpal joint is saddle allowing for flexion/extension, adduction/abduction and circumduction. Metacarpalphalangeal joints are condyloid allowing for flexion/extension, abduction/adduction and finger circumduction. Interphalangeal joints hinge allowing for flexion/extension. Greater movement occurs between the proximal carpals than the distal carpals.

**Ligaments:**

Dorsal ligaments have more laxicity allowing for greater wrist flexion than extension. Palmar ligaments are stronger. The extensor retinaculum allows for the passage of extensor tendons and prevents bowstringing of the wrist tendons during hyperextension. Within the ligaments of the ulna and proximal carpal bones is the triangular fibrocartilage complex. It acts as a cushion and stabilizer between the carpal bones and ulna. The ulna is inconsistent in size from individual to
individual and a shorter ulna would increase the shear creating vulnerability to injury at this region.

*Muscles:*

**Wrist muscles:**

![Wrist muscles diagram](21-4a)

**Flexors:**
- Flexor carpi radialis
- Flexor carpi ulnaris
- Palmaris longus
- Flexor digitorum superficialis
- Flexor pollicis longus
- Flexor digitorum profundus

![Flexors diagram](21-5)
Extensors:
- Extensor carpi radialis longus
- Extensor carpi radialis brevis
- Extensor carpi ulnaris
- Extensor digitorum
- Extensor digiti minimi
- Extensor indicis
- Abductor pollicis longus
- Extensor pollicis brevis
- Extensor pollicis longus

Hand muscles:

Flexors:
- Flexor digitorum superficialis and profundus
- Flexor pollicis longus and brevis
- Flexor digiti minimi
- Interossei
- Lumbricals

Extensors:
- Extensor digitorum
- Extensor pollicis longus and brevis
- Extensor digiti minimi
- Dorsalis muscles
Abductors:
   - Abductor pollicis brevis
   - Abductor digiti minimi

Adductors:
   - Opponens pollicis
   - Adductor pollicis
   - Opponens digiti minimi

Nerves:

Nerves pass through the upper extremity as branches of the brachial plexus; median, ulnar, radial and musculocutaneous nerves. Entrapment causing compression or elongation can occur anywhere along the nerve path from the shoulder to the hand.
**Fascia:**

Fascia serves to protect as well as assist in organizing the array of myotendinous structures within the hand and wrist. It also provides for passage of nerves, blood vessels and lymph.

**Traumatic injury from acceleration/deceleration impact:**

There are a variety of conditions of the upper extremity that can occur from trauma associated with acceleration/deceleration impact. Fracture and/or dislocation of the elbow, wrist or hand can occur. Posterior Elbow Impingement Syndrome in which the ulna olecranon process impinges into the olecranon fossa of the humerus is common in hyperextension injuries; symptoms include loss of elbow extension, swelling, crepitus and locking. Radial rotation can occur at the proximal radioulnar joint with forceful pronation/supination; the radius head becomes fixed in rotation on the ulna. Ulna-olecranon block can occur with abnormal extension impinging the olecranon synovium; swelling prevents the olecranon from fitting into the fossa, pain and loss of movement occur. Sprain of the ulnar collateral ligament can cause painful valgus stress; complications range from ulnar neuropathy to degeneration of the medial epicondyle. Radial collateral ligament injury can occur from excessive varus stress; symptoms are painful locking, snapping and instability. Most wrist ligament sprains occur from hyperextension.

Preexisting elbow conditions can complicate traumatic injury. These can be RA, osteoarthritis, loose bodies, pushed elbow, superior radial rotation and ulna-olecranon block, and three conditions found in children; little league elbow, posterior dislocation of the elbow, and pulled elbow.

The tendons at the elbow take a lot of strain. Bicipital tendinosis, bicipital avulsion, triceps tendinosis, triceps avulsion, lateral epicondylosis and medial epicondylosis are all possible with acceleration/deceleration impact. Trigger points can occur in the arms and forearms. It is important to observe for torsion injuries and their affects on the upper arm, shoulder and neck. They can be found in the brachialis, the supinator and the pronator teres.

The brachioradialis has fascial connections to the extensor retinaculum of the wrist which serves to stabilize the wrist during elbow flexion. Adhesions within the brachioradialis will tighten the
muscle and pull on the retinaculum. This would have a direct affect on the tendons of the first compartment of the wrist (extensor pollicis brevis and the abductor pollicis longus). These tendons and fascial sheaths can develop a tenosynovitis.

There are five nerves that can become entrapped in the elbow region; radial nerve, posterior interosseous nerve, ulnar nerve, median nerve and musculocutaneous nerve. Symptoms of compression are paresthesia, numbness, pain and/or atrophy depending on if it is a sensory or motor branch. Also important to differentiate is at what point along the nerve the compression is occurring.

*Radial nerve* can be compressed in front of the subscapularis between the clavicle and humerus, under the axilla, at the lateral triceps head in the Fibrous Arcade, over the humerus spiral groove, between the brachialis and brachioradialis, at the radiocapitellar joint.
21-10

*Posterior interosseous* nerve can become compressed at the fibrous arcade.

21-11

*Ulnar nerve* can become trapped in the subscapularis, at the Arcade of Struthers over the triceps and aponeurosis of the medial intermuscular septum, at the medial intermuscular septum, in the cubital tunnel (distal to the medial epicondyle), and at the aponeurosis of flexor carpi ulnaris.
Median nerve can be trapped under the subscapularis, between the clavicle and pectoralis major, and between the humeral and ulnar heads of the pronator teres causing Pronator Syndrome. Pain in the flexor forearm with repetitive pronation and wrist flexion is common.
Musculocutaneous nerve may be trapped in the inferior of the pectoralis major, inside the coracobrachialis, lateral to the biceps tendon prior to branching into the lateral antebrachial cutaneous nerve. Symptoms are weakness of biceps and brachialis and paresthesias and pain at the lateral forearm.

In the wrist, DJD can be found at the scaphoid and distal radioulnar joint causing decrease in forearm pronation. Decrease in wrist flexion could be from a loss of joint play at the radiocarpal joint from sprain. A decrease in supination could be from a fixation of the distal ulna with the triquetral bone. A decrease in wrist extension can be due to a loss of joint play in the midcarpal joint. Carpal subluxation can occur after wrist sprain. The most commonly fractured carpal is the scaphoid from extreme dorsiflexion. The lunate-capitate ligament can be injured during hyperflexion of the hand. Nearby ligaments can also be injured leading to midcarpal instability. It is more common for a hand bone to break than a ligament to tear. However the ulnar collateral ligament of the thumb at the metacarpal-phalangeal joint can tear due to abduction stress.

Wrist tendons are organized into compartments protecting them from injury. However, it also allows for more than one tendon to be injured at a time. The flexor tendons are more protected than the extensor tendons because they travel deeper. The most commonly injured tendons are in the first dorsal compartment (abductor pollicis longus and extensor pollicis brevis) and is termed Intersection Syndrome. The extensor carpi ulnaris is the second most commonly injured tendon followed by the extensor carpi radialis longus and brevis, flexor carpi ulnaris and flexor carpi radialis. Tenosynovitis deteriorates the tendon creating inflammation and adhesions in the tendon sheath leading to thickening. Tendinosis can occur in the tendons of the hand in the extensor pollicis longus, extensor indicis proprius, and extensor digiti minimi.
Fascia of the wrist and hand is intricate and delineates function. Tendon sheaths can be injured creating fixations of the tendons they house and dysfunction of the muscle/tendon complex and associated bones. The tendons are vulnerable to compression syndromes within the retinaculum.

Aponeuroses found throughout the forearm and hand associate with the wrist and hand muscles and tendons. The strongest is the palmar aponeurosis which assists in the delineation of muscle groups and provides for smooth movement of the fingers. Pathology causes a variety of compression syndromes and contractures within the hand.

21-14

*Carpal Tunnel Syndrome* can be caused by inflammation to the lumbricals, carpal bone fracture or dislocation. Injury to the tendons and muscles may not be at the wrist but may occur as a tenosynovitis at the forearm or of the pronator teres to reproduce symptoms.

21-15

*Guyon’s Ulnar Tunnel Syndrome* is usually caused by trauma. It is at the ulnar aspect of the wrist formed by the palmar carpal ligament and an aponeurosis of the flexor carpi ulnaris muscle. There is a compression of the sensory branch to the fifth and fourth fingers, as well as motor innervation to the interosseii, adductor pollicis, hypothenar and lumbrical muscles. The ulnar nerve bifurcates inside this tunnel into its sensory and motor divisions.

Compression to the *superficial radial nerve* can occur proximal to the dorsal wrist or proximal forearm. Supination and pronation tend to aggravate it.
Compression to the *distal posterior interosseous nerve* can occur as the nerve passes over the distal radius entering the wrist capsule.

Section 22: Other Regions Commonly Injured during Acceleration/Deceleration Impact (continued)

**Lower Extremity:**

**Hip and Knee:**

For a more complete understanding of the soft tissue function, injuries and treatment of the hip and knee please refer to Soft Tissue Injury 110, Linda Simon, DC.

The hips and knees are vulnerable during acceleration/deceleration impact. The hips and lower back are more likely to be injured during a side impact as the body is thrown laterally side to side.Impacts in which the vehicle spins can also lead to a shearing of the lower body as it responds to torsion forces while being restrained. It is common for the knee to be injured from hitting the dash or jamming the foot into the brake. Preexisting conditions such as DJD can increase vulnerability to injury and healing times.

**Hip:**

**Bones:**

![Diagram of Hip Bones](22-1)

![Diagram of Hip Bones](22-2a)
Bones are the *femur*, and *pelvis (ischium, ilium, pubis)*

**Joints:**

The hip joint is a ball and socket allowing for stability with less range of motion. Acetabulum depth is increased by a labrum. The roof receives the most force. The function of the hip is to support body weight and provide for locomotion. It has three axes of rotation. Flexion is 120 degrees with knee extension and 140 degrees with knee flexion. Extension is 20 degrees with knee extension and 10 degrees with the knee flexion; the difference from loss of hamstring function in flexion. Abduction of one hip is in conjunction with the other hip equally. Maximum hip abduction is 90 degrees. Adduction and medial rotation is 30 degrees; lateral rotation is 60 degrees. Circumduction is not circular but an irregular curve established by the three planes of movement.

As man evolved into the erect position, hip ligaments coiled around the femoral neck clockwise. Extension tightens, flexion loosens them making it an unstable position. When a person is seated crossed-legged, adduction is associated with flexion and external rotation creating hip instability. Here, force applied to the femoral shaft can cause posterior dislocation with or without fracture of the acetabulum. This can occur during acceleration/deceleration impact.
**Ligaments:**

Ligaments are capsular, transverse acetabular, iliofemoral, pubofemoral, ischiofemoral and ligament teres.

**Muscles:**

*Flexor muscles*: Those with an * are mentioned more than once.

- psoas
- iliacus
- sartorius
- rectus femoris
- tensor fascia lata
- anterior fibers of the gluteus medius
- anterior fibers of the gluteus minimus
pectineus
adductor longus
gracilis.

Extensor muscles:
gluteus maximus
posterior fibers of gluteus medius
posterior fibers of the gluteus minimus
hamstrings (semimembranosis, semitendinosis, biceps femoris)

Abductor muscles:
gluteus medius
gluteus minimus
tensor fascia lata
*gluteus maximus
piriformis

Adductor muscles:
adductor magnus
adductor longus
adductor brevis
*gracilis
*hamstrings
*gluteus maximus
quadratus femoris
obturator externus
*pectineus
obturator internus

_Lateral rotators:
*piriformis
*obturator internus
inferior and superior gamelli
*quadratus femoris
*pectineus
*gluteus maximus
*gluteus medius

_Rotators:
*tensor fascia lata
*gluteus minimus
*gluteus medius

Pelvis is stabilized by simultaneous contraction of the adductors and abductors bilaterally. Any imbalance causes pelvic tilt.

_Bursa:_

Bursa of the gluteus medius, gluteus minimus, obturator externus, obturator internus, psoas, iliopectineal, ischiogluteal, vastus lateralis.

_Nerves:_

![Diagram of nerves](image)
**Lumbar plexus** is formed by L1, 2, 3 and part of L4 nerves derived from the spinal cord between T9 and T11 and are located in the psoas. There are six nerves: iliohypogastric (T12-L1), ilioinguinal (L1), genitofemoral (L1, 2), lateral femoral cutaneous (L2, 3), femoral (L2, 3, 4), obturator (L2, 3, 4) and the lumbosacral trunk to the sacral plexus (L4, 5).

**Sacral plexus** is formed by L4, 5, S1, 2, 3 nerves. There are 9 nerves; superior gluteal (L4,5,S1), inferior gluteal (L5, S1,2), posterior femoral cutaneous (S1,2,3), common peroneal (L4,5,S1,2), tibial (L4,5,S1,2,3), nerve to the quadratus femoris and gamellus inferior (L4,5,S1), nerve to the obturator internus and gamellus superior (L5, S1,2), and 2 nerves to the genital region (S2,3). In the thigh, the peroneal and tibial nerves fuse to form the sciatic nerve.

**Blood Vessels:**

Blood Vessels of the hip and thigh are housed in the femoral triangle, a region bordered by the inguinal ligament, adductor longus, sartorius, pectineus and iliopsoas.
**Fascia:**

The tensor fascia lata is strong, dense and invests the thigh muscles. Laterally it runs from the iliac crest to the tibia as the iliotibial tract which attaches to the tibial lateral condyle.

**Traumatic injury from acceleration/deceleration impact:**

Preexisting conditions such as coxa valga (femur shaft angled to more than 125 degrees), coxa vara (femur shaft angled to less than 125 degrees), anteversion (internally rotated femoral condyles), retroversion (externally rotated condyles), hip dysplasia, pelvic distortion, osteoporosis, DJD, RA can make the lower extremity more vulnerable to increased injury from trauma. Ligament injury is less common in the hip. Trauma can injure them but fracture of the femoral neck and head are more common especially in the elderly. The labrum can tear leading to pain, catching, the hip giving way, a painful pop or click from passive flexion with rotation. This is a surgical condition.

Contusion, strain and laceration can occur to muscles of the lower extremity from extreme injury. Severe burns can be caused by an explosive air bag. Scar tissue and adhesions can create trigger points. Hematoma can also occur. Atrophy can develop from neurological dysfunction but can also be present with scar tissue and adhesions. Pay close attention to the iliopsoas, gluteals and quadratus lumborum after acceleration/deceleration impact with low back sequela.
These muscles will react when a restrained or unrestrained patient is tossed around. Trigger point development is common and atrophy can occur. These muscles must be rehabilitated. In women, the tensor fascia lata is a common secondary injury due to improper pelvic mechanics and hormone influence on the fascia of the iliotibial band. If treating the iliotibial band does not help alleviate the patient’s condition, look to the sartorius for the initiating cause. Sartorius strains are common with cross-legged positions. Hamstrings can be strained from a forceful slam of the brake. Inflammatory conditions such as RA, gout, infection, muscle tears, synovitis, cellulitis can lead to bursitis.

Nerve root trauma can result from injury affecting the IVF. Radicular pain into the lower limbs, decrease in deep tendon reflexes, muscle spasm or fasciculation, paresthesia, decreased sensitivity to pin prick and atrophy are all symptoms. Be wary of cauda equine syndrome. This patient is a medical emergency and must be sent to the hospital immediately. Nerve entrapment can occur with fibrosis or loss of elasticity in muscular tissue. Trauma can injure the blood vessels and lymph.

The transversalis fascia includes the diaphragm, iliopsoas, pelvis and thigh. The fascia of the quadratus lumborum affects movement of the ilia, lumbar spine and the iliolumbar ligament and can be injured in acceleration/deceleration impact.

**Knee:**

**Bones:**

Bones of the knee are *femur, tibia, fibula* and *patella.*
**Joints:**

The knee allows for flexion/extension, and rotation when the knee is flexed. In extension, the knee is more vulnerable to stress which can be a factor in trauma. The patella and its underlying structures can be injured when hitting the dash. The knee joint (largest and most complicated joint in the body) is a hinge that allows for some rotation. Axial rotation occurs as the tibia rotates around a pivot point at the condyles.

The plica, found in 60% of the population is a remnant of mesenchymal tissue near the medial infrapatellar fat pad.
The menisci deepen the tibial articular surfaces and act as an elastic coupling mechanism to transmit compressive forces between the femur and tibia.

Proximal tibiofibular joint is strengthened by the anterior and posterior ligaments of the fibula head and moves slightly during ankle dorsiflexion and plantar flexion. The distal tibiofibular joint articulates the distal fibular and tibia and is responsible for ankle stability and strength.

**Ligaments:**
The external ligaments strengthen the fibrous capsule and are important in stability during flexion/extension and patella tracking. They are the patellar ligament, lateral collateral ligament, medial collateral ligament (most commonly injured ligament in the knee), oblique popliteal ligament, coronary ligaments and arcuate popliteal ligament.

The internal ligaments are the cruciate ligaments which are within the articular capsule between the medial and lateral condyles. The anterior cruciate is weaker and attaches to the tibia anteriorly. The posterior cruciate is stronger and attaches posteriorly. They stabilize the knee and maintain articular surface contact as the joint hinges. Rotational stability is determined by the cruciate and collateral ligaments.

**Muscles:**

*Extensors:*
quadriceps femoris(rectus femoris, vastus lateralis, vastus medialis and vastus intermedius)
Flexors:
The hamstring group (biceps femoris, semitendinosus, semimembranosus),
Gracilis
Sartorius
Popliteus
Gastrocnemius
Soleus
plantaris.

Medial rotators:
Sartorius
Semitendinosus
Semimembranosus
Gracilis
popliteus

Lateral rotators:
biceps femoris
popliteus
tensor fascia lata
**Bursa:**

Suprapatellar, popliteus, subcutaneous prepatellar, subcutaneous infrapatellar and deep infrapatellar.

**Nerves:**

The obturator nerve innervates the adductors, obturators and gracilis. The femoral nerve innervates the quadriceps, pectineus, sartorius, iliacus and psoas. The sciatic nerve separates again at the knee into the common peroneal and deep peroneal nerves. The tibial nerve innervates the gastrocnemius, popliteus, plantaris, soleus, tibialis posterior and flexor muscle groups.

**Blood Vessels:**

The femoral artery is the main blood supply to the lower limb. It descends behind the popliteal fossa and branches into the anterior and posterior tibialis arteries through the leg.

**Fascia:**

Knee fascia lies within the popliteal fossa and tensor fascia lata.

Section 23: Other Regions Commonly Injured during Acceleration/Deceleration Impact (continued)

**Lower Extremity** (continued):

**Knee** (continued):

**Traumatic injury from acceleration/deceleration impact:**

Shin splints (medial tibial stress syndrome) can be caused by a slam on the brakes or the shin hitting the dash. Patella malalignment can occur from excessive lateral forces causing external rotation of the tibia while the quadriceps femoris is contracting. Complicating factors are DJD, RA, or any joint mice. Medial plica syndrome can occur from injury.
The medial meniscus is more susceptible to injury. Usually there is a rotation component with a valgus or varus aspect. Compression and shearing tear the meniscus. Ligament injury can occur concurrently with meniscus tear. Trauma with valgus and external rotation forces will injure the medial collateral ligament. Trauma that forces hyperextension injures the lateral collateral ligament. Accompanying injuries can be tears to the lateral capsule, biceps tendon, iliotibial tract and arcuate complex (capsular ligament between popliteus muscle and fibula). Anterior cruciate ligament is usually injured from extension and external rotation of the femur on the tibia, and internal rotation of the tibia on a flexed knee. Posterior cruciate ligament is injured from hyperflexion with the foot and ankle in plantar flexion. A rotational strain may overstretches the coronary ligaments.

Gastrocnemius/soleus can be injured from a sudden slam on the brakes. Hamstrings, iliotibial band and sartorius have already been covered.

Bursitis can occur to the prepatellar, infrapatellar, popliteal and pes anserine from impact.

The peroneal, saphenous, sural and tibial nerves can all become entrapped in injured tissue.

Aneurysms are often found behind the knee. Be wary of preexisting conditions such as varicose veins thrombophlebitis and edema.

Fascia of the knee is most exposed at the popliteal fossa. It is continuous with leg and thigh fascia and referred pain from adhesions is common radiating into the ankle, buttck and thigh.

**Foot and Ankle:** For a more complete understanding of the soft tissue function, injuries and treatment of the hip and knee please refer to Soft Tissue Injury 111, Linda Simon, DC.

The ankle and foot are very vulnerable yet very vital to the support structure and functionality of the entire skeleton and frame. Its movements, balance and proprioception are closely associated with the knee, hip, pelvis and vertebral column.
Ankle:

_Bones:_

Bones of the ankle are the _tibia_, _fibula_, and _talus_.

_Joints:_

The tibia and fibula articulate distally. The medial malleolus and articulates with the talus; lateral malleolus articulates with the lateral side of the tibia and talus. The head of the talus has facets each for the articulation with the navicular and calcaneus. The ankle joint (tibiotalar joint) is a hinge allowing for flexion and extension. The distal tibiofibular joint is fibrous.

The ankle is most stable in dorsiflexion. This is helpful during acceleration/deceleration impact as the foot is more likely to be in dorsiflexion. Transverse stability in the ankle depends upon the tight interlocking of its bony surfaces as well as the medial and lateral collateral ligaments which stabilize the talus. Dorsiflexion is 20-30 degrees. Plantar flexion is 30-50 degrees.
Ligaments:

Lateral collateral ligaments: anterior talofibular, calcaneofibular, posterior talofibular. Medial collateral ligaments: anterior talotibial, posterior talotibial, deltoid (comprised of tibionavicular, anterior tibiotalar, posterior tibiotalar and tibiocalcaneal ligaments). Capsular ligaments thicken anteriorly and posteriorly. The tibiofibular joint ligaments are: interosseous, anterior tibiofibular, posterior tibiofibular.

Muscles:

Dorsiflexors:
extensor hallucis longus
tibialis anterior
extensor digitorum longus
peroneus tertius
**Plantar flexors:**
Gastrocnemius
Soleus
peroneus brevis
peroneus longus
tibialis posterior
flexor digitorum longus
flexor hallucis longus.

**Bursa:**
Calcaneal bursa exists between the tendocalcaneus or Achilles tendon and the superior of the calcaneus tuberosity.

**Nerves:**
The nerves associated with the ankle and feet are associated with the lumbar and sacral plexii.

**Blood Vessels:**
The popliteal artery divides into the anterior tibial and posterior tibial arteries. The anterior tibial descends divides into the medial malleolar, lateral malleolar and dorsalis pedis arteries.

**Fascia:**
The deep crural fascia divides into a superior extensor retinaculum and inferior extensor retinaculum. The superior extensor binds the tendons of the muscles in the interior compartment
of the leg. The inferior extensor retinaculum attaches to the antero-superior of the calcaneus. It forms a loop around the peroneus tertius and extensor digitorum longus tendons.

**Foot:**

The foot is vulnerable to injury during acceleration/deceleration impact as it usually braced to the brake, gas pedal or floor of the vehicle.

**Bones:**

![Diagram of foot bones](image)

The tarsal bones are the talus, calcaneus, cuboid, navicular, 1st, 2nd, and 3rd cuneiform bones. There are 5 metatarsals and 14 phalangeal bones.

**Joints:**

Assisted by axial rotation of the knee, it allows for three degrees of freedom so the foot can take any position in space and adapt to the surface it contacts. There are three axes of movement; transverse, long axis of the leg and of the foot. The most important joints for shock absorption are the intertarsal and tarsometatarsal joints. The total range of motion of adduction/abduction is 35-45 degrees; supination (52 degrees), pronation (25 degrees). Adduction with supination and
extension and creates inversion. Abduction with pronation and flexion creates eversion. With knee and hip rotation, total range of motion for inversion and eversion is 90 degrees.

The joints are the intertarsal, tarsometatarsal, intermetatarsal, metatarsophalangeal and interphalangeal. The intertarsal joints consist of the talocalcaneal, transverse tarsal (talonavicular and calcaneocuboid), cubonavicular, and cuneonavicular joints.


**Ligaments:**

At the subtalar joint, the ligaments are interosseous talocalcaneal (anterior and posterior bands), lateral talocalcaneal and posterior talocalcaneal. At the midtarsal joint, the ligaments are the plantar calcaneonavicular, dorsal talonavicular, bifurcated, dorsal calcaneocuboid, plantar calcaneocuboid and interosseous between the cuneiforms. Laterally there are several dorsal ligaments. The intermetatarsal joints are stabilized by dorsal, plantar and interosseous ligaments. For the metatarsophalangeal joints, each has a fibrous capsule strengthened by collateral ligaments. The plantar ligament forms part of the socket for the head of the first metatarsal.

**Arches:**
The plantar surface of the foot is supported by 3 arches; medial longitudinal arch, lateral arch and transverse arch. The weight of the body is applied at the keystone. The anterior arch is the shortest and lowest and the medial arch is the longest and highest as well as most important during standing and movement.

**Muscles:**

*Extensors:*
- Extensor digitorum brevis
- Extensor digitorum longus
- Extensor hallucis longus

*Flexors:*
- Flexor digiti minimi brevis
- Flexor hallucis brevis
- Flexor digitorum longus:
- Flexor hallucis longus:
- Flexor digitorum brevis:
Abductors:
Abductor digiti minimi
Abductor hallucis

Adductors:
Adductor hallucis

Deep muscles:
Lumbricals
Dorsal interosseii
Plantar interosseii

Bursa:
Lateral to the 5th metatarsal there is a bursa.

Nerves:
The foot is innervated by the sacral plexus.

Blood Vessels:

On the dorsum of the ankle is the anterior tibial artery which divides into the medial malleolar, lateral malleolar, dorsalis pedis and the lateral tarsal arteries.
Fascia:

The deep fascia of the foot is continuous with that of the leg. On the dorsum, it is continuous with the extensor retinaculum. Plantar, it is continuous with the plantar fascia. The plantar aponeurosis is comprised of bands of connective fibers that support the longitudinal arches and holds the foot together.

There are three fibrous tunnels (inferior extensor retinaculum, posterior to the lateral malleolus, posterior to the medial malleolus). They maintain the position of tendons and protects them.

Traumatic injury from acceleration/deceleration impact:

Be wary of preexisting conditions with foot injuries. These can range from DJD, RA, gout, bunions, hallux valgus, sesamoiditis, claw toes, hammer toes, forefoot and rearfoot deformities, diabetic neuropathy, Morton’s neuroma. The most common joint to experience a capsular lesion
in the ankle and foot is the talocalcaneal joint. The most common sprain is a varus sprain involving the lateral ligaments.

The tendons of the peroneals, gastrocnemius and tibialis can all develop tendinosis. Sudden ankle dorsiflexion of the ankle, a sharp blow or abrupt strain may rupture the plantaris tendon. The calcaneal and retrocalcaneal bursa can become inflamed due to Achilles tendon damage or excessive pressure on the region.

The most commonly injured nerve in the lower limb is the common peroneal nerve at the lateral fibula. It can be lacerated during fracture of the fibula neck or overstretched from rupture of the fibular collateral ligament. Tear of this nerve results in paralysis of the dorsiflexor and everter muscles producing foot drop. Tear of tibial nerve produces paralysis of the leg flexor muscles, loss of sensation and use of intrinsic muscles of the sole of the foot. Acute metatarsalgia is from a fibrous swelling of the 4th digital nerve.

Plantar fascitis can result from trauma. Continued strain can produce a bony spur.

Section 24: Injuries to the Thoracic Spine and Rib Cage during Acceleration/Deceleration Impact

**Thoracic Spine and Rib Cage:**

For a more complete understanding of the soft tissue function, injuries and treatment of the thoracic spine and rib cage please refer to Soft Tissue Injury 108, Linda Simon, DC.

Injury and dysfunction of the thoracic spine and rib cage can be very painful. Yet, this region is often neglected. Rib sprains, diaphragm and iliopsoas contractures, scoliosis can cause severe pain in the thoracic spine and rib cage as well as be complicating factors in injury.
Bones:

Structurally, there are two additional sets of articular facets on T1-T10 and one additional articular facet on T11-12 for the ribs. The spinous processes are elongated and in the mid thoracic region angle inferiorly to protect the spinal canal when the thoracic spine is flexed. T1-4 retain cervical spine features as the spinous processes are horizontal. Vertebrae increase in size more inferiorly.
Ribs 1-7 are true ribs because they articulate directly with the sternum through costal cartilage. Ribs 8-12 are false ribs because they attach to the sternum through the either the costal cartilage of another rib or not at all. The upper 7 costal cartilages connect with the sternum; that of ribs 7-10 meet inferiorly to form the costal margin. The cartilage of ribs 11 and 12 ends in the abdominal muscular wall. Ribs 11 and 12 have no articulation with the sternum.

Ribs 3-10 are typical ribs with a head, neck, tubercle and body. The rib’s body ends at the costal cartilage for anchorage with the sternum.

Ribs 1, 2, 11 and 12 are atypical ribs. The anterior scalenes attach to the first ribs and the brachial plexus and subclavian arteries pass behind it. Before the age of 25 the sections of the sternum are not fused as complete fusion occurs at age 40.
**Joints:**

The joints of the thoracic wall include those of the ribs and sternum, ribs and spinal column, intervertebral facets, and intervertebral discs. Between the ribs and spinal column, there are two articulations; costovertebral joint and costotransverse joint. These joints form a joint couple unit that is mechanically linked. Combined, the elevation of the ribs increases the transverse diameter of the lower thorax and the anterior-posterior diameter of the upper thorax. In the middle of the rib cage, both diameters are increased.

The thoracic spine and rib cage allow for flexion, extension, lateral flexion and rotation. Rotation distorts the rib cage. Rib concavity on ipsilateral rotation increases and flattens the opposite side and vice versa. The sternum is subjected to shearing forces as it becomes altered obliquely. The thorax is more flexible in youth than in senior years from costal cartilage ossification allowing for rigidity. T12 is the point of inflexion between the lumbar lordosis and thoracic kyphosis. It acts as a swivel point of the entire vertebral axis. Lumbar spine rotation is 5 degrees in each direction whereas thoracic spine rotation is about 35 degrees in each direction. The rib cage does not hinder thoracic rotation as it is 4 times greater than in the lumbar spine.
The movement of the thorax is to increase and decrease intrathoracic volume through pressure changes brought about by the intake and expelling of air. With the spinal column fixed, increasing the volume of the thorax is due to an increase in chest diameter in three dimensions; vertical diameter, transverse diameter and anteroposterior diameter.

**Ligaments:**

The ligaments of the thoracic spine and rib cage can be categorized by articulation. Costosternal joints have no ligaments. There are two ligaments associated with the costovertebral joint: interosseous ligament and radiate ligament which has three bands and attaches to the adjacent vertebral bodies and IVD annulus. The costotransverse joint has three ligaments; interosseous costotransverse, posterior costotransverse and the superior costotransverse ligament.
**Muscles:**

*Chest muscles:*
- platysma
- pectoralis major
- pectoralis minor

*Rib Cage muscles:*
- intercostalis external
- intercostalis internal
- intercostalis innermost
- subcostalis
- transversus thoracic
- levatores costorum
- sternocostalis
- diaphragm
- psoas
- iliacus
- quadratus lumborum.

*Back muscles:*
- serratus anterior
- serratus posterior superior
- serratus posterior inferior
- trapezius
- latissimus dorsi
- rhomboid group
- splenius capitus
- splenius cervicus
- sacrospinalis
- iliocostalis
- longissimus
- spinalis.
- Semispinalis
- multifidus
- rotatores
- Interspinalis
- Intertransverse

*Primary muscles of inspiration:*
- intercostal external
- sternocostalis
- diaphragm
Accessory muscles of inspiration:
- scaleneus anterior
- scaleneus medius
- scaleneus posterior
- serratus anterior
- latissimus dorsi
- pectoralis major
- iliocostalis (superior fibers)

Primary muscle of expiration:
- intercostalis internal

Accessory muscles of expiration:
- abdominal group (rectus abdominus, external oblique, internal oblique, transversus abdominus);
- iliocostalis
- longissimus
- serratus posterior inferior
- quadratus lumborum

Bursa:

The scapulothoracic bursa lies between the inferior medial portion of the scapula and the rib cage.

Nerves:

The spinal cord is housed in the spinal canal throughout the thoracic spine with 31 pairs of spinal nerves exiting the cord. The length and obliqueness of the nerve roots increase progressively more inferiorly. Dorsal rami pass backward to supply muscles, bones, joints, and skin of the back. Ventral rami of T1-11 are intercostal nerves. Nerve contributions to the muscles of the thoracic spine and diaphragm descend from the cranium and cervical spine. The diaphragm is innervated by the phrenic nerve that descends from C3,4. The trapezius is innervated by CN 11. The latissimus dorsi is innervated by roots of C6-8. The rhomboids are innervated by roots of C5. And the levator scapulae are innervated by roots of C3-5.

Blood Vessels:
The blood vessels of the thorax arise from the aorta. Once the aorta leaves the heart, it descends as the thoracic aorta which pierces the diaphragm at the aortic hiatus at the level of the vertebral disc between T12, L1. The thoracic aorta gives branches as the bronchial, esophageal and diaphragmatic arteries. The coronary, posterior intercostal and subcostal arteries also arise from the thoracic aorta.

**Fascia:**

There are many fascial elements; fascia of the anterior abdominal wall, fascia of the posterior abdominal wall, fascia of the deep back muscles, pectoral fascia and transversalis fascia.

**Traumatic injury from acceleration/deceleration impact:**

After an acceleration/deceleration impact injury, look for complicating factors such as osteoporosis, DJD, RA, ankylosing spondylitis, DISH, Scheureman’s Disease, congenital defects. Be wary of preexisting scoliosis as this condition can greatly affect the extent of injury and outcome of treatment. Osteochondrosis or costochondritis can be complicating factors or can be caused by seat belt or air bag injuries. This is more common in younger patients. In patients with a history of breast or lung cancer, look to the spine for metastases which could make the spine more vulnerable to fracture. Fracture of the thoracic spine and rib cage can occur during traumatic events. The air bag has been found to cause rib and sternal fractures. Ribs 3-10 are most commonly injured.

Spinal fractures can result from excessive flexion and/or extension force. Rotational shears can cause disc injury as well as ligament tear.

Compression fractures can result from a hyperflexion trauma.

Margin or chip fractures can occur from hyperflexion or hyperextension with compression or avulsion.
Fulcrum or Chance fracture is the horizontal splitting of the spinous process and neural which can be caused by seat belt injury in which the body is thrown forward against the restraining seat belt.

Sudden hyperflexion may lead to ligamentous avulsion of the spinous process. Severe hyperextension can lead to compression fracture of the spinous process. Ligament sprains are more likely in the costovertebral and costotransverse joint supportive ligaments as they are the most vulnerable. Shearing forces can tear the posterior spinal ligament in the thoracic spine, however rotary injuries are less likely to the spinal ligaments due to the protection afforded by the ribs.

Injury to muscle can be from a direct blow as a contusion, a strain is from excessive tensile force, a laceration or ischemia induced muscle damage. Special attention should be made to atrophy which can result from paralysis, immobilization or neurological conditions. Patients who are rehabilitating from acceleration/deceleration impact tend to be less mobile. Initiating mobility to the spinal and rib muscles once inflammation has retreated will assist in preventing atrophy.

Costoclavicular compression syndrome occurs when the brachial plexus and neurovascular tissues of the subclavian artery are compressed between the clavicle and the 1st rib. Traumatic injury can create this situation and cause pallor, coldness, cyanosis of the hands, numbness and tingling in the fingers.

Peripheral neuropathy can be caused by intervertebral disc disease or foraminal compression. Changes seen with this condition consist of muscle and bone atrophy, skin alterations or responses, and loss of sensation. Peripheral neuropathy at T1,2 levels create symptoms in the arm due to its contributions to the brachial plexus. Neuropathy at the mid thoracic levels will produce symptoms in the side or front of the trunk. Compressions in the T11,12 nerve roots will create pain in the iliac fossa and the sex organs. Cervical disc lesions radiate to the upper trunk and will create pain at the upper thoracic levels and shoulders.

Upper motor neuron lesions in the spinal cord of the thoracic spine can affect the lower extremities and organs as follows:

<table>
<thead>
<tr>
<th>Organ</th>
<th>Spinal Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>C8-T4</td>
</tr>
<tr>
<td>Lungs</td>
<td>T2-5</td>
</tr>
<tr>
<td>Esophagus</td>
<td>T4-5</td>
</tr>
<tr>
<td>Stomach/duodenum</td>
<td>T6-8</td>
</tr>
<tr>
<td>Liver and gall bladder</td>
<td>T7-8</td>
</tr>
<tr>
<td>Pancreas</td>
<td>T8</td>
</tr>
</tbody>
</table>
Within the fascia, the connective tissue elements can tear and develop fibrous adhesions which can limit muscular movement and support of structures. Adhesions can also block lymphatic drainage from organs and tissues creating local congestive responses.

Pneumothorax is the presence of air in the pleural cavity resulting from lung disease or injury and causes a partial collapse of the lung. Rib fracture can be a common cause of this condition and is found with severe acceleration/deceleration trauma. Pneumothorax is a medical emergency but is treatable when detected promptly.

Section 25: Injuries to the Lumbopelvic Spine during Acceleration/Deceleration Impact

**Lumbopelvic Spine:**

For a more complete understanding of the soft tissue function, injuries and treatment of the lumbopelvic spine please refer to Soft Tissue Injury 109, Linda Simon, DC.

The lumbopelvic spine is one of the most complicated and structurally significant regions of the skeletal frame. It provides the foundation for the spinal column, maintains the body’s center of gravity, allows for flexibility and strength, and is a highly adaptable region especially during pregnancy and child-birth. Injuries to the region are not usually life threatening but can be life altering. The lumbopelvic spine is the base of biomechanical operation. When the weight of the body rests on one limb, the pelvis tilts to the opposite side forcing the vertebral column to bend convex toward the resting limb. The extents of the lateral curves depend upon the anatomy of the sacroiliac joints. A more horizontal joint creates greater lordosis and kyphosis where a more vertically oriented joint creates less lordosis and kyphosis. The discs closer to the sacrum take greater force. Ranges of movement of the lumbopelvic spine constitute flexion and extension, lateral flexion, and axial rotation of 5%. Movement is coupled for lateral flexion and rotation.
There are 5 lumbar vertebrae, 1 sacrum, 1 coccyx and 2 os coxae which comprise each of the pelvic bones (ilium, ischium and pubis).
There is the pelvis major (ala of the sacrum, the iliac fossa and the sacral base) and pelvis minor (coccyx, sacrum, pubis symphysis and the ischial tuberosities).

**Joints:**

The joints of the lumbopelvic spine are the intervertebral joints, intervertebral discs, lumbosacral joints, sacroiliac joints, sacrococcygeal joint and pubic symphysis. The lumbosacral joints are the weakest in the vertebral column and are among the most complex and diverse in the human body.
Sacroiliac joints operate with nutation and counternutation which are rotational. With nutation, the sacral base rotates anteriorly and inferiorly while its apex rotates superiorly and posteriorly; iliac bones approximate and ischial tuberosities move apart. With counternutation, the sacral base rotates posteriorly and superiorly while the apex rotates inferiorly and anteriorly; iliac bones move apart and ischial tuberosities are brought closer together. The thoracolumbar fascia is a major force in the locking of the sacroiliac joints.

**Ligaments:**

Intervertebral joints are supported by capsular ligaments. The vertebral arches are joined by segmental ligaments: ligamentum flavum, interspinous, supraspinous and intertransverse ligaments. Intervertebral discs are supported by anterior and posterior longitudinal ligaments.
Lumbosacral joints are stabilized by capsular and iliolumbar ligaments.

Sacroiliac joints have sacroiliac, sacrospinous, sacrotuberous and the short axial ligament.

Sacroccocygeal joint is comprised of interosseous ligament, anterior sacroccocygeal ligament and three lateral sacroccocygeal ligaments.
Pubis symphysis has several short but strong ligaments: interosseous; anterior, posterior and inferior ligaments. The inguinal ligament serves as a site of attachment for the aponeuroses of the abdominal muscles.

**Muscles:**

*Muscles of the posterior abdominal wall:*
- diaphragm
- psoas
- iliacus
- quadratus lumborum.
*Back muscles:*
latissimus dorsi
sacrospinalis (iliocostalis, longissimus and spinalis)
serratus posterior inferior
semispinalis
multifidus
rotatores
interspinalis
intertransverse
Abdominal muscles:
- rectus abdominus
- external oblique
- internal oblique
- transversus abdominus

Muscles of the anterior thigh:
- sartorius
- quadriceps femoris (rectus femoris, vastus lateralis, vastus medialis and vastus intermedius)
- iliacus
- psoas
Muscles of the adductor group:
- adductor magnus
- adductor brevis
- adductor longus
- gracilis
- obturator externus
- pectineus

Muscles of the hamstring group:
- semimembranosus
- Semitendinosus
- biceps femoris
**Lateral muscle:**
tensor fascia lata

**Muscles of the gluteal group:**
gluteus maximus
gluteus medius
gluteus minimus
piriformis
obturator internus (gamellus inferior and gamellus superior)
quadratus femoris

**Bursa:**
gluteofemoral bursa
ischial bursa
trochanteric bursa
bursa of the gluteus medius
bursa of the gluteus minimus
bursa of the obturator externus
bursa of the obturator internus
psoas bursa
bursa of the vastus lateralis
Nerves:

Muscles innervated by the lumbar plexus (L2,3,4) are:
- psoas major and minor
- iliacus
- sartorius
- pectineus
- quadriceps femoris group (rectus femoris, vastus lateralis, medialis and intermedius)
- adductor group (adductor brevis, adductor magnus, adductor longus)
- gracilis

Muscles innervated by the sacral plexus (L4,5, S1,2,3) are:
- piriformis
- gluteus maximus
- gluteus medius
- gluteus minimus
- tensor fascia lata
- quadratus femoris group
- gamellus inferior and superior
- obturator internus
**Blood Vessels:**

Four arteries enter the pelvis; internal iliac, median sacral, superior rectal and ovarian.

**Fascia:**

The transversalis fascia lines the abdominal wall. The fascia of the posterior abdominal wall (iliac fascia, quadratus lumborum and thoracolumbar fascia) encloses each of the muscles it is associated with.

**Traumatic injury from acceleration/deceleration impact:**

Be wary of preexisting complicating factors such as osteoporosis, osteochondrosis, osteomalacia, stenosis, infection, malignancy, fracture, osseous defects, congenital defects and scoliosis. Also be wary of capsular lesions, osteoarthritis, rheumatoid arthritis, Still’s disease, ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, chronic spinal fibrositis, intersegmental dysfunction, dislocation, intervertebral disc disease, facet syndrome, intrapelvic protrusion, osteitis condensans ili, osteitis condensans pubis and osteitis pubis. Any of these conditions alone or in combination make the spine more vulnerable to injury and/or increase healing time after injury.

Compression fractures can occur in the anterior superior of the vertebral body from hyperflexion and may present with plate infraction. Chip fractures can avulse from the anterior superior or inferior body from hyperflexion or hyperextension.
Burst fractures of the vertebral body can be due to axial compression without hyperflexion. Fulcrum or Chance fracture is the horizontal splitting of the spinous process and neural arch that also encompasses the superior vertebral body, laminae, pedicles, transverse process, and arch. The cause of this is a seat belt injury during acceleration/deceleration impact. Articular fractures are usually from direct trauma or sideway twist injury. This is painful and usually accompanied by other spinal fractures or dislocations. The most common causes of fractures to the pelvis are from direct blows, falls from a height, crushing injury or major automobile accidents.

Pelvic fractures usually occur in more than one location and can lead to a complete break in the pelvic ring. The most common sites for pelvic fracture are the ischium and the pubic ramus.

Joint dislocation is rare in the lumbopelvic spine. Ligaments can tear but are much stronger in this region leading the bones to be more vulnerable to fracture. The IVD, however, is more vulnerable to tearing especially from acute traumatic injury.

Muscle injury is common in the lumbopelvic spine. The iliopsoas can be sheared during a lateral or rotary impact. Also commonly injured is the quadratus lumborum, erector spinae and gluteal muscles. These muscles usually develop spasm and trigger points which must be addressed. Look to the tensor fascia lata for a preexisting fibrosis as the mechanics of the pelvis can be altered from this condition. After injury or as a preexisting condition, the abdominal core muscles can be weak which can contribute to lumbopelvic instability. Chronically short hamstrings can also restrict pelvic movement and complicate any injury.

Injury to the iliohypogastric (T12-L1), ilioinguinal (L1) and genitofemoral nerves (L1,2) can cause sensory loss. Trauma to the lateral femoral cutaneous (2,3) can lead to paresthesias and pain over the lateral anterior thigh. The femoral nerve (L2,3,4) can be traumatically affected by spinal cord injury and pelvic fracture and cause paralysis of the iliopsoas and/or quadriceps femoris with sensation loss in the medial thigh and leg. Obturator nerve (L2,3,4) can lead to impairment of the adductors. With superior gluteal nerve (L4,5,S1) injury, there is paralysis of the gluteus medius and minimus weakening abduction of the leg. Inferior gluteal nerve
(L5, S1,2) is injured more frequently with paralysis of the gluteus maximus. Posterior femoral cutaneous nerve (S1,2,3) injury leads to pain or sensory loss at the upper medial thigh and genitalia.

Traumatic sciatic nerve (L4,5,S1,2,3) injury can result from herniated disc, dislocation of the hip, pelvic fracture. There would be hamstring paralysis causing loss of leg flexion, steppage gait and inability to stand on the heels or toes.

Traumatic injuries to the arteries are serious. Any one of these conditions could lead to an embolism that could travel toward the heart and be fatal. These conditions are out of the scope of this course.

Fascitis and fascial tears create pain and limit movement and fluid flow. Swelling is common and can limit lymph, arterial and venous flow. The fascia of the quadratus lumborum if compromised will restrict movement of the ilia, lumbar spine and can affect the biomechanics at segments associated with its attachment at the iliolumbar ligament. Iliac fascitis attached to the inguinal ligament could create pain and swelling and dysfunction of associated tissues. Pelvic fascitis can create functional deficits in sex organs as well as swelling and pain in the surrounding tissues.

Internal injuries to the abdomen and thorax are common with severe traumatic incidents and can be life threatening. Most of these injuries are discovered in emergency settings at the scene of an accident or at the emergency facility. It is unlikely but not impossible for patients with internal injuries to appear for care in a conservative care facility. Patients still ambulatory and in shock can sometimes underestimate the severity of their condition. It is always prudent to advise patients to seek immediate medical care if there is any possibility of internal injury, biochemical imbalance from; for example, a severe burn, or appears with some neurological deficit. The diagnosis and management of these conditions is out of the scope of this course.

Hour 6
Section 26: Complicating Factors for Acceleration/Deceleration Impact

There is a vast array of issues that determine injury and treatment success. Some factors depend on the mechanics of the actual impact and have been previously discussed. Equally important is the condition of the patient at the time of trauma. So many variables exist that outcome should not be predetermined by computer models in which important factors are overlooked. But in fact, they are not considered to the detriment of many accident victims. As a practitioner and advocate in a legal system designed to place the patient at the disadvantage, understanding and documenting complicating factors allow the practitioner to justify necessity of care as well as better explain to the patient why their symptoms have not subsided as quickly as they had hoped or why they will continue needing care. The AMA Guidelines to Whole Man Impairment Ratings define complicating factors and the amount of time that should be added to the patient’s care to accommodate for them. These are merely guidelines as each patient would heal at their own pace.
In third party liability, the patient must be considered as they were at the time of incident. The medical-legal liability allows for return of the patient to the condition they were just prior to the incident (as though it had never occurred). Some cases may never return to the pre-accident condition. For those patients, a level of disability can be calculated using several methods such as AMA Whole Man Impairment Ratings. These objective methods contribute to health considerations for the rest of the patients’ lives as well as any settlement reached by the third party payer.

Age has an important effect on the extent and type of injury sustained. Patients under 16 are more vulnerable to cord injury but usually suffer less fracture due to the flexibility of their paraspinal ligaments. Patients over 60 may show osteoporosis making them more vulnerable to fracture. Hyperextension injuries with spondylolisthesis can injure the central cord. Older patients with prior injuries, arthritis, in poor physical condition and poor diet will also heal more slowly or may not completely heal at all.

Spinal canal size is an important factor with disc herniations and cord injury after trauma. Those with narrower spinal canals are at a greater risk of neurological deficit than those with larger canals. In canals of 10mm or less there is direct bony pressure on the spinal cord. Even a minor injury can have serious neurological deficits in these patients. In canals that are 16 inches or less, moderate hyperextension injury can lead to severe spinal cord swelling and neurological deficits. Canals that are 19mm or more are much less vulnerable to cord deficit after injury.

The following can narrow the spinal canal:
- Hypertrophic posterior facets
- Ossification of the posterior longitudinal ligament
- Pseudospondylolisthesis
- Congenital malformation
- Overlap of the articular facets from hyperlordosis

Cervical spine pathology commonly complicates injury and healing. Degeneration of articular structures alters spinal functionality and structure leading to longer healing times and poor prognosis. Degeneration at the joints of Luschka is more common in the lower cervical spine. Hypertrophic bone formation can protrude to the IVF causing neuropathy or into the transverse foramina causing vertebral arterial compression. Disc degeneration can be a preexisting condition in older individuals with the lower cervical spine most affected. Decrease in disc height will approximate structures and decrease mobility between the posterior facets allowing for degeneration. The canal and the IVFs can be altered by spondylophyte formation. Lack of motion at a vertebral level causes increased vulnerability of the vertebral components above and below causing disc herniation and spur formation. This loss of movement can be documented with lateral cervical X-rays where the patient’s neck is in flexion, extension and neutral.

Inflammatory conditions such as advanced ankylosing spondylitis complicated by secondary muscle atrophy and RA (which has the additional disadvantage of weak ligaments) cause complications that must be addressed and documented with acceleration/deceleration impact.
Biomechanical variants cause the spine to compensate in manners that make segments more vulnerable to injury. Congenital block, hemivertebrae or scoliosis all put stress on different parts of the spine which must be evaluated for injury.

Loss of cervical lordosis is common after acceleration/deceleration impact but may also be present prior to the injury. Here, the weight of the head is transferred to the vertebral bodies and not the articular facets which are adapted for the weight. A reversal of the cervical lordosis is common after injury to the posterior longitudinal ligament or in those with bad posture. Weight bearing is altered allowing for the development of degenerative changes usually to the disc.

Segment fixation which can be caused by congenital malformations and biomechanical joint fixations can make the segments above and below more vulnerable to injury. Preexisting segmental fixations allow for greater injury risk.

Scoliosis is common and varies in severity and symptomatology. Any imbalance in the spine makes it more vulnerable to injury and increases healing time. Ligaments, joints, muscles and fascial components that are stressed by the curvature will be more vulnerable to injury. Damage is consistent with mechanism of injury and how the spine was tossed about during impact. Compression to the ribs, lateral spinal structures and discs are common. Internal injury to the thorax and abdomen are also more common with scoliosis. It is also not uncommon for the scoliosis to decompensate and worsen after injury. This can occur with even the most stable scoliosis cases. Spastic and shortened gross muscles may pull on the entire spinal column like an accordion creating exacerbations of old conditions and the creation of new ones directly related to the curvature. In older patients, there may be osteophytes that would complicate any injury.

Pelvic Crossed Syndrome is a common condition in which deconditioned patients suffer from inappropriate muscle firing due to poor posture, lack of exercise and possible obesity. Here, the iliopsoas and erector spinae are tight and abdominal muscles and gluteus maximus are weak. Tight hip flexors cause a flexion of the hip, anterior pelvic tilt and increased lumbar lordosis. This increases weight bearing to the posterior of the disc jamming the posterior facets. The hamstrings are also usually tight to decrease the pelvic tilt and compensate for weak gluteals. This affects gait, hip extension and leads to hypermobility of L4, L5 and hypomobility of the thoracolumbar region.

Shoulder Crossed Syndrome is a condition in which poor posture and deconditioning creates tight pectoralis, levator scapulae and trapezius; and weak cervical flexors, rhomboids and serratus anterior. These patients have an elevation and protraction of the shoulders and forward head posture which over stresses the upper cervical spine with hyperextension. A secondary overstressed area is C5-T4. There may be hyperlordosis in the upper cervicals with kyphosis from C5 to T4. It is common to have shoulder dysfunction from muscle imbalance of the rotator cuff and deltoids with this condition.

When individuals have Pelvic Crossed Syndrome, Shoulder Crossed Syndrome or both prior to a traumatic event, these patients can be very challenging to treat. Their symptoms are usually highly varied with the development of neurological sequela or Thoracic Outlet Syndrome due to the lack of muscle tone or balance. There may be extremity conditions unrelated to neurological
conditions but as a direct result of the muscle imbalance. The patient may develop shoulder issues, hip issues or both. Usually these patients need correction of their injuries and may also need rehabilitation of their spinal structures as well.

Myofascial compromise is common and found with trigger points, stress points, headaches, neck pain, jaw pain and any number of soft tissue structural problems afflicting the patient prior to impact. Most of these issues will worsen or complicate the injury sustained. All must be documented and addressed.

Immune conditions can make the patient a poor candidate for healing. It is common with diabetics that their muscles do not respond as quickly and as efficiently as those without this condition. Frozen shoulder is more common in diabetic women and can occur after injury to the shoulder or in patients with preexisting Shoulder Crossed Syndrome.

Pregnancy can complicate healing as the ligaments are soft and the injuries can be more severe. Seat belt injuries can be highly dangerous to pregnant women and it is important to discuss with all pregnant patients that they wear their seat belt below the fetus at the level of the ASIS to avoid injury to their baby during a possible MVA.

Medications can complicate healing as some can cause increased bleeding, muscle pain such as with Fosamax, ligament weakness as in steroids. Understanding what medications or supplements a patient is taking will assist the practitioner in the best plan for the patient’s recovery.

Section 27: Examination of the Cervical Spine

**History:**

A thorough history of the patient’s condition prior to the trauma, past and family history, detailed description of the accident, full history of their symptoms just after the impact and up to the time of their consultation is vital. Police reports, hospital or other physician records after the incident will give you a complete picture of what happened to your patient. For medical-legal purposes, exam notes should contain all aspects of OPQRST and daily notes should contain all aspects of SOAP. Reexams should be performed every 8-12 visits or if the patient’s condition suddenly changes.

It is common for hospitals to diagnose only cervical strain acceleration/deceleration impact. This should not be the working diagnosis or a medico-legal if the patient’s condition is far more involved than a strain. Objective testing and complete examination and history override any diagnosis that may diminish the severity of the patient’s injuries. Communicate this to the patient and/or their attorney. Advise the patient not to give their insurance company information regarding their health but to contact you as the practitioner for objective findings, or their legal representative.
Observation:

Mood, mental responsiveness, fear, anxiety, aggression, disorientation, memory loss, suspicion and cooperation can be indicators of post-traumatic injury and may require psychological and/or neurological evaluation. How the patient holds and moves their head can indicate antalgia, spasm, or malingering if the antalgia does not match the complaints or objective findings.

Palpation:

Anterior bony palpation: supine

Hyoid bone – above the thyroid cartilage and opposite C3 body. Patient swallows to demonstrate hyoid movement.

Thyroid cartilage – Inferior to the hyoid, opposite C4,5 vertebral bodies.

Carotid tubercle – One inch laterally from the first cricoid ring (opposite C6). Palpate unilaterally to avoid occlusion causing carotid reflux.

Posterior bony palpation: supine

Occiput.

Inion – EOP is midline on the occiput.

Superior nuchal line – bilaterally lateral from the inion, this ridge leads to the mastoid processes.

Mastoid process – lateral end of the superior nuchal line.

Spinous processes - C2-C7, some are bifid.

Facet joints – pain during palpation indicates joint dysfunction. Note spacing between joints which may indicate ligament tear.

Motion Palpation: seated

There are three levels a joint can be moved passively. Active movement is during exercise. Passive movement is beyond active movement and is attained upon joint mobilization (movement is limited by the resistance barrier). With motion palpation, the joint is brought to the elastic barrier. The final level as with manipulation goes beyond the resistance barrier into the paraphysiological space to the limit of anatomical integrity. During motion palpation, the
practitioner feels for limitation, swelling and pain. Motion palpation should be gentle, slow and the patient’s head should be stabilized to prevent aberrant movement.

For the posterior joint, stabilize the patient’s head anteriorly and contact the side of the spine being examined. Rotate, laterally flex and flex the patient’s neck to the opposite side being examined to “locked out” the joints. Move each joint into the elastic barrier. Lateral flexion and rotation is examined by moving the patient’s head and directing the line of drive. For extension, the patient’s head is extended but remains in lateral flexion and rotation. For flexion, the practitioner contacts the anterior cervical spine (do not compress the carotid artery). With the patient’s head fully rotated, laterally flexed and flexed, contact the anterior tubercles of the side to which the head is turned and further move the joints.

**Anterior soft tissue structures:**

SCM – rotate patient’s head away. Swelling and/or hematoma can be noted after acceleration/deceleration injury. Spasm of one side (torticollis) causes the head to remain fixed in rotation and flexion.

Scalenes – anterior, medial and posterior scalenes can be palpated with the head turned away. They can be inflamed and/or with hematoma after a trauma. Anterior scalene, if swollen, can impinge on the vascular components and produce Thoracic Outlet Syndrome.

Lymph chain – near SCM, swelling indicative of infection can cause torticollis.

Thyroid gland – enlargements can indicate disease.

Carotid pulse – next to the carotid tubercle, palpate one artery at a time.

Parotid gland – normally unpalpable near the mandible angles. Enlarged gland is indicative of disease.

Supraclavicular fossa – superior to the clavicle, lateral to the suprasternal notch. Swelling can be secondary to injury. A cervical rib can be palpated in the fossa.
Posterior soft tissue structures:

Trapezius – EOP, superior nuchal line, mastoid processes to T12; clavicle, acromion and the spine of the scapula. Acute hyperflexion injures this muscle. Swelling, trigger points and spasm are common.

Sub-occipital muscles – palpate as a unit. It is common for injury and swelling with trauma. Spasm can cause headaches.

Levator scapulae – palpate from superior scapula to the cervical spine. Commonly injured in acceleration/deceleration trauma. Trigger points are near insertion to the scapula.

Posterior cervical musculature – assess for swelling and spasm.

Lymph nodes – antero-lateral of the trapezius, if palpable can indicate disease.

Greater occipital nerves – either side of EOP are not usually palpable. After acceleration/deceleration injury, they can become inflamed and palpable. A common cause of headache.

Superior nuchal ligament – EOP to C7 spinous is not usually palpable. Injury can cause swelling. A depression between spinous processes could indicate tear.

Percussion:

Percussion can identify fracture. If accustomed to percussion, lightly tap on the spinous processes.

Passive Ranges of Motion:

Passive ranges of motion should NOT be performed on a patient who has had acute cervical trauma. The spine may be unstable and neurological damage could be caused by passively moving the spine.

Passive Functional Testing:
Soto Hall – patient is supine. Place one hand on their sternum to stabilize the thoracic and lumbar spine. With the other hand at the occiput, flex the patient’s head and neck on the sternum to pull the posterior spinous ligaments compressing the vertebral bodies. In the event of vertebral injury or compression fracture, pain will be produced locally.

**Nerve root evaluation:**

Maximum Cervical Compression – patient’s head is laterally flexed then rotated to one side. Positive is pain or increase of pain on that side.

Jackson’s Compression – patient turns their head to each side. Exert a downward pressure on the top of the patient’s head after each rotation. Positive is pain or increase in pain upon movement.

Spurling’s Test - patient laterally flexes and rotates their head to one side. Place one hand on the top of the patient’s head, the other as a fist delivers a quick mild strike to the top of the other hand. Pain or exacerbation of pain is positive.
Distraction - grasp the patient’s chin and occiput, one in each hand and slowly lift their head. A positive finding is decrease of pain.

Bakody’s Sign – this is an antalgic posture seen with nerve root impingement at the foramen. The patient will walk with their hand on top of their head which relieves their pain.

Bikele’s Sign – patient seated, shoulder abducted, extended and externally rotated, elbow flexed. Extend the patient’s elbow to stretch the nerves of the brachial plexus. Increase of radicular pain is positive.
Nerve evaluation:

*Dermatome Evaluation:*

Pain perception – With sharp pin, the pressure needed to cause pain in the affected extremity can be compared with the pressure needed to cause pain in the unaffected extremity.

Findings are as follows:
Anesthesia – complete loss of sensation.
Hypoesthesia – decreased sensation.
Hyperesthesia – increased sensation.
Hyperalgesia – increased sensitivity to pain.

Temperature sensitivity – loss of hot and cold. Use ice for safety.

Two point discrimination – use hairless skin as on the palmar forearm. Touch two pins to the patient in close proximity then gradually separate their distance until the patient can feel them separately. Normal on the hands is 2-5 mm, on the back it is 30-70 mm.

Vibratory perception – place a tuning fork over bony prominences in the upper and lower extremities. It is within normal limits for no sensation with senior citizens below the knee.

Sense of position – grasp the big toe at its sides and flex the joint while the patient has their eyes closed. The patient is asked which joint and in which direction it moved.

Stereognosis – the ability of the brain to know weight and form of an object in their hand. The patient closes their eyes and an object (such as keys) is placed into their hand for identification.
Light touch – stroke the skin gently with cotton.

Topognosis – the ability to perceive tactile stimulation. The patient closes their eyes and is asked to identify the location on an arm or leg of where they had just been gently touched.

**Deep tendon reflexes:**

Damage to a lower motor neuron can lead to a decrease of the normal reflex. Damage to an upper motor neuron can lead to a pathological reflex. Reflexes are graded as follows:
- Grade 0 – no response
- Grade 1 – hyporeflexive
- Grade 2 – normal
- Grade 3 – hyperreflexive
- Grade 4 – clonus

The following are deep reflexes accessible to testing:

- **Maxillary or Jaw Jerk (motor portion of CN5)** – with the patient’s mouth half open, tap each half of the patient’s jaw. Normally the jaw jerks shut. A hyperreflexive reaction on one side can indicate a frontal lobe lesion.

- **Biceps (C5 – musculocutaneous nerve)** – with a neurological hammer, strike your thumb over the patient’s biceps tendon. This reflex is diminished with C5 nerve root injury.

- **Brachioradialis reflex (C6 – radial nerve)** – neurological hammer strike is at the posterior forearm just above the wrist.

- **Triceps reflex (C7 – radial nerve)** – neurological hammer strikes the triceps tendon superior to the olecranon.

- **Patellar reflex (L4)** – contact inferior of patella and strike with a neurological hammer.

- **Achilles reflex (S1)** – strike the tendon with a neurological hammer.

**Section 28: Examination of the Cervical Spine (continued)**

**Nerve root evaluation:**

**Pathological Reflexes**

Spinal cord injury results in a loss of inhibition of these primitive neurological responses normal with infants under six months. All of these tests do not need to be performed. Choose an upper extremity test and lower extremity test to confirm suspicion of injury.
Upper Body Testing:

Chaddock’s Wrist Sign – ulnar side of the forearm is stroked with the blunt end of a neurological hammer. Wrist flexion and hand and fingers extension is a positive finding.

Forced Grasping Sign – stroke the palmar surface of the patient’s hand and the fingers close in a grasp.

Lower Body Testing:

Babinski’s Sign – stroke the bottom of the patient’s foot. The great toe extends and remaining toes extend and flare out is a positive sign.

Schaffer’s Sign – upon squeezing the Achille’s tendon there will be a Babinski Sign.

Rossolimo’s Sign - Upon tapping on the ball of the patient’s foot, there will be a flexion of the patient’s toes. This is not a Babinski sign.

Spinal cord evaluation:

Increasing the intrathecal pressure of the spinal cord exacerbates the symptoms of a space occupying lesion as in the following test:

Bradburne’s Sign – spinal cord contusion, compression or shock between the fifth and sixth cervical segments results in Thornburn’s Position; upper limb abduction, flexion and external rotation of the forearms.

Blood Vessels:

Passive vascular evaluations are limited to the axillary and subclavian arteries. Vertebral and carotid arteries are best evaluated with Doppler and /or contrast studies. Wright’s Test (passive) and Adson’s Test (active) evaluate blood flow through the thoracic outlet.

Wright’s test must be preceded by Allen’s Test which evaluates the patency of the radial and ulnar arteries into the forearm and wrist. If this is not done, the information gathered from Wright’s test can be inaccurate.
Allen’s Test is performed with the patient seated. Lift the involved upper extremity over the patient’s head for several seconds. Compress both radial and ulnar arteries at the wrist and allow the patient’s arm back down during compression. Free one of the arteries at the wrist and watch for blood flow to return back into the patient’s hand. Repeat the test releasing the other artery. If both arteries allow for blood flow then Wright’s Test can be performed. If one artery is compromised, Wright’s test cannot be performed and the patient needs a referral to a vascular specialist.

Wright’s Test - With the patient seated, both arms at their sides, stand behind and palpate their radial pulse. Raise their arm to 180 degrees as the shoulder is placed into an external rotation and abduction with slight extension. Monitor the pulse as the arm is raised to determine if it decreases or ceases and if so, at what arm angle. Repeat on both sides for comparison. The test is positive if the pulse is reduced or ceases at a level inconsistent with the opposite side. If both sides have a loss or decrease in pulse at the same arm position the test is not positive. A positive finding would be neurovascular compression of the axillary artery as seen in Hyperabduction Syndrome. A cause of this could be spastic scalene muscles.

Active Ranges of Motion: seated

*Flexion/extension* – patient touches their chin to their chest then looks at the ceiling. Observe fluidity and range.
Rotation – patient turns their head from side to side keeping eyes level.

Lateral Flexion – patient attempts to touch their ear to their shoulder bilaterally. Shoulder elevation created inaccurate results.

Functional Testing: seated

Shoulder Depression - depress the patient’s shoulder as they laterally flex their head away. A positive finding indicates muscle tension or nerve root adhesions.

Muscle Strength Testing: seated

Flexion - SCMs (bilaterally), scalenes and anterior flexors.

Stabilize the patient’s sternum and place the other hand on their forehead. They flex their head against resistance.

Extension - splenius, semispinalis, rectus capitus, trapezius.

Stabilize the upper thoracic spine and scapulae and cup the other palm over the occiput. The patient extends their head against resistance at the occiput.
Rotation - SCM (unilaterally), scalenes.

Stand in front and stabilize their opposite shoulder. Cup the mandible and temporal bone and ask the patient to rotate their head toward the hand against resistance.

Lateral Flexion - scalenes.

Stabilize their shoulder and contact the ipsilateral temporal/parietal region. The patient laterally bends against resistance.

Muscle Strength Grading:
Grade 0 – No muscle contraction. Verify with EMG.
Grade 1 – Slight contraction but the muscle is too weak to move a joint.
Grade 2 – Poor strength but muscles can move the joint through complete ROM.
Grade 3 – Fair strength. The patient can move through full ROM without resistance.
Grade 4 – Good strength. Normal ROM with resistance.
Grade 5 – Normal strength and ROM with heavy resistance.

Neurological Motor Testing: patient is seated, test for resistance.

C5 - axillary and musculocutaneous nerves: deltoid and biceps.

Deltoid: flexes, extends and abducts the shoulder
Anterior deltoid:

The patient’s shoulder is neutral, elbow flexed, forearm neutral. Stand behind them to stabilize their shoulder and contact the biceps as they resist posterior pull by flexing their shoulder.

Posterior deltoid:

Contact the patient’s posterior elbow as they resist an anterior push by extending their shoulder.

Medial deltoid:
Stand to their side, stabilize their shoulder and contact their lateral elbow. The patient resists medial push by abducting their shoulder.

**C5,6 - musculocutaneous nerve:** *biceps*

*Biceps:* flexes elbow and supinates forearm. Elbow flexion is sufficient to test C5.

![](image1)

The patient’s shoulder is slightly flexed, elbow flexed 45 degrees and forearm halfway between supination and pronation. Stabilize their elbow and contact their forearm just above the wrist. The patient resists downward pull by flexing the elbow.

**C6 motor function:** *biceps* and *wrist extensors.* (There is no pure assessment of C6 since the biceps is innervated by C5 and C6 and the wrist extensors are innervated by C6 and C7. Evaluate both).

*Biceps:* see above

*Wrist extensors:* *extensor carpi radialis longus* and *brevis, extensor carpi ulnaris*

![](image2)

The patient’s shoulder is neutral, elbow flexed 90 degrees, wrist extended slightly. Brace their elbow to their body with one hand and press against the dorsum of their wrist with the other. The patient further extends their wrist against resistance.
C7 motor function: *triceps* (radial nerve), *wrist flexor group* (median and ulnar nerves)

*Triceps*: Extends the forearm at the elbow.

The patient’s shoulder is slightly flexed, their elbow is flexed with forearm parallel to the floor. Hold the patient’s elbow and grasps their forearm (halfway between supination and pronation) just above the wrist. The patient resists an upward force.

C7 - ulnar and medial nerves: *wrist flexors* (*flexor carpi radialis* (median nerve – pure C7) and the *flexor carpi ulnaris* (ulnar nerve – C7,8, T1).

*Wrist Flexors:*

With the patient seated, their wrist flexed, hand in a fist; pull their fist out of flexion as they resist.

C8 motor function: *finger flexors* (*flexor digitorum superficialis* (median nerve) and *profundus* (median and ulnar nerves))
Finger flexors:

Have the patient flex their fingers against resistance.

T1 motor function: finger abductors (dorsal interossei and abductor digiti minimi - ulnar nerve)

Finger abductors:

With the patient’s fingers abducted, squeeze the patient’s fingers together against resistance.

Dynamometer: To evaluate motor strength of the upper extremity record the patient’s maximum grip. Repeat three times for each extremity.

Active neurological evaluation: seated

Valsalva’s Maneuver –The patient is asked to bear down as if straining at the stool by way of forcible exhalation against a closed glottis. An increase in cervical pain and radicular neuralgia is positive for nerve root compression from a disc.
Dejerine’s Sign – Coughing, sneezing and straining can increase radicular symptoms from CSF blockage (herniated or protruded intervertebral disc, spinal cord tumor or compression fracture).

**Active blood vessel evaluation:**

Allen’s Test must be performed prior to Adson’s Test.

Adson’s Test determines compression of the subclavian artery at the thoracic outlet from cervical rib, elongated C7 spinous, or spastic anterior or medial scalenes. A positive finding is common after acceleration/deceleration injury.

With the patient seated, radial pulse is taken at the wrist as the patient’s arm is abducted, extended and externally rotated. The patient takes a deep breath and rotates their head toward the arm being tested. Follow up with a Reverse Adson’s Test in which the patient rotates their head away from the tested arm. With compression of the subclavian artery, there will be a marked decrease or absence of the radial pulse.

**Healing:**

It has been said that it is better to break a bone than tear a ligament. This is not the case with the cervical spine. Structures protected by the bones are so vulnerable to fracture that permanent neurological damage can occur.

Joints can heal usually with cartilage and ligament damage. Torn cartilage can heal but usually frayed which sets the joint up for DJD. Motion assists the cartilage in healing as it increases circulation but be careful not to stress the joint beyond its capacity to remain intact.

Ligaments have limited circulation and heal with scar tissue or not at all. Rehabilitation and treatment can be successful but know when it is necessary to refer the patient to a surgeon for repair. Within 4 weeks after injury is optimal.

Nerve tissue can heal if immediate attention is taken to decrease inflammation. Rehabilitation can be accomplished with nerve damaged patients including upper and lower motor neurons. It is
a slow and difficult process but important to a patient limited by their injuries. Rehabilitation 111, Linda Simon, DC, covers neurological recovery in detail.

Muscle scar tissue and adhesions complicate function after injury. Identify scar tissue to minimize its development as it can diminish stretch and strength and cause dural sheath and nerve root compression syndromes.

Blood vessels can be decompressed as in Thoracic Outlet Syndrome. Identify tissues responsible for compression for affective treatment.

Fascia can heal when torn. Limit scar tissue and adhesions that can turn an acute problem into a chronic one with possible functional and neurological consequences.

Section 29: Imaging of the Cervical Spine and Advanced Diagnostic Imaging

It is imperative to have the best understanding of injuries incurred to the cervical spine and its soft tissue components. Depending upon the nature of injury, complicating factors, likelihood of disease, and the impact on therapy, the practitioner will decide which tests are necessary in the evaluation of the patient. An important deciding factor for advanced testing is that it should be based on clinical verification and the focus of treatment, as opposed to clinical proof. Also, when the exam findings are inconsistent, further verification needs to be sought.

**Plain film X-ray**, **CT**, **MRI**, **diagnostic ultrasound**, **bone scan**, **PET scan** will all provide information on the bones, joints, ligaments and muscles of the cervical spine. **EMG** and **nerve conduction** studies will provide information of a neurological nature. **Doppler** and **contrast dye** studies will provide information for vascular flow. Once the information is received, a course of treatment can be best formulated.

**Plain film X-ray**: This still provides the most clinically relevant information. However, considerations need to be made before exposing a patient to radiation. First is age. If the injury is minor with no complicating factors, or neurological or vascular components, the practitioner should weigh the risks of exposure with the benefits of films. Pregnancy is another vital consideration. No films should be taken of a pregnant patient. Exposure should also be considered. If the patient has had a history of frequent exposure to radiation, the benefits of films should be weighed against their lifetime of exposure.

Depending upon the patient’s history and exam findings, the practitioner should determine which films will provide them with the most accurate information. Curvature angles, stenosis, degeneration, facet imbrication, fracture, dislocation and possible disruption of ligaments can be seen in plain film. Metastasis, infection, and calcification of arteries, ligaments, joints, muscles and glands can also be viewed.

The following films are the standard and minimal required in viewing the cervical spine:

**A-P** – An A-P view will assist in diagnosing spinal curvature and degeneration. Viewed are the vertebral bodies of C3-C7, disc spaces, endplates, spinous processes, transverse processes, lateral
masses, arches and joints of Luschka. Vertebral rotation, lateral flexion and spinal lateral curvature can be seen.

**APOM** – This A-P view with open jaw will provide information on the upper cervical spine. Important to note is the orientation in space of the atlas as well as its relationship to the occiput and axis. A lateral shift of the atlas can indicate a tear of the transverse ligament. Of course, degeneration should also be noted.

**Lateral** – A neutral lateral view will provide information on the cervical curve, lateral masses, translation, disc spaces, vertebral endplates, anterior and posterior longitudinal ligaments, atlas-occiput and atlas-dens relationship. A break in the continuity of the anterior or posterior longitudinal ligaments may indicate disc bulging or with a history of trauma, ligament or disc tear. And increase in the atlanto-dens interval (ADI) can indicate transverse ligament instability. Normal interval is 1 – 3 mm.

Lateral flexion and extension films should be added to the study with any history of acute traumatic insult to the cervical spine:

Lateral in extension – A lateral view with the patient’s neck in extension provides information on whether there has been a break in the continuity of the anterior longitudinal ligament. Also, compared to the neutral lateral view is the translation of particular segments in relation to others. The extent of extension in relation to another region can also be seen. One can detect crush fractures.

Lateral in flexion – A lateral view with the patient’s neck in flexion will provide information on whether there has been a break in the continuity of the posterior longitudinal ligament.

Translation of the segments can also be seen. Excessive translation or flexion can mean a break in continuity of ligaments of the joint capsule. Tears in the ligamentum nuchae and interspinous ligaments can be seen as excessive space between spinous processes or a fanning out of the spinouses. Fracture can be seen.

Oblique views: Right and left anterior oblique views will provide the practitioner with information on the intervertebral foramen. When a patient presents with radicular symptoms, it may be prudent to take oblique views to determine if their radicular symptoms may be stemming from compressed foraminal interspace.

Normal cervical angle can be determined from a horizontal line through the anterior and posterior tubercles of the atlas and another line through the inferior of the body of C7. Right angles are drawn from each line and the intersection determines the degree of cervical angle. Normal is 35-45 degrees. Hyperlordosis is over 45 degrees, hypolordosis common with acceleration/deceleration injuries is less than 35 degrees.

Gravity line of the cervical spine is drawn vertically from the dens and should pass just to the anterior third of the body of C7. Vertical line forward of C7 indicates a forward protruding or goose-neck posture. This is a sign of anterior muscle spasm and great stress is placed on the
posterior lower cervical spine and musculature. Vertical line behind the anterior third of the body of C7 indicates hyperlordosis and possible muscle splinting of the posterior musculature.

George’s line is drawn along the posterior bodies of the cervical spine following the posterior longitudinal ligament. Stair-stepping of the line can indicate flexion or extension dysfunction with or without anterolisthesis or retrolisthesis. A break in the line usually indicates a disruption of the ligament and possible alteration of space for the spinal cord. The continuity of the posterior longitudinal and anterior longitudinal ligaments, posterior interspinal ligaments, and ligamentum nuchae can be viewed. This line can also be drawn with flexion and extension lateral views.

**Advanced Diagnostic Imaging:**

Ordering an advanced scan is a decision that needs to meet some criteria. Conflict in examination findings, suspicion of fracture or dislocation of the bony margin of the neural canal and articular pillars, central nervous system symptomatology, persistent neuromotor deficiencies, or pain resistant to improvement greater than 4-6 weeks are all reasons to order an advanced imaging study. An MRI can view disc desiccation and minimal protrusion, slight infoldings of ligaments, facet arthropathy, spinal cord tumors, edema or hemorrhage. However, a minimal disc protrusion finding without foraminal occlusion, or thecal sac encroachment or effacement of exiting nerve roots must be considered normal in asymptomatic and symptomatic patients. A 1990 Harvard study revealed that 70% of disc protrusions seen on MRI are found on asymptomatic patients. Thus the cause of their symptoms and/or dysfunction cannot be 100% ruled in with a positive finding of disc protrusion.

**CT scan:** This sectional study using ionized radiation is most reliable for bone disorders. There is no need for contrast agents and it removes the overlapping of shadows seen on plain films. Clearly viewed are fractures, dislocations, arthropathy, malformations, stenosis and facet hypertrophy. It is most commonly used in acute traumatic insult especially if the patient is unconscious. Bony abnormalities such as fractures and dislocations in relation to the spinal cord are best seen. In conjunction with plain film, 98% of fractures and 99% of dislocations are detected.

CT myelography identifies disc protrusions. This technique uses contrast dye. However, CT and MRI is the best combination to provide the most information for bony and neurological components of injury. MRI can also detect spinal cord contusion and edema. And there is no need for contrast dye with spinal MRI.

CT can also be used for chronic conditions such as degenerative joint disease and post surgical sequela of trauma. One can detect osteophyte proliferation, stenosis (PLL calcification), and the bony relationship with neural elements or nerve roots.
**MRI:** The magnetic resonant imager uses a combination of receiving and transmitting radio signals in cycle to produce the image. TR represents repetition time as the unit transmits a signal for two seconds. TE represents echo time as the unit is receiving a signal for 30 seconds then sixty seconds. Two images are then produced; T1 weighted (30 seconds) and T2 weighted (60 seconds). T1 weighted can detect nerve root compression at the facets, vertebral bodies and the spinal cord but due to its bad fluid resolution it is not reliable to differentiate in spinal cord disease. T2 weighted is more suited for fluid contrast and intricacies in the spinal cord can be detected such as thecal sac, nerve roots, intervertebral disc hydration, cerebral spinal fluid, and cord contusion. Ligaments can be viewed but disruptions can only be detected with large defects in large ligaments. Muscle tissue can be viewed on MRI detecting changes in muscle bulk as well as muscle contour. T1 weighted can detect anatomic detail, picking up subacute hematoma, fatty infiltration and atrophy. T2 weighted is best suited for muscle injury as it detects edema and hemorrhage and can determine tear and hematomas. Dynamic MRI has recently been shown to be better suited for ligamentous injury.

Contraindications of MRI are any metal in the body. The patient must be screened prior to recommending MRI to rule out metal implants of any kind which would disqualify them from the procedure. There is also a risk to individuals who are exposed to ferromagnetic particles such as auto mechanics and metal lathe operators.

The most comprehensive study that provides the greatest information after trauma is a combination of CT and MRI to view as many of the soft tissue and bony structures for injury.

**Bone Scan:** This nuclear medicine procedure will allow for the highest quality bone sensitivity with the least radiation exposure for the patient. A radionucleotide is absorbed by bone based on its metabolic rate in a three part procedure. Fractures just a few hours old can be detected whereas in plain film it could take up to 10 days. Fractures can also be delineated from artifacts that could be confusing in plain film. Tumors, infections, soft tissue inflammation and severe strains that affect the tenoperiosteal junction will also be seen. Soft tissues can be viewed as well as the kidneys and brain tissue. Besides, fractures, bone scans can be useful in detecting bone bruises, pars defects, osteonecrosis, plantar fascitis, muscle injury, tendonitis, bursitis, frostbite, electrical burns, chronic radiation injury, osteoarthritis, cancer and inflammation of a disc.

**EMG:** Electromyelography assesses the motor peripheral nervous system through measurement of the electrical impulses of the skeletal muscles. Monitoring the response of the fibers of the motor unit during stimulation of the motor nerve, an action potential can be recorded on an oscilloscope. Auditory signals are also produced and can be characteristic for particular types of disorders. The initial readings are of the patient at rest. The patient is then asked to gradually increase the force of contraction of the muscle being tested. The oscillation pattern becomes denser as contraction increases. With chronic partial denervation, the pattern is reduced or incomplete. Findings will be progressive as the affects of acute trauma are altered over time, perhaps months. Deemed somewhat reliable, the EMG is limited by the variance in nerve innervation from patient to patient and the fact that most peripheral lesions affect primarily the sensory system.
Surface EMG is a variation of needle EMG as electrodes are placed over the skin of the muscle being evaluated. It has served useful in the management of headache, chronic pain, stress, incontinence and recovery from stroke.

_Nerve Conduction Velocity:_ This procedure is used to evaluate neuropathy. It must be performed on a nerve that has two points available for stimulus since it is the time of impulse travel that is recorded. The evaluation is of motor and sensory function. The motor NCV study is useful in evaluating the ulnar, median, tibial, peroneal, musculocutaneous, radial, facial, spinal accessory, femoral and phrenic nerves. The sensory NCV records information through the use of nerve action potentials. This is a more sensitive system than the motor NCV thus it can detect mild problems earlier. It should be noted that 20% of all individuals have anomalous innervation in the arm or leg. Sensory NCV is used to detect diffuse sensory disorder, local cutaneous nerve lesions or disorders that create damage to sensory fibers in a mixed nerve.

_PET Scan:_ Positron Emission Tomography detects areas of increased metabolism due to glucose uptake. A glucose molecule tagged with radioactive fluorine is injected intravenously. Byproducts create residue that is recorded by a crystal photomultiplier in the unit. It is detecting gamma rays produced by the unstable radioactive fluorine. Metabolic disturbances in soft tissue and brain dysfunction due to metabolic conditions are found. PET scans have been used to detect cancer but it can be less than accurate and should not be the sole diagnostic tool.

_Discography:_ To evaluate the intricate detail of the intervertebral disc, a contrast agent is injected into the nucleus pulposis of several discs. This allows for the isolation of the patient’s problem to a specific level. Radiographs are taken to determine if the nucleus pulposis is intact or if disc material is perfusing through the annulus. It can be a more reliable tool than MRI alone in determining if there is disc damage directly related to the patient’s symptomatology. However, there is a risk of infection due to the invasiveness of this procedure. Also, false positives can be interpreted with increased age.

_Diagnostic Ultrasound:_ Soft tissue can be evaluated, however, the reliability of the procedure depends on several factors. The proficiency of the radiologist has come under scrutiny in many studies as only a highly skilled radiologist well versed and greatly experienced can be relied upon to determine the results of a soft tissue ultrasound scan. As MRI replaced ultrasound in diagnosis of soft tissue injuries, ultrasound is used more as a backup procedure. Ultrasound in soft tissue diagnosis depends on the interaction of propagated sound waves with tissue interfaces in the body. The directed pulses of sound encounter interfaces between tissues of different acoustic impedance, reflection or refraction. The sound waves reflected back to the transducer are recorded then converted into images. Viewed on ultrasound is edema and tissue displacement. Diagnostic ultrasound is more commonly used to determine soft tissue tumors. The reliability of this procedure is still in question as 25% of ultrasound scans have been shown to be inconsistent with actual findings.

_Angiography:_ Acute trauma can result in dissection, rupture or compression of the vertebral arteries as well as damage to the basilar arteries. Although this is an invasive test that also exposes the patient to ionizing radiation, it has been performed for many years due to the
importance of the information in conjunction with the patient’s symptomatology. An alternative known as *duplex sonography* or *Doppler* evaluation will provide information on stenosis, occlusion and hypoplasia of the blood vessel walls as well as blood flow. It is most useful in evaluating subclavian artery compression due to thoracic outlet syndrome. Interesting to note, it has been determined that the subclavian artery becomes compromised due to the compression of its neurological components in the brachial plexus as opposed to direct compression of itself.

*Endoscopy* is recommended if the patient is experiencing symptoms of esophageal tears such as reflux or difficulty swallowing. These patients should be referred to their internist for prophylactic antibiotic treatment for infection secondary to possible aspiration. *CT of the chest with infiltrate* can best determine deeper pharyngeal tears or retropharyngeal hemorrhage.

Note on *trigger point ultrasound*: Although this is considered a highly effective treatment tool for scar tissue and adhesions in myofascial tissue, it can also be used as a diagnostic tool to determine the exact location of the scar tissue, adhesions and trigger points that may have developed as a result of tissue compression and injury. This combination of ultrasound and electrical muscle stimulation can accurately identify the location of scar tissue by the physical principle of resistance. An electric impulse is sent though the ultrasound head. As the sound head is rotated around the area of injury, the current attempts to pass through scar tissue, adhesions and hematomas. When it comes upon denser tissue or an area of increased resistance, the current will feedback upon itself and the build-up will be interpreted by the patient as increased intensity of the current. It is in these areas of increased intensity that scar tissue and adhesions can be found. This becomes a very effective tool in the determination of the location of soft tissue injury because with myofascial damage, it is common for the injury to be distant from the site of pain. Once these areas of scar tissue have been identified, the treatment is in the sound head as steady pulsed ultrasound. It is direct, immediate and the electrical impulse will diminish as the adhesions are decreased. This instant feedback assists the practitioner in determining if the tissues are freed, and if treatment of that particular trigger point is complete for the session. Multiple trigger points can and will be found and can be treated in the same session. Releasing the fixated tissue by diminishing scar tissue and allowing for the tissues to stretch will improve function and decrease pain of not only the specific tissues treated but for the region or limb involved.