

THE RECTUS ABDOMINIS MUSCLE IN MALES AND FEMALES OF KERALA- A CADAVERIC STUDY

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ABSTRACT

BACKGROUND

The rectus abdominis is a long, flat strap muscle which extends vertically upward along the linea alba from the pubic symphysis below to the costal margin above. It is a flexor of the vertebral column and thereby plays an important role in maintaining the normal body posture. As it is a part of the anterior abdominal wall, the strength of the muscle plays a very important role in maintaining the integrity of the anterior abdominal wall. Weakness of the rectus abdominis is seen mainly in multiparous women resulting in the divarication of the recti. The lateral border of the rectus abdominis forms the medial boundary of the Hesselbach's triangle, which is the commonest site of direct inguinal hernia. It arises by two tendinous heads: Medial head arises from the anterior surface of the pubic symphysis and the lateral head arises from the lateral part of the pubic crest and the pubic tubercle. The muscle is inserted on the anterior thoracic wall by four fleshy slips along a horizontal line passing laterally from the xiphoid process and cutting in that order, the 7th, 6th and 5th costal cartilages. The paired recti muscles are separated in the median plane by the linea alba. The muscle is three times as wide superiorly as inferiorly. It is broad and thin superiorly and narrow and thick inferiorly. It has a tendinous origin and a muscular insertion that is in the form of four fleshy slips that are attached in a horizontal manner to the lower part of the anterior thoracic wall. The rectus abdominis is enclosed in the rectus sheath, which is formed by the aponeuroses of the anterolateral muscles of the anterior abdominal wall. The muscle usually presents tendinous intersections along its length.

MATERIALS AND METHODS

The study was carried out in the Department of Anatomy, Government Medical College, Kottayam by the dissection of 20 adult cadavers and 5 foetal cadavers during the routine dissection time of the undergraduates and postgraduates. The cadavers were obtained after ethical clearance and were embalmed prior to the study. The rectus sheath was cut by a midline incision to expose the muscle. Measurements were taken, intersections noted and photographed.

RESULTS

Majority of the cadavers studied (88%) had four tendinous intersections that were adherent to the anterior wall of the rectus sheath, but loosely attached to its posterior wall. This was against the description of three intersections seen in most of the anatomy books. The tendinous intersections above the level of umbilicus were complete in all the cadavers studied. There was also a marginal left-sided preponderance in the length of the rectus abdominis in both male and female cadavers. The pyramidalis muscle was seen to be absent in 25% of the cadavers. None of the foetal cadavers showed tendinous intersections.

CONCLUSION

The tendinous intersections help to increase the power of the muscle by dividing it into columns partially or completely. The presence of four tendinous intersections in most of the cadavers studied was a surprising finding. The absence of tendinous intersections in the foetal specimens could imply that they fully develop after birth, probably after the child becomes ambulant.

KEYWORDS

Rectus Abdominis, Tendinous Intersections, Rectus Sheath, Linea Alba.

HOW TO CITE THIS ARTICLE: Narayanan VK, Peter S, Nair AJ. The rectus abdominis muscle in males and females of Kerala- a cadaveric study. J. Evid. Based Med. Healthc. 2017; 4(46), 2804-2810. DOI: 10.18410/jebmh/2017/556

BACKGROUND

The Rectus Abdominis is a long strap-like muscle that extends along the entire length of the anterior abdominal wall. It is widest in the upper abdomen and lies to the side

Financial or Other, Competing Interest: None.
Submission 25-05-2017, Peer Review 01-06-2017,
Acceptance 06-06-2017, Published 07-06-2017.

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DOI: 10.18410/jebmh/2017/556



of the midline.¹ The muscle arises from below by two tendons, larger one attached to the pubic crest, pubic tubercle and the pectineal line, while the small medial tendon arises from the pubic symphysis. The rectus abdominis muscle is attached above to the xiphoid process and costal margins of 5, 6 and 7 ribs (principally the fibres of the 5th rib). The paired recti are separated in the midline by the linea alba.¹ Linea alba is a band of connective tissue that separates the right and left recti muscles vertically. The fibres of rectus abdominis are interrupted by fibrous bands or tendinous intersections. One is usually situated at the level of umbilicus, another opposite the free end of the xiphoid process and a third about midway between the other

two. Sometimes, one or two incomplete intersections are present below the umbilicus. These intersections pass transversely or obliquely across the muscle in a zigzag manner. They are rarely full-thickness and may extend only half-way through the muscle. They usually fuse with the fibres of the anterior lamina of the sheath of the muscle. The intersections may occur during development or may represent the myosepta delineating the myotomes that form the muscle. They are also said to represent the position of the lumbar or abdominal ribs.² These fibrous bands divide the muscle into segments, resulting in the grid iron 'six-pack' shape in those with low body fat. The medial border of the muscle is closely related to the linea alba. The lateral border may be visible on the anterior abdominal wall as a curved groove, the linea semilunaris, which extends from the tip of the ninth costal cartilage to the pubic tubercle. Linea semilunaris is the tendinous intersection that separates the lateral edge of the muscle from the external oblique and internal oblique muscles that lie on the anterolateral surface of the anterior abdominal wall. The Rectus Abdominis acts as a flexor of the spine and an accessory muscle of respiration. They protect the abdominal viscera from external injury and also compresses the abdominal cavity and maintains the intra-abdominal pressure.

MATERIALS AND METHODS

The study was done in the Department of Anatomy, Government Medical College, Kottayam by dissecting 20 adult cadavers comprising of 16 males and 4 females. In addition, 5 foetal cadavers were also dissected. The cadavers were already embalmed. The dissection was done by first removing the skin over the anterior abdominal wall. The superficial fascia and fat was removed. The rectus sheath was identified. The rectus sheath was reflected to expose the rectus abdominis and the posterior lamina of the rectus sheath. The number of tendinous intersections in the muscle and their positions relative to the umbilicus was noted. The length of the muscle of each side was separately noted. The pyramidalis muscle if present was also dissected out. The superior and inferior epigastric arteries were noted lying on the posterior wall of the rectus sheath and anastomosing with each other within the substance of the muscle. The lower five intercostal nerves and the subcostal nerve supplying the muscle were also identified.

Inclusion Criteria

Embalmed cadavers, which had not undergone autopsy were used for the study.

Exclusion Criteria

Autopsied bodies, bodies with penetrating injuries, stab injuries, putrefied bodies, bodies which had undergone surgeries and bodies with burns were excluded.

RESULTS

In the present study, 20 cadavers comprising of 16 males and 4 females were dissected along with 5 foetal cadavers. On dissection, the recti muscles were seen enclosed in the

rectus sheath. The anterior layer of the rectus sheath was seen to extend along the entire length of the muscle. It was also seen loosely covering the anterior surface of the muscle except in the region of the tendinous intersections, where the sheath was inseparable from the muscle. Subcutaneous fat was seen overlying the anterior wall of rectus sheath, but there was no fat deep to it. There were no major vessels seen running along the anterior surface of the recti muscles of both sides. The posterior wall of the rectus sheath was however deficient in the upper part near the insertion of the rectus abdominis; hence, the muscle was seen directly resting on the xiphoid process and the costal cartilages of the 5, 6 and 7 ribs. The posterior layer was well developed and was seen extending up to the level of the xiphoid process in the midline to the arcuate line below (Fig. 7). The superior and inferior epigastric arteries were seen passing through the posterior surface of recti within the connective tissue, supplying the muscles and forming an anastomotic network within it.

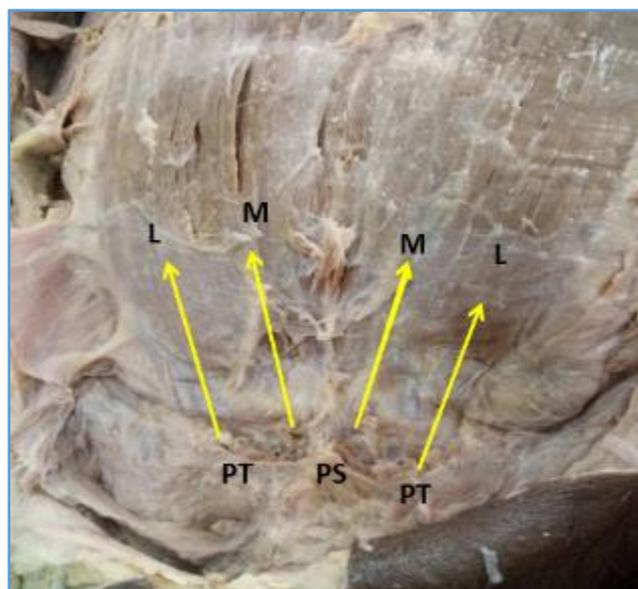


Figure 1. Showing the Origin of Rectus Abdominis

PS- Pubic Symphysis, PT- Pubic Tubercle,
RA- Rectus Abdominis.

L- Lateral head of Rectus Abdominis,
M- Medial head of Rectus Abdominis.

The rectus abdominis was seen arising from the pubic bone by two heads (Fig. 1). The origin was seen to be tendinous and narrow and remained tendinous up to 3 cm from its origin. Pyramidalis muscle when present was seen overlapping this part of rectus abdominis. This overlapping could probably help to reinforce that part of the lower abdominal wall.

The length of the rectus abdominis on the right and left sides were measured.

| | Right Side (cm) | Left Side (cm) |
|----|-----------------|----------------|
| 1 | 33 | 34 |
| 2 | 34 | 36 |
| 3 | 35 | 37 |
| 4 | 36 | 37 |
| 5 | 36 | 38 |
| 6 | 34 | 35 |
| 7 | 37 | 38 |
| 8 | 36 | 38 |
| 9 | 37 | 39 |
| 10 | 33 | 34 |
| 11 | 40 | 42 |
| 12 | 36 | 38 |
| 13 | 30 | 32 |
| 14 | 38 | 39 |
| 15 | 38 | 40 |
| 16 | 38 | 39 |
| 17 | 32 | 34 |
| 18 | 30 | 32 |
| 19 | 32 | 34 |
| 20 | 31 | 33 |

Table 1. Showing the Difference in Length of the Rectus Abdominis on the Right Side and Left Side

An increase in length of 1 to 2 cm in the left rectus abdominis was seen in all the 20 cadavers, which was a striking feature (Ref, Table 1).

| | Right Rectus Abdominis (cm) | Left Rectus Abdominis (cm) |
|---------|-----------------------------|----------------------------|
| Males | 36 | 37.25 |
| Females | 31.25 | 33.25 |

Table 2. Showing the Average Length of the Rectus Abdominis in Males and Females

The average length of rectus abdominis in males was around 36 cm on the right side and 37.25 cm on the left side, while the average length in females was seen to be 31.25 cm on the right side and 33.25 cm on the left side (Ref. Table 2).

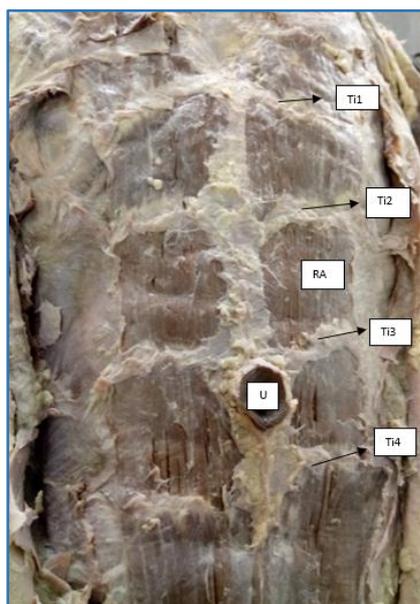


Figure 2. Showing the Rectus Abdominis with Four Tendinous Intersections

RA- Rectus Abdominis, U- Umbilicus.
 Ti1- 1st Tendinous Intersection,
 Ti2- 2nd Tendinous Intersection.
 Ti3- 3rd Tendinous Intersection,
 Ti4- 4th Tendinous Intersection.

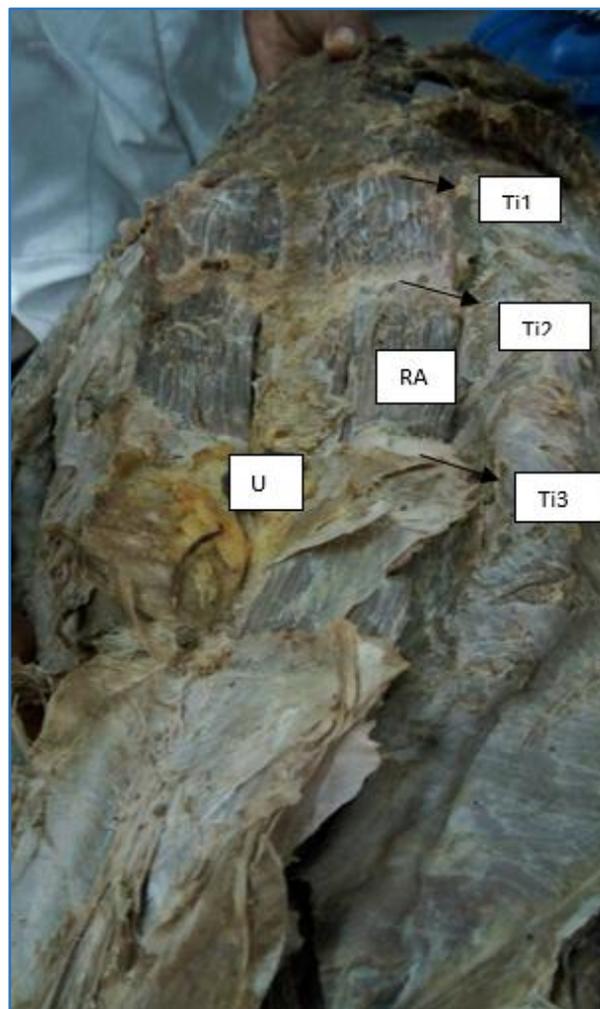


Figure 3. Showing Rectus Abdominis with 3 Tendinous Intersections

RA- Rectus Abdominis, U- Umbilicus.
 Ti1- 1st Tendinous Intersection,
 Ti2- 2nd Tendinous Intersection,
 Ti3- 3rd Tendinous Intersection.

| | WITH 4 TI | % WITH 4 TI | WITH 3 TI | % WITH 3 TI | WITH 2 OR LESS TI |
|---------|-----------|-------------|-----------|-------------|-------------------|
| Males | 14 | 88 | 2 | 12 | NIL |
| Females | 4 | 100 | 0 | 0 | NIL |

Table 3. Showing the Relative Number of Tendinous Intersections (TI) in the Male and Female Cadavers

In this study, it was found that 88% of the male cadavers had four tendinous intersections (fourth one being below the umbilicus) (Fig. 2) and 12% had only three tendinous intersections (Fig. 3) and there were no cadavers having two or less tendinous intersections. All the female cadavers studied were seen to have four tendinous intersections,

which was another striking feature. These tendinous intersections help to divide the longitudinal column of muscle into segments, thereby increasing its power of contraction and preventing divarication of the recti.

| | Complete TI Above Umbilicus | Complete TI at the Level of Umbilicus | Complete TI Below Umbilicus |
|--------|------------------------------------|--|------------------------------------|
| Male | 16 | 6 | NIL |
| Female | 4 | 1 | NIL |

Table 4. Showing the Number of Male and Female Cadavers with Complete TI

In all the 20 cadavers, the tendinous intersections above the level of umbilicus were found to be complete (extending through the entire width and thickness of the muscle), while only 6 males and 1 female showed the presence of complete intersections at the level of umbilicus (Ref, Table 4 and Table 5). There were no complete intersections seen below the level of umbilicus. The tendinous intersections were inseparably fused with the anterior layer of rectus sheath, especially above the level of umbilicus, but could be partially separated at the level of umbilicus. The tendinous intersections were medially fused with the margins of the linea alba and laterally with the aponeuroses of the anterolateral muscles of the anterior abdominal wall.

| | Incomplete TI above Umbilicus | Incomplete TI at the Level of Umbilicus | Incomplete TI below Umbilicus |
|--------|--------------------------------------|--|--------------------------------------|
| Male | Nil | 10 | 16 |
| Female | Nil | 3 | 4 |

Table 5. Showing the Number of Male and Female Cadavers with Incomplete TI

The tendinous intersections were not attached to the posterior layer of the rectus sheath at any level.

| | Right Side | | Left Side | |
|--------|-------------------|-----------------|------------------|-----------------|
| | % Present | % Absent | % Present | % Absent |
| Male | 12 | 75 | 4 | 25 |
| Female | 3 | 75 | 1 | 25 |

Table 6. Showing the Presence or Absence of Pyramidalis Muscle on the Right and Left Side in the Male and Female Cadavers

The presence of pyramidalis muscle was also examined in the cadavers (Fig. 4). On the right side, the pyramidalis was present in 75% of males and females. While on the left side, it was present in 81% males and 75% females. (Ref. Table 6).

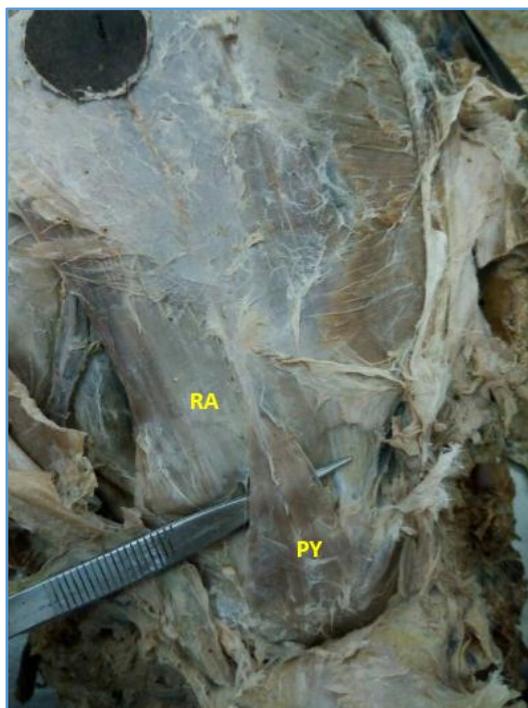


Figure 4. Showing the Pyramidalis Muscle

RA- Rectus Abdominis, PY- Pyramidalis, U- Umbilicus

On dissecting the foetal specimens, no tendinous intersections were observed in any cadavers. The anterior layer of rectus sheath was seen loosely attached to the muscle and could be easily stripped off. The posterior layer of rectus sheath was also very thin and not fully developed. The rectus abdominis muscle was very thin, slender and separated by fibro fatty tissue (Fig. 5).



Figure 5. Showing the Rectus Abdominis in a Foetus

RA- Rectus Abdominis.

The lower 5 intercostal nerves and subcostal nerve were seen obliquely running and entering the muscle through its posterior aspect. The subcostal nerve was seen entering the pyramidalis muscle from its lateral aspect (Fig. 6). The intercostal nerves were accompanied by the small segmental branches of the lower six intercostal vessels.

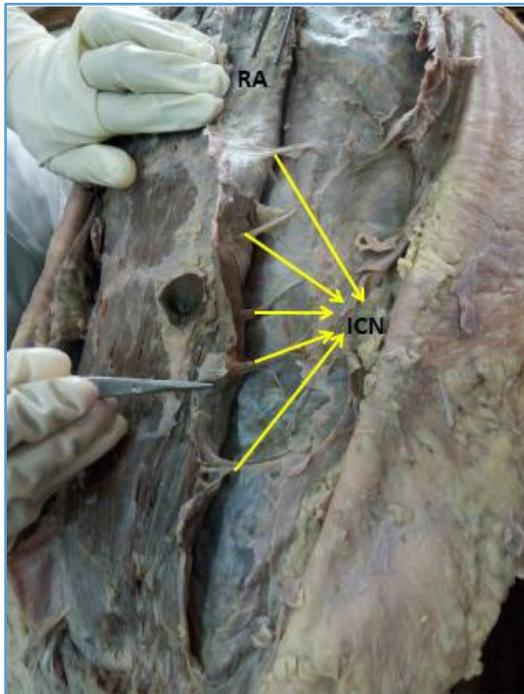


Figure 6. Showing the Intercostal Nerves and Vessels supplying the Rectus Abdominis

RA- Posterior surface of the Rectus Abdominis,
IC-Intercostal nerves and vessels.

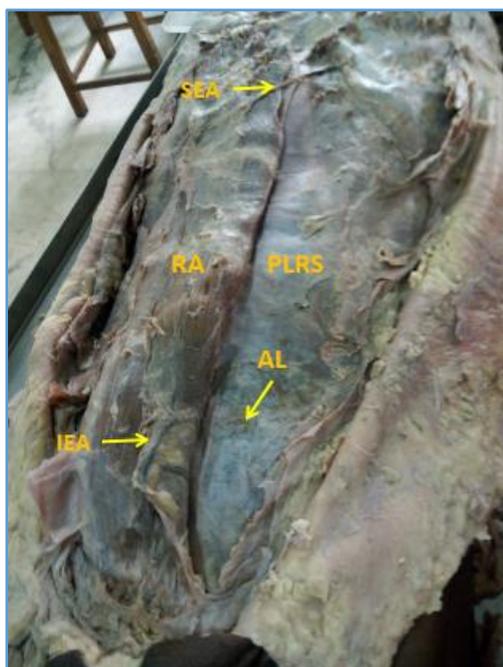


Figure 7. Showing the Rectus Abdominis Reflected to show the Posterior Layer of Rectus Sheath

RA- Rectus Abdominis, PLRS- Posterior Layer of Rectus Sheath, AL- Arcuate Line
SEA- Superior Epigastric Artery,
IEA- Inferior Epigastric Artery

DISCUSSION

The rectus abdominis is a long strap-like muscle that extends through the entire length of the anterior abdominal wall. It widens as it ascends from the pubic symphysis to the costal margin, thus it is wider above and narrow below.³ It arises by two tendinous heads; medial head from the anterior surface of the pubic symphysis and the lateral head from the lateral part of the pubic crest and pubic tubercle. It is inserted by four fleshy slips to the xiphoid process, 7th, 6th and 5th costal cartilages.

The muscle is enclosed within the rectus sheath, which consists of the aponeurosis of the lateral abdominal muscles. The rectus sheath is present on each side of the linea alba. The anterior wall is complete and is made entirely of fibrous tissue, but it differs in thickness at different levels;

- Above the costal margin- The wall is thin and is formed solely by the aponeurosis of external oblique muscle.
- From the costal margin to midway between umbilicus and symphysis pubis- The wall is thicker and is formed by the anterior lamella of the aponeurosis of the internal oblique blending with the aponeurosis of the external oblique muscle.
- From the lower end of the previous extent to the symphysis pubis- The wall is the thickest and is formed by the aponeurosis of external oblique, internal oblique and transversus abdominis. The anterior wall of the rectus sheath is adherent to the anterior surface of the rectus abdominis along the tendinous intersections.

The formation of the posterior wall of the rectus sheath varies at different levels.

- From the costal margin to midway between the umbilicus and symphysis pubis- The wall is mainly composed of fibrous tissue and is formed by the posterior lamella of the aponeurosis of the internal oblique blending with the transversus abdominis aponeurosis. At its lower extent, the wall presents a free margin known as the arcuate line which is concave downwards.
- Below the arcuate line- The wall is deficient and the rectus muscle is covered by the thickened part of fascia transversalis, which separates the muscle from the extraperitoneal tissue and parietal peritoneum.
- Above the costal margin- The wall is deficient and the rectus muscle rests on the 5th, 6th and 7th costal cartilages.⁴

The posterior wall is entirely free from the posterior surface of the rectus muscle separated by loose areolar tissue. This permits passage of blood vessels and lymphatics along the posterior surface of the muscle.

This traditional concept of arrangement of fibres in the rectus sheath underwent a drastic change following the analysis of Rizk in 1980.⁴ According to the newer concept,

the aponeuroses of each flat muscle is bilaminar and their arrangement varies in different regions. The aponeurotic fibres present three linear decussations;

- Along the entire length of linea alba; the decussation may be single or median or triple with one median and two lateral close to the medial borders of the rectus abdominis;
- Along the middle line of the anterior wall of the rectus sheath; this is observed in the region between the umbilicus and the iliac crest;
- At the linea semilunaris in the region between the umbilicus and the iliac crest.

In the present study, it was found that the disposition of the two layers of the rectus sheath corresponded more to the older concept, but linear decussations were also well seen in the anterior layer, particularly in the region of the linea alba.

Each flat muscle has a bilaminar aponeurosis. Of the six laminae on each side, three passes in front of the rectus muscle and three behind. The laminae do not terminate into the linea alba, but decussate with other laminae in the linea alba and continue as the laminae of the contralateral side.⁵ The anterior wall of the rectus sheath between the costal margin and umbilicus has trilaminar architecture consisting of two laminae of external oblique and the anterior lamina of the internal oblique. The posterior wall consists of the posterior lamina of internal oblique and two laminae of the transversus abdominis. Below the umbilicus, the layers change their superficial to deep sequence near the pubis; they are modified by the presence of the conjoint tendon.

The rectus abdominis muscle is supplied by the lower five intercostals and the subcostal nerves. The blood supply is mainly obtained from the anastomotic branches of the superior epigastric artery and inferior epigastric artery, which anastomose within the rectus sheath at the level of the umbilicus within the rectus muscle.³ In the study, it was observed that the lower five intercostal nerves were accompanied by the corresponding vessels, which also contributed to the blood supply of the muscle.

Rectus abdominis muscle is well known to be segmented by tendinous intersections into a certain number of serially arranged compartments. The tendinous intersections are present only on the anterior aspect and fused with the anterior sheath of the muscle.⁶ Three to four tendinous intersections are identified in each rectus abdominis muscle normally. Whetzel et al studied the vascular anatomy of the tendinous intersections of the rectus abdominis muscle.⁷ The rectus abdominis muscle and intersections have been divided into separate numbered zones. Zones 1, 3, 5 and 7 are muscle zones; while Zones 2, 4 and 6 are superior, middle and inferior tendinous intersections.⁸ Upto 17th week of prenatal life, rectus abdominis muscle of human foetuses have no tendinous intersections. They appear as late as between 17th to 20th week of foetal life. The tendinous intersections grow into the muscle from the anterior wall of the sheath.⁹ In the present study, however, there were no tendinous intersections seen in any of the full-term foetuses.

The anterior wall of the rectus sheath was thin, while the posterior wall was underdeveloped. Meenakshi S, Manjunath KY studied 82 recti and found that 21.95% had four intersections, 60.97% had three intersections, 14.63% had two intersections and only 2.44% had a single intersection.¹⁰ The present study of 40 adult recti showed that 88% had four tendinous intersections and 12% had three tendinous intersections. The tendinous intersections represent lines of fusion of myotomes. The tendinous intersections interchange fibres to blend inseparably with the anterior rectus sheath and do not penetrate to the posterior surface of the muscle. The contracting muscle can be seen bulging between the tendinous intersections in an individual who is not too fat.¹¹ In the upper abdominal wall, the linea alba is well developed, right and left recti are separated and both the layers of rectus sheath are present.¹² This statement correlated with the present study. The absence of complete tendinous intersections below the level of umbilicus could be one of the reasons that divarication of recti is more frequently seen below the umbilicus.

Arterial supply of the muscle derives from the epigastric arteries; superior epigastric artery, terminal branch of the internal thoracic artery and the inferior epigastric artery that originates from the external iliac artery. The inferior epigastric artery runs loosely, superiorly on the posterior surface of the rectus abdominis and enters the rectus sheath at the arcuate line, passing upwards and anastomoses with the superior epigastric vessels.¹³

Pyramidalis- This is a small, insignificant triangular muscle that is absent in about 20% people. It lies anterior to the inferior part of rectus abdominis and attaches to the anterior surface of the pubis and the anterior pubic ligament. It ends in the linea alba, which is especially thickened for a variable distance superior to the pubic symphysis. The pyramidalis tenses the linea alba. When present, the attachment of the pyramidalis to the linea alba is used as a landmark for median abdominal incision.¹⁴

CONCLUSION

Rectus abdominis is the prime vertical paramedian muscle of the anterior abdominal wall that maintains the strength and integrity of the anterior abdominal wall. The presence of tendinous intersections highlight the power of the muscle in the functional point of view. Majority of the specimens had 4 tendinous intersections, which was against the commonest pattern of having 3 tendinous intersections. Further studies should be done in this aspect to delineate whether it is a regional/ethnic variation or a standard finding. The marginal left-sided preponderance in the length of the rectus abdominis in both male and female cadaver was another interesting finding, but the reason for this is inconclusive. The absence of tendinous intersections in the foetal specimen would imply that they develop after the child becomes ambulant. Further studies in this regard would also be beneficial.

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