Diaphragm and intercostal muscles

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Skeletal System

Adult Human contains 206 Bones

2 parts:

Axial skeleton (axis):
Skull, Vertebral column, Thoracic cage

Appendicular skeleton:
Bones of upper limb
Bones of lower limb
Structure of Typical Vertebra

Vertebral foramen is formed by the vertebral arch, which consists of pedicle and lamina.

- **Body**
- **Vertebral foramen**
- **Transverse process**
- **Spinous process**
- **Pedicle**
- **Lamina**

**Pedicle**: arranged above each other to form vertebral canal

**Lamina**: originating from each typical vertebra are 7 processes: 2 transverse, 1 spinous, 2 superior articular processes and 2 inferior articular processes.

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Superior articular process

Intervertebral disc
Inferior articular process
Facet joints are between the superior articular process of one vertebra and the inferior articular process of the vertebra directly above it.

The articulation of superior articular process and inferior articular process is a joint, specifically synovial joint, they are called FACET JOINTS.

Joints in-between the bodies of the vertebra are cartilaginous joint.
Atypical Vertebrae

Atlas (1st cervical vertebra)

Odontoid process (Dens: tooth) represents the body of atlas that has fused with body of axis

Axis (2nd cervical vertebra)
Communicates:
sup: skull (atlanto-occipital joint)
inf: axis (atlanto-axial joint)

Atlas (1st cervical vertebra)
Atlas (1st cervical vertebra)

Characteristics:
1. no body
2. no spinous process
3. ant. & post. arches
4. 2 lateral masses
5. 2 transverse foramina

Typical cervical vertebra

Specific to the cervical vertebra is the transverse foramen (foramen transversarium).

is an opening on each of the transverse processes which gives passage to the vertebral artery
Thoracic Cage

- Sternum (G, sternen = chest bone)
- 12 pairs of ribs & costal cartilages
- 12 thoracic vertebrae

Thoracic cage is formed anteriorly by the sternum, at the sides it’s formed by 12 pairs of ribs, and posteriorly it’s formed by the thoracic vertebrae.

**Sternum:**

- Flat bone

**3 parts:**
- Manubrium: superior
- Body: middle
- Xiphoid process: inferior

**QUESTION:** What are the boundaries of the thoracic inlet? Anteriorly, the manubrium, first pair of ribs at the sides, and posteriorly T1.

**QUESTION:** What are the boundaries of the thoracic outlet? Posteriorly T12, at the sides the floating ribs + coastal margins, and anteriorly the xiphoid process.

The thoracic outlet separates the thoracic cavity from the abdominal cavity.

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QUESTION: Where is the diaphragm located? At the thoracic outlet, which separates the thorax from the abdomen.

Intercostal muscles are located within the intercostal spaces, they are flat muscles, these muscles are arranged in a certain arrangement and they have the same arrangement as the abdominal muscles.

**Intercostal Spaces**

The spaces between the ribs contain three muscles of respiration: the external intercostal, the internal intercostal, and the innermost intercostal muscles.

Diaphragm is defined as: flat skeletal muscle, and since it’s a skeletal muscle it has bony attachment at the borders of thoracic outlet, the fibers are converged at the center to be converted to central tendon, and this tendon is a flat tendon. the muscle is flat so the tendon is flat.

Diaphragm is the main muscle of respiration assisted by other muscles located at the intercostal spaces.

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The external intercostal muscle forms the most superficial layer. Its fibers are directed **downward and forward** from the inferior border of the rib above to the superior border of the rib below. The muscle extends forward to the costal cartilage where it is replaced by an aponeurosis, the **anterior (external) intercostal membrane**.

*The muscle starts posteriorly at the sites of thoracic vertebrae, then anteriorly it extends to reach the junction between the rib and its costal cartilage, so it’s deficient anteriorly it’s not attached directly to the sternum, it’s completed by external intercostal aponeurosis.*
The internal intercostal muscle forms the intermediate layer. Its fibers are directed downward and backward from the subcostal groove of the rib above to the upper border of the rib below. The muscle extends backward from the sternum in front to the angles of the ribs behind, where the muscle is replaced by an aponeurosis, the posterior (internal) intercostal membrane.
Angle of rib

- 1st rib
- 2nd rib
- Typical rib
- 11th & 12th
The innermost intercostal muscle forms the deepest layer. It is an incomplete muscle layer and crosses more than one intercostal space within the ribs.
Contraction elevates ribs and increases anteroposterior and lateral dimensions of thoracic cavity, resulting in inhalation.

Relaxation depresses ribs and decreases anteroposterior and lateral dimensions of thoracic cavity, resulting in exhalation.
ACTION:
When the intercostal muscles contract, they all tend to pull the ribs nearer to one another. If the 1st rib is fixed by the contraction of the muscles in the root of the neck, namely, the scaleni muscles, the intercostal muscles raise the 2nd to the 12th ribs toward the first rib, as in inspiration. If, conversely, the 12th rib is fixed by the quadratus lumborum muscle and the oblique muscles of the abdomen, the 1st to the 11th ribs will be lowered by the contraction of the intercostal muscles, as in expiration. In addition, the tone of the intercostal muscles during the different phases of respiration serves to strengthen the tissues of the intercostal spaces, thus preventing the sucking in or the blowing out of the tissues with changes in intrathoracic pressure.
Nerve supply:

Yes, the intercostal muscles are supplied by the corresponding intercostal nerves.

Yes, the intercostal nerves and blood vessels run between the middle and innermost layers of muscles.

Yes, they are arranged in the following order from above downward: intercostal vein, intercostal artery, and intercostal nerve (i.e., VAN).

The intercostal nerves are the anterior rami of the first 11 thoracic spinal nerves. The anterior ramus of the 12th thoracic nerve lies in the abdomen and runs forward in the abdominal wall as the subcostal nerve.
anterior intercostal artery is branched from the internal thoracic artery
posterior intercostal artery is branched from the thoracic aorta
Diaphragm
The diaphragm is a thin muscular and tendinous septum that separates the chest cavity above from the abdominal cavity below.

- It is pierced by the structures that pass between the chest and the abdomen.
- The diaphragm is the most important muscle of respiration.
- It is dome shaped and consists of a peripheral muscular part, which arises from the margins of the thoracic opening, and a centrally placed tendon.

The diaphragm is located between the chest cavity and the abdominal cavity. It has two domes and centrally the central tendon, the right dome is higher is position than the left dome, why? because of the liver (the largest organ inside the abdomen).
As seen from in front, the diaphragm curves up into right and left domes, or cupulae.

The right dome lies at a higher level, because of the large size of the right lobe of the liver.
The domes support the right and left lungs, whereas the central tendon supports the heart.
When seen from the side, the diaphragm has the appearance of an inverted J, the long limb extending up from the vertebral column and the short limb extending forward to the xiphoid process.

The levels of the diaphragm vary with the phase of respiration, the posture, and the degree of distention of the abdominal viscera. The diaphragm is lower when a person is sitting or standing; it is higher in the supine position and after a large meal.
Origin of diaphragm:

**Sternal part:** arising from the posterior surface of the xiphoid process

**Costal part:** arising from the deep surfaces of the lower six ribs and their costal cartilages

**Vertebral part:** arising from upper 3 lumbar vertebrae by two crura and five arcuate ligaments (one median, two medial and two lateral arcuate ligaments)
Sternal part

Costal part

Vertebral part

Diaphragm - inferior surface (abdominal surface)
The right crus arises from the first three lumbar vertebrae and the intervertebral discs. The left crus arises from the first two lumbar vertebrae and the intervertebral disc.

The aorta passes through the diaphragm at the level of T12. Left crus and right crus are continuous with each other anteriorly to the aorta. A ligament is formed by the right crus and left crus, these two crus unite to form a ligament, this ligament is located in the midline, arch in shape. forms: median arcuate ligament.
Right crus has 3 special features

a- It is larger, longer and stronger to overcome the resistance offered by the liver during descent of the diaphragm

b- Some of its muscle fibers run up to left, to surround the esophagus

These fibers appear to act as a sphincter and possibly assist in the prevention of regurgitation of the stomach contents into the thoracic part of the esophagus
Lateral to the crura, the diaphragm arises from the medial and lateral arcuate ligaments.

**Medial arcuate ligament** extends from the body of L2 to the tip of the transverse process of L1.

**Lateral arcuate ligament** extends from the tip of the transverse process of L1 to the 12th rib.

The medial borders of the two crura are connected by a **median arcuate ligament**, which crosses over the anterior surface of the aorta.
why do we have these ligaments? we should not have any spaces between the thorax and abdomen, these enclosed spaces will prevent hernia

Note:

**Medial arcuate ligaments** lie across the upper part of psoas major

**Lateral arcuate ligaments** lie across the upper part of the quadratus lumborum

the posterior abdominal wall is formed by two muscles: psoas major (medial) and quadratics lumborum (lateral).
**Insertion of diaphragm:**

All muscle fibers of the diaphragm converge on a strong aponeurosis called the **central tendon**

pericardium overlies the central tendon

**Note**

The central tendon is shaped like three leaves

**Opening for Esophagus**

**Opening for IVC**

**Opening for Aorta**

esophagus is located within the muscle part, because it acts as a sphincter

the opening for inferior vena cava is located within the central tendon, because it should be continuous for breathing/respiration

inside the diaphragm there is major and minor openings. major structures passing through the diaphragm:

1. aorta
2. esophagus
3. inferior vena cava

aorta is actually not a real opening, it’s located behind the diaphragm

inferior vena cava has to pierce the diaphragm to drain blood from the right atrium of the heart
### Major Openings of the diaphragm

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<th>Level</th>
<th>Structures passing through it</th>
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<td>Oesophageal opening (Left)</td>
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<td>Vena Caval (Right)</td>
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<td>Right phrenic nerve</td>
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**Mnemonic:**

I ate(8) 10 Eggs At 12

I ate(8): I for IVC at T8
10 Eggs: E for esophagus at T10
At 12: A for Aorta at T12
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Opening for IVC (T8)
Opening for esophagus (T10)
Opening for aorta (T12)

Side view: diaphragm

Anterior
Superior view of the diaphragm
Nerve Supply:
Motor nerve supply: The right and left phrenic nerves (C3, 4, 5)
Sensory nerve supply: The central portion of the diaphragm is from the phrenic nerve and the periphery of the diaphragm is from the lower six intercostal nerves.

Arterial supply:
Superior phrenic arteries (from thoracic aorta)
Inferior phrenic arteries (from abdominal aorta)
Musculophrenic artery
Pericardiophrenic artery (from internl thoracic artery)
Phrenic nerves (C3, 4, 5)
Inferior phrenic arteries are branches of abdominal aorta

superior phrenic artery branched from thoracic aorta
Internal Thoracic Artery

- The internal thoracic artery supplies the anterior wall of the body from the clavicle to the umbilicus.

- It is a branch of the first part of the subclavian artery in the neck.

- It descends vertically behind the costal cartilages, a fingerbreadth lateral to the sternum.

- It ends in the sixth intercostal space by dividing into:
  - Superior epigastric artery
  - Musculophrenic artery
A **hiatal hernia** is a **protrusion** of the **abdominal contents** into the thorax through an enlarged esophageal hiatus caused by a weakness or opening in the diaphragm.

**Function of the diaphragm**
1. Muscle of respiration
2. Muscle of abdominal straining: The contraction of the diaphragm is raising the intra abdominal pressure
3. Weight-lifting muscle
4. Thoracoabdominal pump: Pump for blood and lymph

On contraction, the diaphragm pulls down its central tendon and increases the vertical diameter of the thorax.

Increase in the intra-abdominal pressure: coughing, sneezing, child labor, feces, urine, vomiting