Science Letters ISSN 2345-5463

DOI: https://doi.org/10.47262/SL/13.2.132025180

Review article
2025 | Volume 13 | Issue 2 | Article ID 1325180sl

ARTICLE INFO

Received
May 12, 2025
Revised
July 11, 2025
Accepted
July 14, 2025
Published
August 20, 2025

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Keywords
Anterior abdominal wall
Fascia
Functions
Muscles

How to Cite
Balogun OA, Oyedun OS, Adebayo AT, Orundiran VO, Oja GB, Ajeleti AO. Interrelationship between the multiple layers of fascia and muscles in the anterior abdominal wall and their relation to functions. Science Letters 2025; 13(2):1325180sl

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Interrelationship Between the Multiple Layers of Fascia and Muscles in the Anterior Abdominal Wall and Their Relation to Functions

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Abstract

Strong, flat muscles make up the abdominal wall and line the abdomen between the ribs and pelvis. These muscles form a framework for the trunk, help with its motion, ensure the organs' position, and allow active changes in the contents of the belly. The ventral abdominal wall is the multi-layered covering that encloses the abdominal organs, providing them with flexible coverage. It is structurally outlined as a six-sided region delineated on its superior border by the xiphoid process, laterally by midaxillary lines, and on its inferior border by the pubic symphysis. There are two parts to the wall of the abdomen: the anterolateral and posterior abdominal walls. This intricate arrangement contains many sheets of tissues from the surface extending far down, including: skin, superficial fascia, muscles, and peritoneum. It is made up of muscles that spread over the lower thoracic and lumbar vertebrae posterior to the ventral abdominal wall. The anterior abdominal wall is important in maintaining anatomical position and gravity as determined by the muscles in its compartment. This review describes the structure of the ventral abdominal wall and summarizes the neurovascular functions and their importance as a medical procedure. Understanding the layering of the abdominal wall is necessary for surgeons when attempting effective body contouring in this area. Adequate knowledge reduces difficulties that may be encountered through the location of incisions and dissection without altering the vascular supply. The intricacy of this wall affords its many functions and adds to a patient's well-being.

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Introduction

Muscularity of the abdominal walls is intricately woven. These walls overlap and are attached to the posterior abdominal wall and paravertebral tissues. It produces an uninterrupted and elastic slip of tissue through the anterolateral regions of the abdomen [1]. There is no clear-cut margin between the lateral and anterior walls; the term 'anterolateral' connotes the wall to this layer of muscles from the rear to the front. These muscles are flanked by the ribs and pelvis on the anterior part of the body and support the trunk, permitting motion and fixing organs in position by controlling intra-abdominal pressure; they are distensible and are capable of allowing changes in the size of abdominal contents [2]. Both deep abdominal and intrinsic back muscles constitute the fundamental muscles that keep the body steady, stable, and protect the spine. Fasciae, muscle, nerves, and vasculature constitute the anterolateral abdominal wall (AAW). This feature allows a wide variety of functions for the requirements of the gastrointestinal tract [3].

Surface Anatomy

Imaginary straight lines drawn from the midclavicular point on the midclavicular plane to the mid-inguinal point and the transverse lines passing through the subcostal plane and the intertubercular plane illustrate the abdomen. Two straight and two transverse lines split the abdomen into nine regions. The abdomen is divided into four quadrants by a straight median line and a transverse line through the transumbilical plane. The inner aspect of the AAW is properly seen when the peritoneum is opened up and various folds and ligaments are present. In the free border of the falciform ligament is the ligamentum teres, which is a rudiment of the umbilical vein. The right and left lobes of the liver lie next to the internal aspect of the AAW. Below the umbilicus are five folds; the most central is the median umbilical ligament, a rudiment of the fetal urachus. It courses from the umbilicus to the bladder. The next are the medial umbilical ligaments, which are the remnants of obliterated umbilical arteries, on both sides of the median ligament, and lastly, the lateral umbilical folds in which the inferior epigastric vessels pass to the arcuate line from the femoral ring [2].

Structure

The surface of AAW is formed by skin and subcutaneous fatty tissue. The skin type found is the thin type and hairy, subject to the sex and race. There is no consistency in the thickness of the AAW and the subcutaneous fatty tissue; this is one of the few parts where too much fat is found in obese people, especially in males [1]. The abdomen lacks skeletal support, being made up of the lower ribs and vertebral column at the back. The abdominal wall is so arranged that it connects superiorly to the bones of the thoracic cage and inferiorly to the pelvic bones. Nine distinct layers are seen in the abdominal wall from outside to inside: skin, subcutaneous tissue, Camper's fascia, Scarpa's fascia, external oblique muscles, internal oblique, transversus abdominis muscle, transversalis fascia, extraperitoneal fat, and parietal peritoneum.

Fascial Plane

The abdominal wall consists of superficial fascia, which is a single layer with some amount of fat present. This is beneath the skin and on the muscles of the AAW. As one moves down the abdomen, the fascia separates into two, which are the superficial and deep layers, superficial vessels and nerves, and superficial inguinal lymph nodes that lie between these layers in the groin region [1]. The Camper's fascia is the first fatty layer of the AAW. This holds loose areolar tissue, located deep in the skin, over Scarpa's fascia. Its function is to support the adipose tissue with its 3-dimensional architecture of fibrous septae, as shown by magnetic resonance imaging [4]. From the xiphoid process to the seventh and 10th costal margins, Camper's fascia extends laterally and to the inguinal ligaments inferiorly. It becomes the subcutaneous fat of the thigh as it continues underneath the inguinal ligament. In the midline, the fascia passes beyond the symphysis pubis. After joining Scarpa's fascia, it becomes the dartos tunic of the scrotum in males and the fatty tissue of the mons pubis and labia majora in females [5]. The functions of this fascia include its role in healing and forming a solid barrier over the abdomen [6,7]. Also, it protects and provides insulation to the organs of the abdomen by reducing and distributing rigor over a expanse area to decrease the quantity of effect that is spread within. In addition, adipose tissue performs the function of an insulator to ensure that the temperature within the abdomen is maintained. There are differences in the depth and uniformity of tissue depending on where the Camper's fascia lies, thereby attaching the skin to the muscles [8]. The abdominal fascial layers are important and should be considered when it comes to abdominal surgery. Care must be taken to prevent distorting vital vessels in the fascial planes. With the proper closure of the fascia, exposure, and the formation of probable out-bulging of bowels through the walls and seromas will be prevented. Two varieties of closures exist: mass and individual fascial closure, both with skin closure.

The former closure is known to have a lesser reappearance of herniations and seroma formation because the gap linking the Camper's and Scarpa's fascia is closed. When each fascia closes, this may create a gap through the layers, resulting in a higher probability of developing a seroma and dehiscence. Recommendation includes using only one suture, which gradually absorbs to reduce the frequency of herniation [9,10]. During cesarean delivery, the correct estimation of the Camper's fascia is essential; a subcutaneous adipose tissue less than 2 cm lowers postoperative wound disruption [9, 11]. Nevertheless, a thickness of 3 cm or more subcutaneous fat is not likely to lower the possibility of wound disruption in vertical midline incisions [12]. Camper's fascia strengthens and insulates the abdominal wall. Camper's fascia's strength is important clinically when looking at the propensity of developing postoperative hernia. The fascia provides backing to prevent the hernia from extending vertically. Extreme burns have the power to cause injury to Camper's fascia if the skin is penetrated, causing an escalated dehydration. The fat content of Camper's fascia disallows dehydration through the skin. In the absence of this fatty layer, serious hypovolemia is a possibility. Interruption of the fascial plane negatively affects the nerves. When there is interference, likely, the cutaneous nerves in the skin interfere abnormally with the nerve supply to the abdominal muscles, thus resulting in irregular communication and permitting a cross-talk between both nerves. To forestall this problem, the correct orientation of the fascial planes after surgery is vital [5, 13]. With a more highly dense collagenous connective tissue layer of the AAW, Scarpa's fascia is significantly slimmer than Camper's fascia. Within it are plenty of elastic fibers and loose connective tissue. It is located mostly in the lower abdomen with fibers that are well-developed and progress on the sides of the abdomen, on top of the rectus sheath. The growth of the fascia is not inadequate in the center of the abdomen, unlike the lateral aspect. In the past, Scarpa's fascia was known to be localized only to the inferior part of the abdomen and perineum, but recently, findings from radiographs show that the fascia extends across the whole torso [14, 15]. Recent findings have shown that the differences in the organization and width of this fascia are connected to which body part and sex [16]. Scarpa's fascia is abundant in the anterior region of the body than in the posterior part. This has been reported more in females than in males. In females, Scarpa's fascia goes as far as the labia majora. Scarpa's fascia is an important tissue that surgeons have to be careful of, as a result of what it does when abdominal incisions heal and its medical implications in the formation of fascial planes around extravasation of body fluids [17]. Scarpa's fascia has an important function in segregating the Camper's fascia from the muscles below. This permits the sliding of Campers' fascia on the layers of the AAW and lessens the abrasion of muscles and assists in abdominal muscle flexion, extension, and rotation. Because collagenous fibers are parallel in orientation towards the force, Scarpa's fascia tolerates enormous pressure in only one direction, thus allowing the fascia to offer support and flexibility for the neurovasculature running within the muscles. Scarpa's fascia readily protects the abdominal cavity organs [17].

Muscular Plane

Anterolateral abdominal wall muscles

The AAW is shaped by the contributions of three sheets of large flat sets of two muscles: the external oblique, internal oblique, and transversus abdominis. In the middle of the AAW, these three muscles' aponeuroses join to produce the rectus sheath, which surrounds the rectus abdominis and pyramidalis and subsequently makes up the linea alba [3].

External oblique

This constitutes the topmost of the AAW muscles. Its fibers run inferomedially and originate from the 5th through 12th ribs. Nearing the midclavicular line, its fibers produce an aponeurotic sheath, which runs through the rectus abdominis to the Linea alba in the midline. Working with the internal oblique, when it contracts, it allows the vertebral column to rotate and to be laterally flexed. The inguinal ligament is formed on its inferior border, running between the anterior superior iliac spine and pubic tubercle [2]. This trunk can twist because this muscle allows it to, but only on the other side of whichever external oblique is doing the contraction.

Internal oblique

The external oblique muscle is superficial to this muscle, with which it works in synergy. Their contraction permits rotation and lateral flexion of the vertebral column. It takes its origin from the inguinal

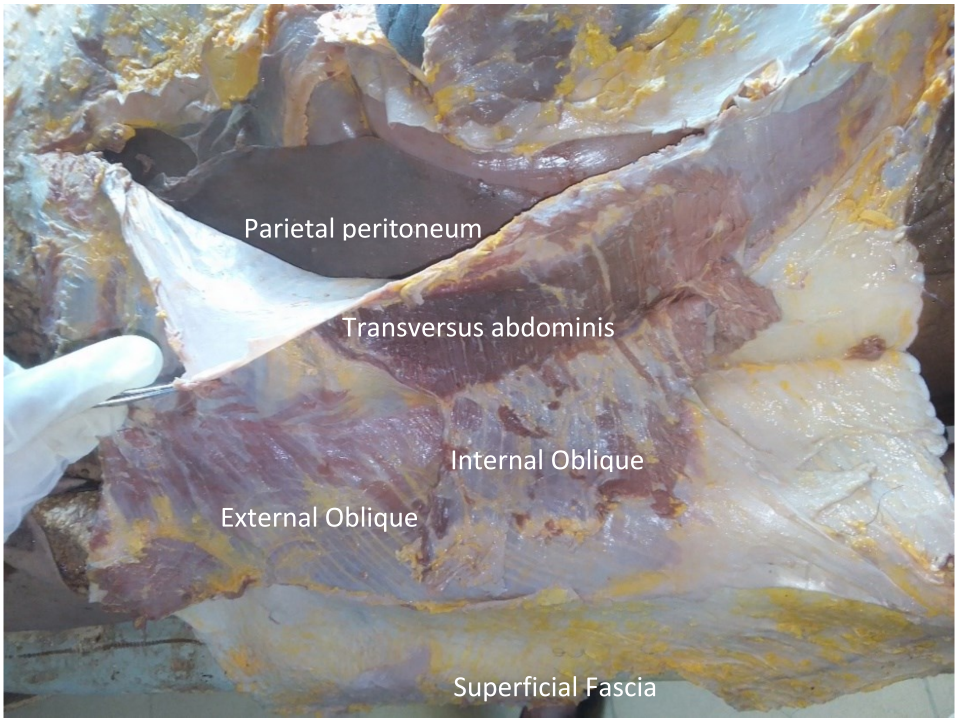

Fig. 1 Layers of the anterior abdominal wall showing superficial fascia, external oblique, internal oblique, transversus abdominis, and parietal layer of peritoneum.

ligament, iliac crest, and lumbar fascia. The direction of its fibers is anteromedially, rectangular to the external oblique before becoming aponeurotic [2]. In the midline, its role in the formation of the rectus sheath is different between its superior and inferior fibers. The superior fibers split to envelop the rectus sheath anteriorly and posteriorly. At its lower part, all fibers run anteriorly to meet the rectus abdominis muscle. Posteriorly, this part of the rectus sheath becomes lacking, without any aponeurotic layer connecting the rectus abdominis and the transversalis fascia. The arcuate line lies on the lower end of the posterior rectus sheath. The action of this muscle is opposite to the external oblique muscles, which twist the trunk to the left, requiring the internal oblique on the left and the external oblique on the right to contract together [2].

Transversus abdominis

This is the innermost of the AAW muscles. It is from the 5th through 10th costal cartilages, the inguinal ligament, the iliac crest, and the lumbar fascia. Its fibers travel horizontally and later become aponeurotic while approaching the rectus sheath. Posteriorly, its superior part runs to the rectus abdominis, contributing to the posterior rectus sheath. Its aponeurosis travels to the muscle just below the arcuate line, thereby making a contribution to the anterior sheath. Compression of abdominal contents occurs when the transversus abdominis contracts. The conjoint tendon is constituted by the inferior part of the internal oblique and transversus abdominis [2]. Essentially, it functions to secure the trunk and sustain internal abdominal pressure. The relationship of all three muscles to rectus abdominis notwithstanding, all three muscular layers approach the Linea alba in the center.

Rectus abdominis

This is an elongated and thin muscle, which runs in the same direction as the Linea alba in the rectus sheath. It originates from the pubic symphysis and crest and courses to join the 5th through 7th costal cartilages. It exerts a great force of flexion on the vertebral column. Three tendinous intersections divide each muscle belly into four distinct muscle segments. The ventral part of the rectus sheath is tethered to these tendinous intersections. These are described as a ‘six-pack’ in athletes [18]. It functions mainly to move the body between the ribcage and the pelvis.

Pyramidalis

This triangular muscle may not always be present; it lies anterior to the rectus abdominis in the lower part of the rectus sheath. It originates from the body of the pubis and increases the tension on the linea alba when it contracts. However, a few people don't have it on both sides [19].

Functions

There are different fiber orientations in the abdominal muscles; they all act in three planes when they move and are connected by having the same site of connection or by fascia [20]. The actions of the abdominal muscles can be complex. Physical activity happens when the brain is controlled by a number of variations through which the abdominal muscles work together to regulate the movement of the spine, pelvis, and rib cage during gait. Movement of the trunk, stabilization of the vertebral column, and the compressing of the wall of the abdomen are the key roles of the muscles of the AAW. Other functions of the wall include protecting the abdominal viscera, maintaining the anatomical position, assisting in vigorous expiration, and contributing to activities that increase intra-abdominal pressure [2, 3]. The external oblique muscle flexes the trunk bilaterally while there is a lateral flexion ipsilaterally and trunk rotation contralaterally. The internal oblique muscle flexes the trunk bilaterally and unilaterally and also does lateral flexion and trunk rotation ipsilaterally. The transversus abdominis compresses abdominal viscera bilaterally and does trunk rotation ipsilaterally. The abdominal muscles are not bulky but have thin and flat structures. The "six-pack abdominal" structure is due to decreased belly fat, enabling vertical muscle detail to be seen. In forced breathing, the internal intercostal muscles and the abdominal muscles contraction is required in expiration. As inspiration sets in, the muscles of the rib cage contract while the abdominal muscles relax, and vice versa during expiration [21].

Anterolateral wall muscles (excluding transversus abdominis) work as accessory muscles of respiration by lowering the ribs to allow vigorous expiration when there is a physiological demand for airway ventilation [2]. Flexibility of the trunk relies solely on the bony deficiency of the AAW, which permits expansion to allow active alterations in the capacity of organs of the abdomen. The wall of the abdomen encloses and offers a framework that allows the growth and effectiveness of the organs of the abdomen. When abdominal muscles contract simultaneously, this facilitates the production of intraabdominal and intrathoracic pressure needed to cough, vomit, sneeze, and defecate. This activity may assist in stabilizing the trunk when loads are lifted. The different muscle arrangement permits a person to switch the body parts. The upper part of the body is required to move constantly, either for sitting down, standing up, walking, or swirling. These muscles have different orientations, insertions, and attachments to allow, so many motions. Activities achieved via motion are reliant on a continuous cycle when the muscles relax and contract on the bony structures that surround them in order for movement to occur. The anterolateral wall has many functions that would not have been possible without the elements that make up the wall [20]. In addition, it enlarges with physiologic needs to be able to allow for enlarged abdominal girth, such as obesity, childbirth, or postprandial state, to permit a large volume of food stored within the gastrointestinal tract [22,23]. Strain to abdominal muscle includes overstretching and inappropriate techniques used in contact sports that entail rigorous activities [24].

Neurovascular Plane

Superiorly, subclavian vessels supply and drain the abdominal wall. The second part of this artery being the internal thoracic artery, passes down beneath the internal intercostal muscles, behind the first six costal cartilages in the thoracic cavity. It descends through the sternocostal triangle of Morgagni into the abdomen in front of the diaphragm. On entering the abdomen, it branches into the musculophrenic artery and later continues as the superior epigastric artery. The musculophrenic artery supplies the anterolateral diaphragm and hypochondrium. The epigastric and umbilical regions and rectus abdominis muscle are supplied by the superior epigastric artery, which lies in the rectus sheath [2]. The lateral abdominal wall and lumbar regions are supplied by branches of the thoracic aorta, tenth, eleventh posterior intercostal, and the subcostal arteries. These arteries extend to supply the internal oblique and transversus abdominis muscles. On the inferior aspect of the AAW, the femoral artery supplies the wall superficially, while the external iliac artery supplies the deep areas. A branch of the external iliac artery, the inferior epigastric artery, supplies the deep suprapubic and umbilical regions. Parallel to the inguinal ligament is the deep circumflex iliac artery, which supplies the deep iliac fossa regions [2]. The femoral artery gives origin to the superficial epigastric and superficial circumflex iliac arteries. The superficial iliac fossa region is supplied by a superficial epigastric artery. The venous drainage is similar to the arterial supply, with the exception that the internal thoracic veins empty into the brachiocephalic veins. The azygous vein on the right and the hemiazygos vein on the left receive the tenth, eleventh posterior intercostal, and subcostal veins [2]. An anastomosis may exist between these veins and paraumbilical veins in the umbilical region. When there is severe portal hypertension, there is a possibility that these anastomoses allow for a portosystemic shunt, by being swollen as the "caput medusae" sign on the abdominal wall [25]. A deep knowledge of the arrangement of superficial and deep epigastric vessels is important for specialists to use in reconstructive surgery when doing free flaps on the AAW [26]. Muscles of the AAW derive innervation from the T7-T12 intercostal nerves. These nerves lie with other vessels between the internal oblique and transversus abdominis. The conjoint tendon of the internal oblique and transversus abdominis, and other muscle fibers that lie inferiorly, are supplied by the iliohypogastric and ilioinguinal nerves. A "transversus abdominis plane" (TAP) block is another way to deliver AAW. Multiple nerves present between the internal oblique and transversus abdominis can get anesthetized, causing a field block. In recent times, using the TAP block in a variety of abdominal surgeries of the abdomen is becoming acceptable [27].

Abdominal body contouring

A surgical procedure that eliminates extra skin and fat from the abdomen, making it smooth and taut, thereby strengthening the muscles to improve contouring, is known as abdominoplasty [28, 29].

Anatomical variations

When the muscular components of the AAW fail to develop, it leads to a newborn with "prune belly syndrome." The skin of neonates with this syndrome has a wrinkled appearance due to the absence of a supporting muscular scaffold underneath it. These children go through several surgical procedures to rebuild the AAW for it to contain the viscera, make breathing better, and for aesthetics [20]. When the abdominal wall is weak, this can lead to several hernias such as incisional, umbilical epigastric and spigelian hernias. The Linea alba may also flatten out while spreading sideways to participate in the formation of the part of the anterior wall that is weakened, leading to an outpouching with a surge in the intra-abdominal pressure, described as diastasis recti. The pyramidalis is not present in 20% of the population [20]. Defects of the AAW may be developmental and have a role to play in a patient's quality of life.

Conclusions

A surgeon's familiarity with the anatomy of the AAW becomes necessary when attempting abdominal wall reconstruction. This procedure requires careful dissection of the various AAW layers and the protection of the blood supply. Inability to avoid damaging the nerves of the AAW can lead to loss and weakness of the abdominal wall [30, 31]. As knowledge of the abdominal wall is expanding, novel procedures for abdominal wall reconstruction and postoperative analgesia can be anticipated. Clinicians and surgeons working on the abdomen should have a detailed understanding of the complexity of this region [3].

Acknowledgements

We appreciate the Gross Lab, Department of Anatomy, Bowen University, Iwo, Nigeria, where the dissection was done.

Conflict of interest

The authors declare no conflict of interest.

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