MRI of the Chest Wall: Making a Long Story Short

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Learning objectives

1. To review the radiological anatomy of the chest wall musculoskeletal structures using MRI and illustrations
2. To describe the clinical and imaging features of the different traumatic and non-traumatic conditions involving the chest wall structures
Background

Magnetic Resonance imaging (MRI) of the thorax has become an important tool in assessment of intrathoracic organs. These studies will additionally routinely image the chest wall structures. Radiologist should be familiar with the normal chest wall anatomy and with the most common conditions affecting this body segment, as many of these conditions might be detected incidentally. In addition, some inherited musculoskeletal conditions have a specific pattern of muscle involvement which can be assessed by MRI. This imaging technique is also a very useful tool when assessing chest wall denervation after trauma or surgery.
Chest wall anatomy

The thoracic wall muscles can be divided into five groups based on anatomical location; anterior, posterolateral, posteromedial, deep chest wall and paravertebral muscles (Table 1).

1. Anterior Chest Wall Muscles

The pectoralis muscles cover the anterior thoracic cage and form part of the anterior wall of the axilla (Fig 1).

Pectoralis major is a large fan-shaped muscle, superficial to pectoralis minor (Fig 2). Its main function is to adduct the arm and rotate it medially. The clavicular fibers also assist to flex the arm (DeFigueired 2013). Recent anatomic studies of the pectoralis major demonstrated its trilaminar configuration: clavicular, manubrial and abdominal laminae. The clavicular laminae originates from the medial one half or two thirds of the clavicle and forms the clavicular head; the manubrial and abdominal laminae originate from the manubrium, sternum, ribs, and costocartilage, and form the sternal head (Chiavaras 2015). These three laminae twist 180 degrees before coalescing into a single tendon prior to insertion at the lateral margin of the bicipital groove of the humerus (Lee 2000). The length of the tendon footprint on the humeral diaphysis is approximately 4-6 cm cephalocaudad and 5 mm in mediolateral dimension (Chiavaras 2015). The distal pectoralis major tendon prior to coalescing consists of anterior and posterior layers that are continuous at their inferior aspects, forming a "U" shape. The anterior layer consists of the clavicular head and superior fibers of the sternal head, while the posterior layer consists of the sternal head by itself, with each layer being approximately 2mm thick. Distally, these two layers fuse medial to their attachment to the humeral diaphysis, although the posterior tendon extends more proximal towards the muscle belly (Chiavaras 2015).

Pectoralis minor is a triangular shaped muscle which originates from the anterior surfaces of ribs 3-5 near their costal cartilages and attaches distally to the medial border and superior surface of the coracoid process of the scapula (Lawson 2011). Its primary function is stabilization of the scapula by drawing the scapula inferiorly and anteriorly against the thoracic wall.

The pectoralis muscles are innervated by the medial and lateral pectoral nerves arising from the medial and lateral cords of the brachial plexus (Carrino 2000).
2. Posterolateral Chest Wall Muscles

Serratus anterior (Fig 3) is the deeper of the two posterolateral muscles. It arises from the superoanterior aspects of ribs 1 - 8 and wraps around the lateral chest, superficial to the rib cage and deep to the scapula, inserting onto the medial border and inferior angle of the scapula. The main function of the serratus anterior is to pull the scapula forwards and around the rib cage during arm anteversion. It is innervated by the long thoracic nerve (C6 - C7) (Fig 4), injury to which leads to the clinical finding of a winged scapula.

Latissimus dorsi muscle is a large fan-shaped muscle covering the posterolateral aspect of the thorax with extensive attachments on the thoracic, lumbar, and sacrospinous processes with a relatively short linear tendon attachment to the proximal humerus (Fig 5,6). Cadaveric dissections have shown that the latissimus dorsi tendon begins posteriorly and then curves inferiorly and anteriorly around the teres major tendons to insert 1 cm anteriorly to the teres major tendon, with the two tendons being joined to one another just proximal to the separate insertion sites on the humerus. Mechanically it is a powerful adductor and extensor of the shoulder. It is innervated by the thoracodorsal nerve (C6-C8).

3. Posteromedial Chest Wall Muscles

Trapezius is a large superficial muscle of the upper back. It can be divided into three parts, based on the orientation of muscle fibres (Fig 7). The superior (descending) fibres of the trapezius arise from the external occipital protuberance, the medial third of the superior nuchal line of the occipital bone, the ligamentum nuchae, and the spinous processes of C1 - C7. The fibres travel inferolaterally to insert into the posterior aspect of the lateral third of the clavicle. The main function of the superior fibres is to support the weight of the arm. The middle (transverse) fibres arise from the spinous processes of C7 - T3 vertebrae and insert into the acromion process and spine of the scapula. These fibres play a role in retraction of the scapula. The inferior (ascending) fibres arise from the transverse processes of T4 - T12, converging as they ascend superolaterally to insert at the medial end of the spine of the scapula. This component of the muscle medially rotates and depresses the scapula. Motor innervation of the trapezius is via the spinal accessory nerve (cranial nerve XI) (Fig 8).

Rhomboids form the deep layer of posteromedial chest wall muscles. Like trapezius, the rhomboid muscles attach the scapula to the vertebral column (Fig 6). The rhomboids act together to keep the scapula pressed against the thoracic wall and to retract the scapula towards the vertebral column. They are innervated by the dorsal scapular nerve. The Rhomboid major arises from the spinous processes of T2 - T5 and inserts onto the medial
border of the scapula. The Rhomboid minor lies superior to rhomboid major. It arises from the spinous process of C7 and T1 and inserts superior to the rhomboid major insertion on to the medial border of the scapula.

4. Deep Chest Wall Muscles

The intercostal muscles lie between the ribs and are responsible for movement of the chest wall during respiration (Fig 8). They can be subdivided into external, internal and innermost fibres. The neurovascular bundle of each rib space runs between the internal and innermost fibres. Innervation is from the intercostal nerves, which are the ventral rami of the thoracic spinal nerves.

Oblique muscles although considered part of the abdominal wall, arise from the lower ribs and could manifest as lateral chest pain. The outermost muscular layer of the lateral abdominal wall is made up from the external oblique muscles. These two muscles arise from the outer parts of the lower 7 to 8 ribs on either side and extends anteroinferiorly to the anterior aspect of the iliac crests, pubic tubercle and to the linea alba in the midline. Towards the midline the muscle forms an aponeurosis. The internal oblique muscle lie under cover of the external oblique muscle. Fleshy fibers arise from the upper surface of the lateral two thirds of the inguinal ligament, the anterior two thirds of the iliac crest, and the thoracolumbar fascia. The posterior fibers pass upward and forward to be inserted into the inferior border of the lower four ribs and costal cartilages and thereafter become continuous with the internal intercostal muscles. The upper fibers form a short free superomedial border {Connell 2003}.

5. Paravertebral Muscles

The paravertebral or paraspinal muscles comprise the transversospinales and the erector spinae muscles. The transversospinales are the more medial group of muscles and assist with rotation and extension. The erector spinae muscles lie vertically oriented alongside the vertebrae (Fig 9) and as the name suggests, they are responsible for extension of the spine to hold it in an erect position.

Iliocostalis forms the most lateral column of these paravertebral muscles. It can be further subdivided into cervicis, thoracis and lumborum fibres. Iliocostalis cervicis arises from the posterior 3rd to 6th ribs and inserts into the posterior tubercles of the transverse processes of the C4-C6 vertebrae. Iliocostalis extends from the lower 6 ribs to the angles of the upper 6 ribs and the transverse process of C7. Iliocostalis lumborum originates from the iliac crest and sacrum and inserts into ribs 7 to 12.
Longissimus is the intermediate column of the erector spinae. It is comprised of capitis, cervicis and thoracis fibres. Longissimus capitis originates from the transverse processes of T3-T1 and inserts into the mastoid process of the temporal bone. The cervicis component originates from the transverse processes of T6-T1 and inserts onto the transverse processes of C7-C2. The fibres of longissimus thoracis originate from the sacrum, spinous processes of the lumbar vertebrae and transverse process of T12. They insert into the transverse processes of the lumbar vertebrae, erector spinae aponeurosis, ribs and costal processes of the thoracic vertebrae.

Spinalis forms the most medial part of the erector spinae group. This muscle can be subdivided into spinalis cervicis, which originates from the spinous processes of T2-C6 and inserts onto the spinous processes of C4-C2, and spinalis thoracis, which originates from the spinous processes of L3-T10 and inserts onto the spinous processes of T8-T2.

**Pathology of the Thoracic Wall**

Pathological conditions affecting the chest wall muscles can be divided according the muscular compartment and by the mechanism (traumatic, iatrogenic, idiopathic, and congenital). For the purpose of this educational exhibit, the authors divided the pathological conditions according to the mechanism.

1. Traumatic Mechanism

- Pectoralis major muscle injury may occur during weight-lifting and, more specifically, during a bench press manoeuvre. Other less common mechanisms of injuries are direct blow, attempting to grasp an object while falling and senile degeneration. When there is a complete rupture, it results in significant disability and cosmetic deformity {Lee 2000}{Chiavaras 2015}. The complex anatomy of the pectoralis major muscle makes imaging and diagnosis of injuries of the tendon difficult. The injuries may be classified by anatomic location; muscle origin, muscle belly, musculotendinous junction, intratendinous, humeral insertion, and bony avulsion *(Fig 11)*{Elmaraghy 2012}.

- Injuries of the pectoralis minor are uncommon, and have been described in beginner skiers due to lack of a correct positioning technique.

- Side strain is caused by an acute tear of the internal oblique musculature where it inserts into the undersurface of the ninth, 10th, or, most commonly, the 11th rib. Most commonly occur in rowers, swimmers, golfers, and canoeists. On MRI, acute injuries are characterized by high signal on STIR images at the muscle, rib, or costal cartilage
interface. A complete tear is defined as separation of muscle fibers creating a space beneath the undersurface of the rib or costal cartilage or discontinuity of fibers at the site of injury. Partial tears are defined as feathery patterns of T2 hyperintensity, representing myofibril disruption with blood or fluid tracking between myofibrils (Connell 2003) (Fig 11).

- Paravertebral compartment syndrome has previously been reported in downhill skiers, surfboarders and weight lifters, as well as in reperfusion injury after surgery of the abdominal aorta. Sport-induced CS mainly affects males aged between 20 and 30 years, and generally starts about 2 hours after training. The pain is typically unresponsive to non-narcotic pain medication. Although it has been reported mainly involving the lumbar paraspinal muscles, the involvement can extend to the thoracic level due to the common thoracolumbar spinal fascia outlying the paraspinal musculature. Typical MRI findings include muscle edema and hyperintense areas on T2-weighted images. Decreased gadolinium uptake suggests muscle necrosis. Patients with CS may be at risk of multi-organ failure due to intravascular volume loss and rhabdomyolysis with myoglobinuric renal failure, and adequate treatment is required to prevent complications (Mattiassich 2013).

2. Iatrogenic

Nerve injury can occur during a surgical procedure. Knowledge of the nerve anatomy would prevent nerve damaging, which will be manifested as muscle denervation. Muscle injury initially is seen as oedema on T2 weighted images with little perceptible change on T1 images. Progressively muscle bulk is reduced and replaced by fatty tissue, which demonstrates high signal on T2-weighted images and low signal on T1-weighted images (Fleckenstein 1993)(Bendszus 2002).

The most common example is atrophy of serratus anterior due to compromise of the long thoracic nerve (Fig 15)(Wiater 1999). The long thoracic nerve follows a long, superficial course from the anterior rami of C5 - C7 to the outer surface of serratus anterior, making it prone to injury at several points. Injuries can occur due to: blunt or penetrating trauma, repetitive strain such as that which occurs in overhead sports like tennis and iatrogenic injury following thoracic surgery or chest drain insertion (Hassan 1995)(Bizzarri 2001). It can also occur as a result of viral infection or as a variant of the Parsonage-Turner syndrome (Feinberg 2010). Since the function of serratus anterior is to stabilize the scapula against the chest wall during elevation of the arm, its paralysis results in prominence of the inferomedial scapula, a clinical finding that is termed ‘winging of the scapula’.
Denervation changes may also occur in the sternocleidomastoid and trapezius muscles as a consequence of spinal accessory nerve (SAN) injury (Fig 16). The superficial location of this nerve, in the subcutaneous tissue of the floor of the posterior cervical triangle makes it vulnerable to injury. This palsy is commonly seen after surgical procedures in the posterior cervical triangle for malignant diseases or after penetrating injuries (Fig 17). Other less common mechanisms include blunt trauma or heavy manual work carrying heavy objects on the shoulder resulting in repetitive microtrauma. Compression by tumours at the base of the skull and fractures involving the jugular foramen have also been described as a cause of SAN injury (Charopoulos 2010).

3. Idiopathic or inherited

- Muscle atrophy can occur due to inherited and acquired muscular dystrophies. Facioscapular humeral muscular dystrophy (FSHMD) preferentially affects the muscles of the face, shoulder girdle and upper arm at its onset. It is also characterised by paraspinal muscle involvement (Witting N). FSHMD is an autosomal dominant condition and is the third most common muscular dystrophy after Duchenne and myotonic dystrophy (Emery 1991). The majority of patients present in their third to fourth decade with asymmetric weakness of facial muscles and overhead arm movements (Pandya 2008). On clinical examination, there may be elevation of the scapula and internal rotation of the arm, due to weakness of middle and inferior fibres of the trapezius muscle. Atrophy of the pectoralis major muscle and involvement of the clavicular portion of the sternocleidomastoid muscle are also seen in the early stages (Fig 18, 19). Winging of the scapula may be seen in cases affecting the serratus anterior. Weakness can slowly progress to involve the abdominal wall and lower limb musculature.

- Axial myopathies have received little attention in clinical practice and research, but based in some studies, it appears to be a grossly underestimated feature of many diseases. The axial myopathies are described according to whether axial myopathy is predominant i.e. constitutes the major part of the myopathy, or rather is a part of a more widespread myopathy, i.e. paraspinal myopathy is present, but other musculature is involved to a similar degree (Witting N). MRI can quantify fat infiltration and show oedema. Additionally, MRI may also reveal a characteristic pattern of involvement such as selective affection of the medial or lateral parts of the erector spinae muscles. Some of the most known axial myopathies include selenoprotein deficiency, myopathy due to mutations in the lamin A/C gene, and metabolic myopathies as glycogen storage disease type II (GSDII, Pompe disease, acid maltase deficiency) and McArdle disease (glycogen storage disease type V), among others (Fig 20).

4. Congenital
· Congenital absence of pectoralis major muscle, also known as Poland Syndrome is a rare condition that involves the pectoralis muscle is Poland Syndrome, which is a congenital anomaly consisting of unilateral partial or complete absence of the sternocostal head of the pectoralis major muscle and ipsilateral brachysyndactyly (Chen 2012).
Images for this section:

**TABLE 1 - Muscle groups of the thoracic wall**

<table>
<thead>
<tr>
<th>Muscle Group</th>
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<td>Anterior muscles</td>
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<tr>
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<td>- Pectoralis major</td>
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<td>Posterolateral muscles</td>
<td>- Serratus anterior</td>
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<td>- Latissimus dorsi</td>
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<td>Posteromedial muscles</td>
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<td>Paravertebral muscles</td>
<td>- Iliocostalis</td>
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**Fig. 1:** TABLE 1 - Muscle groups of the thoracic wall

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![Axial T1 weighted MRI imaging of the thorax demonstrating the anterior chest wall muscles: pectoralis major (asterisk) and pectoralis minor (circle).](image)

**Fig. 2:** Axial T1 weighted MRI imaging of the thorax demonstrating the anterior chest wall muscles: pectoralis major (asterisk) and pectoralis minor (circle).
**Fig. 3:** Axial T1 weighted image showing a normal right pectoralis major tendon (arrow) inserting into the middle third of the humeral shaft. Note the normal pectoralis major muscle (asterisk)
**Fig. 4:** Axial (A) and sagittal (B) T1 weighted images of the thorax demonstrating the serratus anterior muscle (arrow). Note in (B) how the muscle fibres converge to insert at the inferior margin of the scapula (arrow).

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**Fig. 5:** Anatomy of the long thoracic nerve. Diagram shows the course of the long thoracic nerve (1) superficial to the serratus anterior muscle (2) over the antero-lateral chest wall.

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**Fig. 6:** Axial T1 weighted images (A) and coronal T2 weighted images (B). The bulk of the latissimus dorsi muscle (arrows) lies laterally and superficial to the serratus anterior muscle (asterisk).

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Fig. 7: Anatomy of the Latissimus dorsi muscle

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Fig. 8: Axial T1 weighted image illustrating the trapezius muscle (black arrows) superficial to the rhomboid muscle (white arrows).

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Fig. 9: Anatomy of the spinal accessory nerve (SAN). Diagram shows the SAN (1) located in the posterior cervical triangle, demarcated posteriorly by the trapezius muscle (2) and anteriorly by the sternocleidomastoid muscle (3).

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**Fig. 10:** Axial T1 (A) and coronal T1 (b) weighted images showing the intercostal muscle layers (arrows)

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**Fig. 11:** Normal anatomy of the obliques muscles both the Axial(A) and Cor T2 FS images

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Fig. 12: Axial T1 weighted image demonstrating the components of the erector spinae muscle group: (from lateral to medial) the iliocostalis (a), longissimus (b) and spinalis (c) muscle layers.

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**Fig. 13:** A,B. Complete tear of the pectoralis major. Axial PD fat sat oblique (A) and coronal PD fat sat oblique images (B) show medial retraction of the myotendinous junction (doted arrow) with haematoma (asterisk) at the level of tendon disruption. The remnant of the pectoralis major tendon is seen at the humeral insertion superficial to the biceps tendon.

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**Fig. 14:** Professional cricketer presented with sharp pain in left side when playing shot, unable to continue. Axial and coronal STIR ((A;B) and Coronal T2 (C) images show acute partial tear of the left internal oblique muscle (curved arrows) at its attachment to the left twelfth rib underlying the site of the marker. There is haematoma at this site.

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**Fig. 15:** Post-traumatic long thoracic nerve injury. 41 year old man presented with weakness and winging of the right scapula following previous trauma. Axial T1 weighted images of the thorax demonstrates reduced volume with high T1 signal of the right serratus anterior muscle (arrow) consistent with fatty infiltration. Note the normal appearance of the unaffected left serratus anterior (doted arrow).

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**Fig. 16:** A, B. Spinal accessory nerve injury. Axial and coronal T1 weighted images show atrophy of the right sternocleidomastoid muscle (arrow in A) and right trapezius muscle (doted arrow in B). Compare with the unaffected contralateral side respectively (asterisk in A and circle in B).

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**Fig. 17:** Acute spinal accessory nerve injury. 56 year-old patient who underwent surgery for a subcutaneous lipoma in the left posterior cervical triangle. A) Axial T1 weighted images show a large poorly capsulated lipoma in the left posterior cervical triangle (asterisk). B) Axial GRE image show the post-surgical oedema in the resection area (arrow). C) Post-surgery the patient developed left shoulder pain and arm weakness. Coronal T2 FS image show muscular oedema within the left trapezius muscle (triangle) consistent with muscle denervation related to spinal accesory nerve injury.

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Fig. 18: Facioscapulohumeral muscular distrophy (FSHMD). A,B) Axial and sagittal T1 weighted image demonstrate an almost completely absent (arrowhead) left trapezius muscle. The right trapezius is markedly atrophic (arrow). C, D) Axial and coronal T1 weighted images show moderate fatty infiltration of the right serratus anterior muscle (dotted arrows) compared with the left unaffected side (asterisk)

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Fig. 19: Different patient with FSHMD. A,B) Axial T1 weighted images at different levels of the chest wall. Bilateral wasting of the trapezius (doted arrows in A) and asymmetric fatty atrophy of the right serratus anterior muscle (doted arrow). C, D) Axial and coronal T1 weighted image show marked fatty atrophy of the right pectoralis major and minor muscles (arrow and triangle) compared with the contralateral side (circle)

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**Fig. 20:** Axial T1 images at the level of the mid-thoracic (A) and lumbar spine (B) and Sagittal T1 (C) demonstrates dramatic almost complete fatty replacement of paraspinal muscles (asterisk) in this 31 year old male patient with back pain and difficulty walking

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Conclusion

MR imaging of the thorax can be used to investigate and diagnose certain pathological conditions affecting the chest wall structures. Also, with the increasing use of MR imaging of the thorax to investigate the intrathoracic organs, many such lesions are being discovered as incidental findings. Familiarity with the anatomy and both normal and abnormal MR appearances of the chest wall musculature is essential for those radiologists who routinely interpret thoracic MR imaging.
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