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Original Article

Anatomy Section

Assessment of Superficial Fascia and Abdominal Fat of Anterior Abdominal Wall using Computed Tomography: A Retrospective Study

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ABSTRACT

Introduction: The advancements in technologies have created new promenade pertaining to the anatomy of the anterior abdominal wall and body contouring surgery. This kindle the anatomist and surgeon to redefine the anatomy of the anterior abdominal wall. Anterior abdominal wall was routinely tutored as two layers, but the controversy regarding the existence and extent prevails. From the literature search, it was evident that preservation of Scarpa's fascia is the pivot in determining the outcome of abdominal surgeries.

Aim: To document the existence and extent of the Membranous Fascia of Scarpa (MFS) and compare the abdominal fat between age and sex-matched Computed Tomography (CT) images at 3 levels i.e., i) L1 vertebrae, ii) umbilicus and iii) anterior superior iliac spine and also to compare the distribution of abdominal fat.

Materials and Methods: This retrospective cross-sectional study was conducted in collaboration with the Department of Radiology at Sri Manakula Vinayagar Medical College and Hospital, Puducherry, from November 2019 to December 2020. A total of 60 CT images, that were age and sex matched were collected from the Medical Records Department. Data were analysed using Statistical Package for Social Sciences (SPSS) version 24.0 for windows. Types and extent of fascia were expressed in percentage, fat distribution as mean. The difference in mean between two and three independent groups was made using the Student's t-test. The statistical tests applied were two tailed and p-value<0.05 were considered significant.

Results: Single layer of the MFS was observed with 93.3%, 76.7% at level 1; 53.3%, 66.7% at level 2, 70%, 63.3% at level 3, among CT images of male and female respectively. The findings supported the presence of MFS on the entire anterior abdominal wall and 8 different patterns of MFS were observed. The anterior abdominal wall showed three layers of superficial fascia, with superficial fatty, MFS, and deep fatty zone. On comparing the abdominal fat, superficial fat was significantly high among females at all three levels. However, the deep fat though high among females in all the three-level; it was significantly high only at levels 1and 2 among subgroup 1 (p-value=0.003 and 0.001 respectively) and level 1 of subgroup 3 (p-value=0.01).

Conclusion: The study decipher 3 layer theory of superficial layer of the anterior abdominal wall and superficial fat was significantly high among females, supporting that gender to be high-risk for surgical intervention. Redefining anatomy would guide for better and fruitful outcomes in surgical interventions.

Keywords: Abdominal contour, Female obesity, Membranous fascia, Scarpa's fascia, Visceral and superficial fat

INTRODUCTION

The advances in the insights related to the anatomy of the anterior abdominal wall have opened new avenues related to abdominoplasty and other body trimming surgeries and therefore it is imperative to revisit the anatomy of the anterior abdominal wall [1]. Controversies exist about the existence and extent of the abdominal fascia of Scarpa, which was evident by a varied explanation by a variety of authors across the globe. This is largely due to the varied dissection technique and perception of the abdominal layer, by the anatomists. Scarpa's layer is elaborated as a single layer [2,3], two layer [4-6], three layers [7-9], and sometimes multiple layers [10]. But, it is indeed the abdominal fat that forms a pivot for controversies regarding the number of layers [11]. The regions of occurrence of membranous fascia of Scarpa's [MFS] is also debatable. Last's anatomy describes it as existing along the lower thorax and abdomen [12] and few rebut mentioning that it exists all over the body [13-15]. Abdominal fat assessment, monitoring, and reduction have been part of the regular existence of any human from adolescents even to the elderly. The terminology of abdominal fat includes subcutaneous and visceral. Visceral fat serves as the marker of metabolic syndrome and predictor of cardiac events [16]. These varied descriptions and surgical importance of MFS kindled to revisit its anatomy. Why keen on Scarpa's fascia? The obesogenic environment had made people get linked with either short-term or long-term processes of body contouring methods. Body contouring surgeries fall in the short-term process of body shaping. MFS has a predictive role not only in body contour surgeries [17,18] but also in most of the surgeries of the anterior abdominal wall like hernia repair etc., [19]. Understanding better anatomy of this fascia's existence and extent will help surgeons to explore its clinical implication for better patient outcome and care. With conventional teaching of anterior abdominal wall anatomy, surgeons unambiguously conclude that the MFS exists only below the level of the umbilicus [19]. Knowing the clinical implication of MFS and its varied explanation, this retrospective cross-sectional study was devised to document the existence and extent of the MFS and to compare the abdominal fat between age and sex-matched CT images.

MATERIALS AND METHODS

This retrospective cross-sectional study was conducted in collaboration with the Department of Radiology at Sri Manakula

Vinayagar Medical College and Hospital, Puducherry, from November 2019 to December 2020. The study was approved by the Institutional Research Committee and Institute Ethical Committee [EC/33/2019]. Sample size was 60 (30-male and 30-female). CT images were selected for the study.

Sex-matched, 30 CT images of each sex, between the age group of 21-60 years were obtained from the Medical Records Department during the above study period. Images were of 1 mm thickness from Philips 16 slice CT scanner of 350mAs and 90KV.

Inclusion and Exclusion criteria: CT images of asymptomatic patients where MFS and fat could be made out were chosen, on the other hand CT images of patient with metabolic syndrome, diabetes, other chronic debilitating conditions were excluded as it would interfere with the measurement of abdominal fat.

The horizontal and vertical extent of MFS was mapped at 3 levels: Level 1- at the level of first lumbar vertebrae, Level 2- at the level of umbilicus which corresponds between the 3rd and 4th lumbar vertebrae, and Level 3- at the level of Anterior Superior Iliac Spine (ASIS).

To compare and document the abdominal fat superficial and deep to the MFS, the CT images were categorised into three subgroups according to age:

- Subgroup 1: 21-30 years;
- Subgroup 2: 31-50 years; and
- Subgroup 3: 51-60 years.

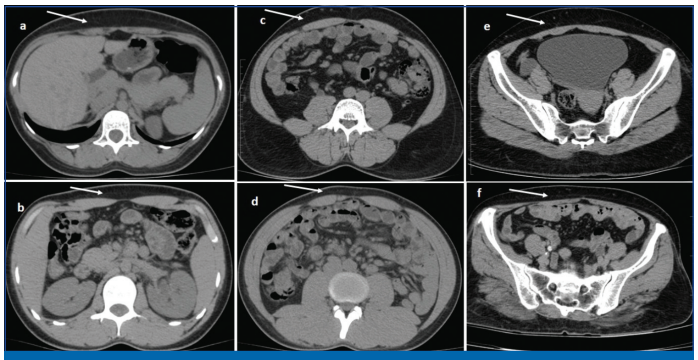
Abdominal fat was measured at Linea Semilunaris (LS) of all three levels.

STATISTICAL ANALYSIS

Data were analysed using the SPSS version 24.0 for windows. Types and extent of fascia were expressed in percentage. Comparison of abdominal fat among the groups was done by student's t-test. A p-value<0.05 was considered significant.

RESULTS

Observation of 60 axial CT scans of the abdomen showed the existence of MFS, which is identified as a radiolucent layer below the skin, but to of different extent, especially beyond the LS [Table/Fig-1].



[Table/Fig-1]: Axial section of CT images showing MFS.
Axial section of CT images, at level 1 (a,b); level 2 (c,d); level 3 (e,f). Arrow indicates MFS at Various level a-L1 level Not reaching(NR), b-L1 level Reaching(R); c-L2 NR, d-L2 R; e-L3 NR, f-L3 R

[Beyond LS, the membranous fascia is divided into multiple layers based on which they are divided into 4 types- 1 Single layer, 2 Double layer, 3 Multiple layers, 4 Not clear]. All the observations are at the level of LS.

At all the three levels, maximum males and females had single layer [Table/Fig-2]. That is 93.3% of males and 76.7% of females at the level L1, 53.3% of males and 66.7% of females at L2, and 70% of males and 63.3% of females at L3. None had non-clear membranous layer at LS.

Level	Types of fasciae	Male (n,%)	Female (n,%)
L1	1	28 (93.3%)	23 (76.7%)
	2	2 (6.7%)	3 (10%)
	3	0	4 (3.3%)
	4	0	0
L2	1	16 (53.3%)	20 (66.7%)
	2	9 (30%)	9 (30%)
	3	5 (16.7%)	1 (3.3%)
	4	0	0
L3	1	21 (70%)	19 (63.3%)
	2	2 (6.7%)	7 (23.3%)
	3	7 (23.3%)	4 (13.3%)
	4	0	0

[Table/Fig-2]: Types of Fasciae.

Beyond LS, the membranous layer was traced till midline for its existence. Membranous fascia had different course.

[1] It was reaching midline (R);

[2] It was not reaching midline (NR) but dip into the fatty layer; and

[3] It was not clearly (NC) made out in the midline.

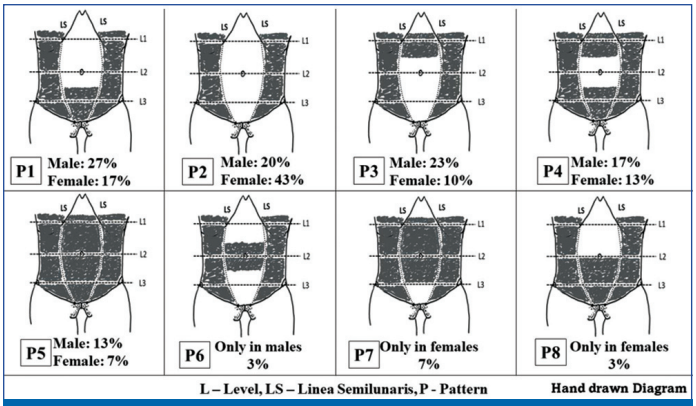
At the level of L1, the membranous fascia of 50% of males reached midline. An almost equal percentage of males (26.7% and 23.3%) had not reaching and not clear membranous fascia respectively. In females, level L1 showed no predominancy; instead, 36.7%, 33.3%, 30% of membranous fascia respectively reaching midline, not reaching midline and not clear radiologically. At the level of L2, 80% of males and 73.3% of females had membranous fascia not reaching midline. At the L3 level, 53.3% of males had membranous fascia reaching midline and 46.7% of females had fascia not reaching midline [Table/Fig-3].

Level	Male (n,%)			Female (n,%)		
	R	NR	NC	R	NR	NC
L1	15 (50%)	8 (26.7%)	7 (23.3%)	11 (36.7%)	10 (33.3%)	9 (30%)
L2	4 (13.3%)	24 (80%)	2 (6.7%)	5 (16.7%)	22 (73.3%)	3 (10%)
L3	16 (53.3%)	10 (33.3%)	4 (13.3%)	10 (33.3%)	14 (46.7%)	6 (20%)

[Table/Fig-3]: Extent of Membranous Fascia of Scarpa.
[R-Reaching midline, NR-Not reaching midline, NC- Not clear]

Incorporating the horizontal and vertical extent together resulted in 8 patterns of MFS of the abdominal wall [Table/Fig-4]. In all the patterns, MFS was obvious till LS. Five of the patterns were common to both sexes. The most common pattern (P1) seen in males (27%) was the one where MFS didn't meet midline beyond LS in zone 1 and 2 but was a continuous layer in zone 3. Total of 17% of females had this pattern of existence. The next most common pattern (P2) in males (20%) where the MFS didn't reach midline in all the 3 zones. This was the most common pattern observed in females (43%). Pattern (P3) with fascia continuous in zone 1 but not reaching the midline in zone 2 and 3. 23% of males and 10% of females had this pattern. Males (17%) and females (13%) had the pattern (P4) where MFS fused to midline except for zone 2. Male (13%) and female (7%) had the peculiar pattern of MFS reaching midline in all 3 zones (P5).

Pattern (P6) was present in 3% of males with not reaching MFS at zone 1,3 and reaching at zone 2. No female showed such a pattern. Pattern (P7 and P8) was present only in females with a distribution of 7% and 3% respectively. P7 was non reaching MFS in zone 3 and reaching midline in the other two zones. P8 was an inverse pattern of P7 with not reaching MFS at zone 1 and reaching MFS at zone 2,3.



[Table/Fig-4]: Eight Patterns of Superficial Fascia of Anterior Abdominal Wall [Hand drawn by authors].

Comparison of abdominal fat showed that fat deposition superficial to Scarpa's fascia was significantly high ($p<0.05$) among females at all three level (L1, L2, L3). The deep fat was significantly high ($p<0.05$) among females at L1, L2 in subgroup1, and L1 in subgroup 3. Though not statistically significant, females have high mean deep abdominal fat in all other levels [Table/Fig-5].

Sub-Groups	Level	Superficial [mm]		p-value superficial	Deep [mm]		p-value deep
		Male	Female		Male	Female	
1 (21-30 years)	L1	6.5±2.4	11.4±3.7	0.003*	3.9±2.2	9.1±4.8	0.003*
	L2	8.6±1.8	12.5±4.6	0.023*	7.7±3.4	14.7±4	0.001*
	L3	7.1±2.1	12.4±4.5	0.003*	8.01± 5.9	11.7± 3.4	0.10
2 (31-50 years)	L1	8.6±3.3	14.3±6.2	0.02*	6.03± 2.7	7.6± 1.4	0.11
	L2	8.9±3.2	14.4±4.1	0.004*	10.1± 3.9	9.8±3.8	0.88
	L3	11.2± 3.6	16.1±5	0.022*	8.2±3.8	8.2±4.5	0.98
3 (51-60 years)	L1	6.2±2.6	13.5±3.8	<0.001*	4.5±2.1	8.8±4.5	0.01*
	L2	8.1±2.8	13.8±4.7	0.005*	9.3±5	10.4± 4.5	0.62
	L3	8.5±2.9	16.04± 6.2	0.003*	10.3± 6.2	10.5±5	0.93

[Table/Fig-5]: Distribution of superficial abdominal fat.
*Indicates significant p-value <0.05 by student 's - t test; n=30 in each group; A p-value<0.05 was considered significant

DISCUSSION

Routine anatomy teaching, explains that the superficial layer of the anterior abdominal wall is two, fatty layer of camphor and the membranous layer of Scarpa, and it is evident below the level of the umbilicus and remains a single layer above it [2-4]. Controversy regarding the existence and extent of the MFS of Scarpa is timeless. Though anatomists acknowledge the presence of MFS, consensus regarding its extent was not reached.

In the present study, it was observed that the presence of fat helped in visualising the layer of MFS which was a radiolucent layer in CT images. It was a single layer till LS, later with the presence of abdominal fat the MFS layer is counted. A majority had a single layer, and at all three levels, no image showed absence of MFS. The present study supported the presence of MFS till LS after which it was divided into several layers. Hence, LS became the surgical landmark for delineating the number of layers. Though multiple fat deposits were seen radiologically, fat superficial to MFS was measured as superficial fat, deep to MFS were put together and measured as deep fat. MFS is considered as the plane of dividing abdominal wall fat. The results were parallel to the study by Kumar P et al., which also suggested that the fat deposited in the abdominal wall corresponds to its multilayers and it reduced laterally [20].

In contrast to the classical description regarding the extent, the Last anatomy mentions its presence in the lower thoracic and entire abdominal wall [12]. Abu-hijleh MF et al., confirmed the presence of the membranous layer in all the regions of the body and its thickness varied with the region, gender, and body surface [13]. Ullah SM et al., demonstrated the existence of membranous fascia by dissecting seven embalmed cadavers [21]. The results of the present study also support the existence of the same in the region of the entire abdomen by radiological observation.

Observations from the present study showed anterior abdominal wall has three zones of superficial fascia: the superficial fatty zone, MFS, and the deep fatty zone. The presence of fat on either side of the collagenous layer of MFS guided to assess its extent. This finding was coherent with the previous studies of Chopra J et al., Lancerotto L et al., and Markman B and Barton FE Jr [7-9].

The anatomists stick to two layers of the superficial fascia of the anterior abdominal wall as the interpretation of Henry Gray regarding the disposition of fascia was carried forward. Though the canon of anatomy was not fixed to the above theory, surgeons view the fascia from an anatomical perspective and hence Gray's interpretations were categorically considered [6]. Markman B et al., [9], in the study based on morphological observations and CT scan, documented that 'superficial fascia' exists as a discrete layer separating the fat into superficial and deep compartments and also added that he confirmed Gray's theory of two layered anterior abdominal wall [9]. This was the polemic statement of Markman B his observation of the three layered theory confirmed the two layered concept of Gray.

Recently, the Fascia Research Society had proclaimed the definition of fascia, as a three-dimensional continuum of soft, collagen-containing, loose and dense fibrous connective tissues that permeate the body. It incorporates the element of connective tissue [15]. As per the definition and annotations from the present study, the functional 3-dimensional environment of the superficial fascia of the anterior abdominal wall is provided by fat organised in the superficial and deep fat zone, and collagen present in MFS. The same was also observed radiologically in the present study.

Even though the technical definition of superficial fascia or subcutaneous tissue is the same across species the morphological aspects tend to differ, largely due to the amount of fat lodged in it. The process of fat deposition in humans is to balance the act of immune function and reproduction, which signifies its selectivity to the female gender. The adaptive feature of fat deposition is now a maladaptive nature as the mechanisation of the modern world replaced the physical effort, leading to an obesogenic environment [22]. Eight different patterns of MFS were observed in the present study. The diversity observed between the most common pattern of MFS in the current study and study by Chopra J et al., [7]. In the current study, the most common pattern of MFS observed in female was, the MFS not reaching midline at all the three levels. This was the most common pattern of MFS among males in the study by Chopra J et al., [7]. The rationale for variation might be the fat and its localisation in the abdominal wall.

Female preference of abdominal fat deposition was also observed in the present study. Fat deposition superficial to Scarpa's fascia is significantly high ($p<0.05$) among females at all three-level (L1, L2, L3). The deep fat is significantly high ($p<0.05$) among females at L1, L2 in subgroup1, and L1 in subgroup 3. Though not statistically significant, females have high mean deep abdominal fat in all other levels. This was contrary to the study by Harley OJ et al., where deep fat among females was high in the mid abdominal and lower abdominal region [23].

Observation of anatomy and maintaining the same, brings better outcome in surgery [1]. Observation of anterior abdominal wall anatomy forms fulcrum in body contouring surgery. The three layered theory of anterior abdominal wall was updated in Gray's anatomy [24].

Subcutaneous Abdominal Fat (SCAT) and Visceral Abdominal Fat [VAT], remain different in several parameters. VAT portrait as a marker of metabolic syndrome, but measures like diet, physical activity, bariatric surgery targets reduction of SCAT. Promising findings by Merlotti C et al., documented that VAT loss is linked to SCAT loss [25]. So, subcutaneous fat was targeted for body contouring procedures. MFS serves as a beacon in abdominoplasty. MFS has a key role in determining patient outcomes in abdominoplasty. Altering the milieu of MFS and fat deep to MFS are considered as one of the red zones in abdominoplasty. Preservation of MSF reduces the rate of seroma formation, duration of hospital stays, and total drain output [1,17,18]. Preserving membranous Scarpa's added significant patient outcome not only in abdominoplasty but also in ventral hernia repair surgeries [26]. Disturbing sub-Scarpa's fat during sub Scarpa's liposuction was an added risk for flap necrosis and seroma formation [27].

Knowledge of the extent and preservation of MFS enhances the better outcome of the patient undergoing abdominoplasty. Surgically, MFS is focused in the infra umbilical region, its importance in the other region needs further expedition, which might be the game-changer in the field of plastic surgery.

Limitation(s)

Since, the aim of the present study was to decipher the extent of membranous fascia and fat of anterior abdominal wall, other anatomical parameters were not considered for analysis. Further studies, both cadaveric and radiological, in all other regions, are required to provide a better insight to fascial architect.

CONCLUSION(S)

This cross-sectional radiological study confirmed a single layer of MFS till LS and the three layer concept of the superficial fatty zone, intermediate membranous layer, and deep fatty zone later to LS. The female preponderance of fat deposit imposes that gender to be the high-risk group for surgical intervention. Better anatomy of the anterior abdominal wall will influence and guide better techniques in surgical interventions.

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