

Transversalis Fascia and Preperitoneal Fascia: A Laparoscopic Study of Live Surgical Anatomy during TEPP Hernioplasty – Final Report and Literature Review.

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ABSTRACT

Background: Despite excellent perspective, bright lighting and high magnification afforded by preperitoneal laparoscopy, there is still little agreement among the practicing surgeons and anatomists about transversalis and preperitoneal fascias. **Methods:** Study Setting – Elective Clinical; Design – Prospective; Population – Adults (≥18 years); Place – J. N. Medical College Hospital, A. M. U., Aligarh; Procedure: Laparoscopic total extraperitoneal preperitoneal (TEPP) hernioplasty; Technique: Standard 3-midline-port technique; Method: Telescopic and instrument dissection; Data collection – Intra-operative documentation and/or video recording; Data analysis – SPSS (v. 21). **Results:** Sixty eight TEPP hernioplasties (Unilateral TEPP 52; Bilateral 8) were successful in 60 patients. Transversalis fascia was of three types – single diaphanous layer (60%), single membranous layer associated with little/no fat (15%) and thin flimsy layer (25%). Preperitoneal fascia was observed as a definite single membranous layer in 83% of the cases, and as a double membranous layer in the remaining 17%. Internal spermatic fascia was found as an extension analog of the preperitoneal fascia in all cases in the present study, with formation of a secondary internal inguinal ring at its beginning. Easily fissile avascular plane was consistently present between preperitoneal fascia and transversalis fascia, suggesting different embryological origins. **Conclusion:** Preperitoneal laparoscopy of inguino-pelvic region confirmed regular presence of easily recognizable preperitoneal fascia distinct from transversalis fascia in all cases, with an easily fissile avascular preperitoneal plane in between them. Transversalis fascia was invariably unilaminar but preperitoneal fascia was at times bilaminar. Instead of transversalis fascia, preperitoneal fascia formed internal spermatic sheath with a secondary internal inguinal ring.

Keywords: Transversalis fascia, preperitoneal fascia, preperitoneal space, holy plane of dissection, TEP, TEPP, TEP anatomy; TEP hernioplasty;

INTRODUCTION

About 75% of all abdominal wall hernias are seen in the inguinal region.^[2,3] Inguinal hernia repair is the commonest general surgical procedure worldwide.^[4,5] It is estimated that 20 millions of inguinal hernia repairs are performed globally every year,^[2] but currently only 15-20% of them are really carried out by the laparoscopic approach in America and around the world.^[6] In 2011, Kulacoglu summarized the current trend for laparoscopic hernioplasty with wide geographical variations – from 1% in Japan,^[7,8] to 4% in UK,^[9,10] to a minority in America and European countries to 15% (unilateral primary inguinal hernia) to ~30% (for bilateral & recurrent inguinal hernia) in Canada,^[11,12] to 30% in Germany.^[13] Technical dexterity with a

longer learning curve is one of the major reasons for such a low ratio of laparoscopic hernioplasty globally in addition to the increased operating times, increased costs and absolute necessity of general anaesthesia, despite the clear advantages, including less acute and chronic postoperative pain, shorter convalescence, and earlier return to work.^[11,14,15]

Laparoscopic total extraperitoneal preperitoneal (TEPP) hernioplasty has become a well-recognized established technique with proven efficacy, reduced post-operative pain and low failure rate, in addition to the early return to activity and work.^[16,17] However, the learning curve of TEP hernioplasty is long and steep, and carries paramount importance for the beginners/ inexperienced surgeons.^[18] The steep long learning curve is often discouraging to many surgeons who therefore declare the laparoscopic technique not worth for such a basic surgery.^[19] 'Initially, the dissection of the extraperitoneal space in the TEP approach tended to be difficult, confusing and therefore hard to learn'.^[20] Therefore, it is a common observation worldwide that the young upcoming surgeons as well as the experienced surgeons not trained in the

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laparoscopic hernioplasty find great difficulties in execution of the TEPP hernioplasty for no apparent reasons/causes which are almost always attributed to the lack of his/her surgical skills or presence of adhesions, although the main cause of difficulties in reality lies in the inadequate understanding of extraperitoneal fascial anatomy & improper dissection,^[16,21-23] leading to its lack of popularity despite the obvious advantages and better results.^[19,24] The inguinal anatomy as viewed through the laparoscope is unfamiliar to most surgeons who often find the preperitoneal dissection tedious and frustrating.^[25,26]

Therefore, accurate anatomical knowledge of the inguino-pelvic preperitoneal area is critical and mandatory to learn before embarking on the technically demanding technique of TEPP hernioplasty, especially from the current as well as the old literature.^[16,26,27] The learning curve for the TEPP hernioplasty encompasses three phases of learning and training.^[27] Basically in the first phase (25 cases) of the learning curve, the surgeon learns the identification of the anatomic landmarks from the posterior preperitoneal perspective and in the second phase (25-40 cases), he/she learns the technique of the preperitoneal dissection. Finally in the third phase (after 45 cases), he/she overcomes the difficulties faced in phase 1 and 2, along with increased surgical performance with speed.^[27]

In 1994, Maurice Arregui observed that 'Because of the increasing interest in laparoscopic inguinal herniorrhaphy, there has been a renewed interest in the anatomy of the preperitoneal area. Numerous publications exist on the anatomy of the vascular, nervous, skeletal and musculoaponeurotic preperitoneal structure, but little information exists on the preperitoneal fasciae.'^[28] Little has changed till today as is evident from a single laparoscopic study of transversalis and preperitoneal fasciae reported in 1997 by Arregui himself apart from the interim reports by the present author.^[22,29,30] Anatomy of the preperitoneal tissues of groin is reported to be complex,^[24] and conflicting information abounds regarding the interparietoperitoneal fascias and fibro-fatty tissues since the time (1804) of Sir Astley Paston Cooper.^[31,32] Moreover, new surgical techniques provide new vision of structures known for centuries.^[32] 'The recent literature on laparoscopy describes the musculoaponeurotic, vascular, and nervous structures of the inguinal area from a transabdominal or preperitoneal vantage point. However, there remains significant confusion regarding the transversalis fascia and the multilayered preperitoneal fascia'.^[34]

Therefore, a prospective doctoral research was undertaken to study the live surgical anatomy of the TEPP hernia repair, especially the transversalis fascia and preperitoneal fascia.

MATERIALS AND METHODS

A doctoral research was designed and carried out prospectively in the elective clinical settings in the Jawaharlal Nehru Medical College Hospital, Aligarh during a period from April, 2010 to November, 2015, under the approval of the Institutional Ethics Committee, Faculty of Medicine, Aligarh Muslim University, Aligarh, India. Adult patients with inguinal hernia were operated laparoscopically by the total extraperitoneal preperitoneal (TEPP) approach under the written informed consent of the patients in the Department of Surgery. All patients were operated by a single experienced senior surgeon, the author. Recruitment Criteria of the present study included (1) Patient's choice of the laparoscopic hernia repair, (2) sufficiently good financial status of patients, (3) Patient's fitness for general anaesthesia as judged in the PAC clinic (pre-anaesthetic check-up), (4) Availability of functioning laparoscopic equipment and instruments. Inclusion Criteria were: (1) adult patient ≥ 18 years, (2) patients with fully reducible primary inguinal hernia, (3) patients with ASA grade I – II only (American Society of Anesthesiologists), and (4) written informed consent for laparoscopic hernioplasty. Exclusion Criteria were: (1) lack of consent for laparoscopic repair, (2) patients < 18 years, (3) patients in ASA grade III-IV, (3) complicated inguinal hernia, (4) recurrent inguinal hernia, (5) femoral hernia, and (6) previous lower abdominal surgery. Patients' demographic characteristics were recorded in terms of age, gender, weight (without footwear), height, and occupation. Deurenberg's formula was used to calculate the body mass index.^[35]

Surgical technique was 3-midline ports with direct telescopic initial dissection without a balloon in the posterior rectus canal under CO₂ insufflation at 12 mmHg pressure. This was followed by further definitive dissection in the preperitoneal space. Details of the surgical technique were consistently the same as reported earlier by the author.^[29,30,36-44] Morphology of the transversalis fascia as well as preperitoneal fascia was observed carefully. Instant documentation and/or video recording were done. Statistical Package for Social Sciences (SPSS v. 21) was utilized for data analysis. A p-value of < 0.05 was taken as significant.

RESULTS

A total of 66 patients with the uncomplicated primary inguinal hernia consented for the laparoscopic hernia repair. Three female patients were excluded due to one or more exclusion criteria. Three patients were excluded due to an early conversion to TAPP (n=1) and open surgery (n=2). Three causes of conversion were (1) frank peritoneal injury just after placement of the 1st optical port, (2)

early injury to the deep inferior epigastric vessels by the instrument just after placement of the 1st working port, and (3) excessive CO₂ retention after the start of the procedure. Thus 68 TEPP hernioplasties (Unilateral TEPP 52; Bilateral TEPP 8) were successful in the 60 patients. Overall mean age and BMI of the patients was 50.1±17.2 years (range 18-80) and 22.6±2.0 kg/m² (range 19.3-31.2) respectively. Patients included manual labourers (N=24), retired persons (N=9), office workers (N=8), students (N=7), farmers (N=6) and field workers (6).

Detailed observations made in the present study about the transversalis and preperitoneal fasciae are described first separately in the following paragraphs for easy understanding, which are then supplemented with some common observations.

Transversalis Fascia

Transversalis fascia in the inguinal region (TF-IR) was found three types – (1) well-defined single diaphanous (well-defined single membranous associated with significant fibro-fatty tissues on its outer side) (SD) in 41 cases, (2) well-defined single membranous with little/no fatty tissue on its outer side (SM) in 10 cases [Figure 1] and (3) thinned-out flimsy (FL) in 17 cases. The mean age and BMI was not different significantly (p >0.05) between the two groups of SD and ATT (SM/FL) or among the three groups (SD, SM and FL) of the TF-IR (Table 1and 2) [Figure 2].

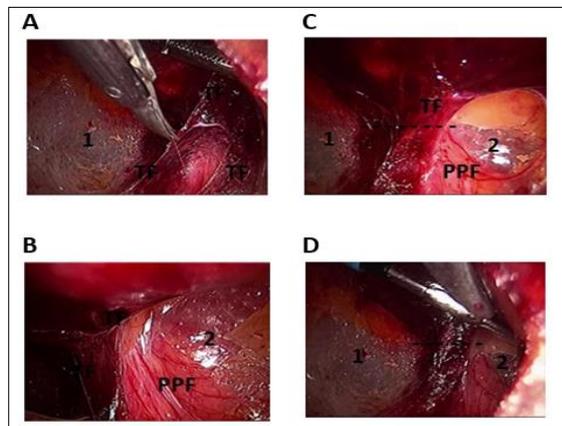


Figure 1: Right TEPP: (A) The single membranous Transversalis fascia (TF) opened up; (B) The TF is seen still closely applied to the second layer of the PRS (posterior rectus sheath) but distinctly separate from the preperitoneal fascia (PPF), especially more evident laterally where the TF is clearly seen as diaphanous; (C) The TF being separated from the PPF covering hernial sac and cord structures; (D) The TF being lifted up and divided to make the communication between the pre-fascial retropubic space (1) with the sub-fascial subinguinal space (2); (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Infraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia

during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

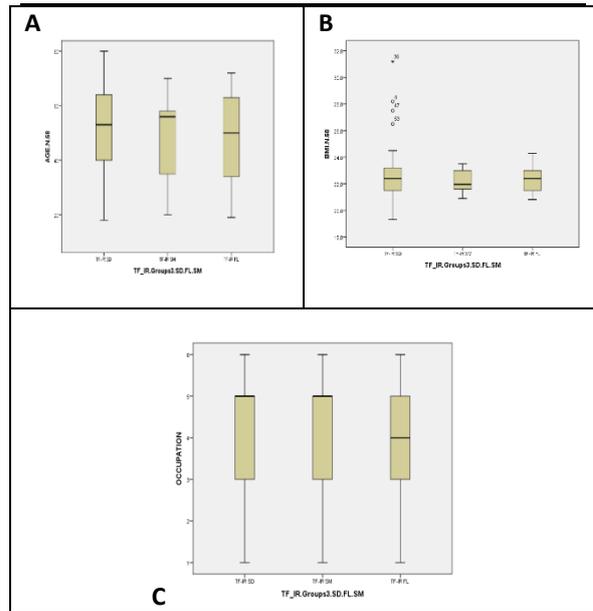


Figure 2: Correlations of Transversalis Fascia Types with Patients' Age (A), Body Mass Index (B) and Occupation (C): TF-IR, transversalis fascia in inguinal region; SD, single diaphanous; SM, single membranous; FL, thin flimsy; Note: Each hernioplasty was counted as one. (Pearson CHISQ CC: p >0.05; Likelihood Ratio: p >0.05; Linear-by-Linear Association: p >0.05); (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Infraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

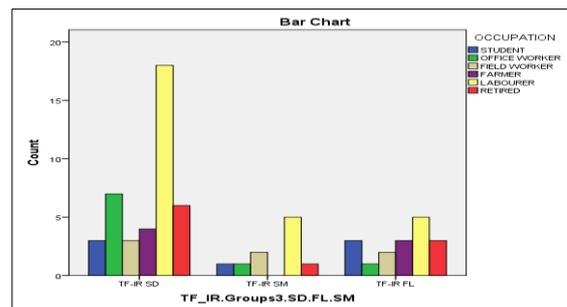


Figure 3: Correlation between Transversalis Fascia of the inguinal region (TF-IR) and the patients' Occupation: SD, single diaphanous; SM, single membranous; FL, thin flimsy; (Pearson CHISQ CC: R=6.799, df 10, Sig. 0.744, p >0.05; Likelihood Ratio: R=7.606, df 10, Sig. 0.667, p >0.05; Linear-by-Linear Association: R=0.218, df 1, Sig. 0.641, p >0.05); (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Infraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

The TF-IR was mirror anatomy on the two sides of the body in all 8 patients with bilateral hernias (SD vs. SD in 3; SM vs. SM in 2; FL vs. FL in 3) (Table 3). Occurrence of SD type of transversalis fascia was found 1.5 times higher as compared to that of the attenuated types (ATT), i.e., SM and FL types (Table 4). Despite apparently wide variation in the incidence of TF types among various workers, the TF types did not have any significant correlation ($p > 0.05$) with the occupation of the patients [Figure 3]. In 54 cases with incomplete posterior rectus sheath (IC-PRS) with formation of a primary Arcuate line, dissection in the posterior rectus canal was easily extended into the in the classical Retzius space as reported earlier by the author [42], and the posterior boundary of the lower part of the posterior rectus canal (distal to the Arcuate line of Douglas) and the classical Retzius space was formed by the transversalis fascia (TF) only. Inferior to the Arcuate line, the deep inferior epigastric vessels (DIEV) were contained within the transversalis fascia (TF) with some reinforcement from the Rectus fascia but superior to the Arcuate line, the DIEV were contained only within the variably thickened posterior epimysium of the rectus abdominis muscle, i.e., the Rectus fascia as reported earlier by the author.^[39,40] In other words, the DIEV vessels were not seen bare anterior to the transversalis fascia even in presence of thin flimsy TF (N=17). Moreover, in these patients with IC-PRS, entry into the preperitoneal space of either medial suprapubic region or lateral inguinal area was achieved by dividing the transversalis fascia at a convenient place as reported earlier by the author.^[44] In all cases, while working within the preperitoneal spaces between the transversalis fascia and the preperitoneal fascia, the DIEV vessels was found contained and covered by the transversalis fascia but always visible across it clearly or faintly depending upon the character (Diaphanous, thin membranous or flimsy) of the transversalis fascia [Figure 4 and 5].

In other words, the transversalis fascia momentarily splitted into two layers to enclose the DIEV vessels and then re-formed [Figure 6] in a fashion analogous to the investing layer of the deep cervical fascia that has been described to split momentarily and to enclose the superficial muscles of the neck.^[45] This anatomic disposition of the transversalis fascia was more clearly observed when the DIEV vessels were taken down inadvertently as happened in 3 out of 68 hernioplasties in the present study: the DIEV vessels were found enclosed within the transversalis fascia but the transversalis fascia itself was found unilaminar on either side of the vessels, indicating the transient splitting of the transversalis fascia at the level of the DIEV vessels as was also reported earlier by the author [Figure 5].^[40]

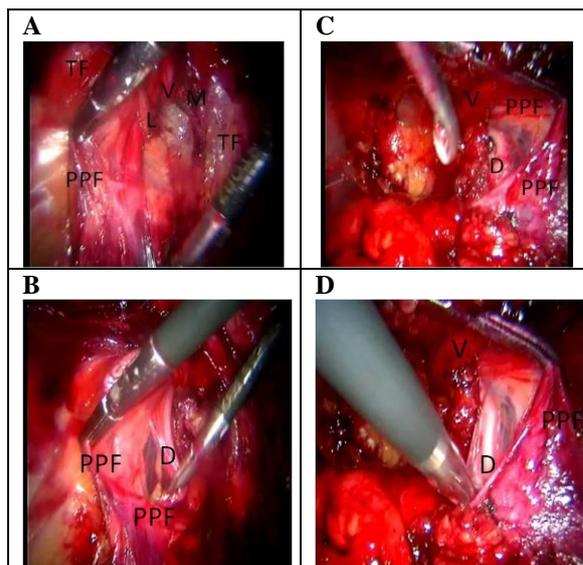


Figure 4: Left and Right TEPP: Well-defined single membranous preperitoneal fascia (PPF) ensheathing the indirect hernial sac and cord structures: PPF is being opened up to separate the cord structures from the hernial sac on the left side (Fig. A & B) and on the right side (Fig. C & D); TF, transversalis fascia; D, vas deferens; V, deep inferior epigastric vessels; L, well-developed interfoveolar ligament; M, medial fascial extension; (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - "A Study of Laparoscopic Surgical Anatomy of Infraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia", Aligarh Muslim University, Aligarh, India, 2016)

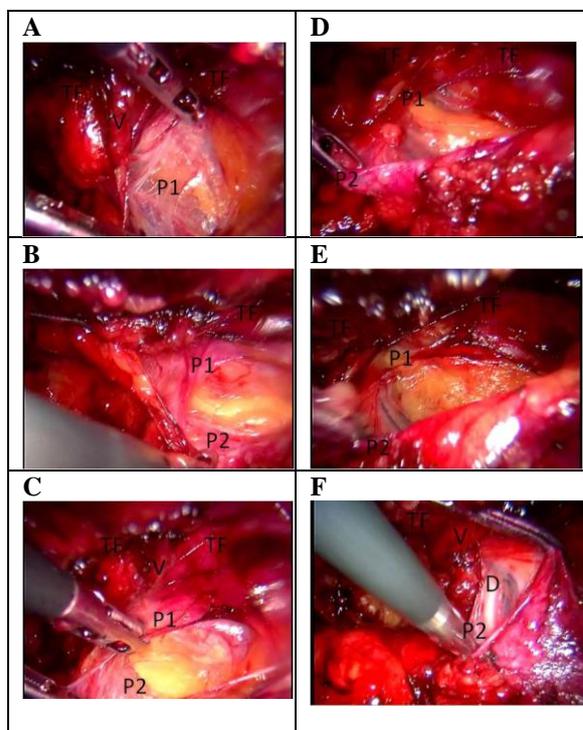


Figure 5: Indirect Hernial Sac Dissection during Right TEPPs: showing a double membranous preperitoneal fascia (PPF-DM); P1, outer thin membranous preperitoneal fascia; P2, inner membranous

preperitoneal fascia still closely applied around the cord structures and indirect hernial sac; TF, well-defined transversalis fascia; V, deep inferior epigastric vessels; (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Intraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

In 14 cases with complete posterior rectus sheath (C-PRS) with absence of a primary Arcuate line, dissection in the posterior rectus canal was also easily extendable into the classical Retzius space as was also reported earlier by the author,^[42] but the posterior boundary of the posterior rectus canal (both upper and lower parts) was formed by both the posterior rectus sheath and the transversalis fascia. Posterior boundary of the classical Retzius space below the insertion of the posterior rectus sheath was formed by the transversalis fascia only. In these cases, the DIEV vessels were contained only within the Rectus fascia throughout their course within the posterior rectus canal as was also documented earlier by the author.^[39,40] Moreover, in patients with C-PRS, entry into the preperitoneal space of either medial suprapubic region or lateral inguinal area was achieved by dividing both the complete posterior rectus sheath and the transversalis fascia at a convenient place as was also documented elsewhere by the author.^[44]

In all cases studied, while working within the preperitoneal space between the transversalis fascia and the preperitoneal fascia, the DIEV vessels were found contained and covered by the transversalis fascia but always visible across it clearly or faintly depending upon the character of the transversalis fascia [Figure 4 and 5]. On the other hand, the cord structures and the indirect hernial sac if present, were found enclosed within a fascial layer (internal spermatic fascia) not derived from the transversalis fascia but derived from the preperitoneal fascia [Figure 4 and 5].

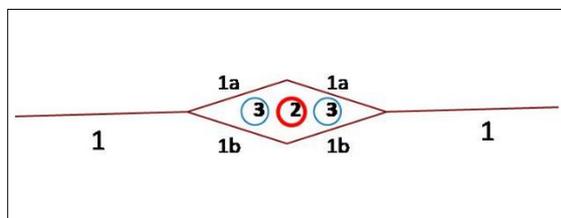


Figure 6: Diagrammatic illustration showing splitting of transversalis fascia: 1, transversalis fascia (unilaminar); 1a and 1b, split layers of transversalis fascia enclosing deep inferior epigastric vessels; 2, deep inferior epigastric artery; 3, deep inferior epigastric veins

Preperitoneal Fascia

The plane of dissection was found avascular underneath the transversalis fascia and the deep

inferior epigastric vessels which were kept anteriorly abutting the anterior abdominal wall. This easily fissile avascular plane was continued upto the deep inguinal ring, and was found readily extendable laterally and medially. Until now the peritoneum or its extension, the indirect hernial sac, was not seen at all or seen only faintly because of the presence of a thin but definite membranous fascia covering the extraperitoneal fat and the parietal peritoneum [Figure 4]. Such an anatomic disposition was undeniable as it was consistently observed in all of our patients who underwent TEPP hernioplasty (N=68). The thin but definite membranous fascia covering the extraperitoneal fat and mimicking the ‘tissue-paper like membrane’ of Colborn and Skandalakis was aptly termed the ‘Preperitoneal Fascia’, and it was called as the ‘Fascia of Anson’ by Redman, or the ‘Fascia of Lampe’ by Condon and Memon et al.^[44,46-48]

In the majority (83.33%) of our patients in the present study, the preperitoneal fascia was observed as a single membranous layer [Figure 4, 5 and 7][Table 5, 6 and 7]. However, in the remaining 16.67% of our patients, the preperitoneal fascia was found double-layer, both layers being thin membranous with little/no loose areolar tissue between them [Figure 8][Table 5, 6 and 7]. Preperitoneal fat present between the preperitoneal fascia and the parietal peritoneum was found minimally fatty in 56.7%, moderately fatty in 33.3%, and excessively fatty in 10% of the patients.

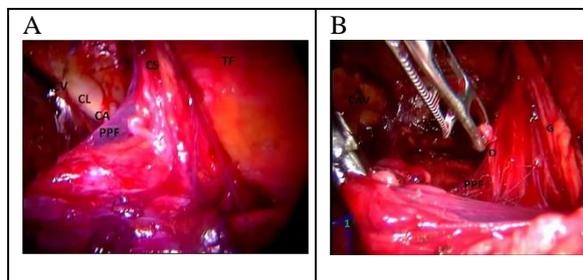


Figure 7: Right TEPPs: Parietalization of the cord structures: (A) a small subclinical indirect hernial sac (associated with a clinically direct hernia) being dissected off the cord structures from within the covering of the preperitoneal fascia (PPF) while the transversalis fascia (TF) is seen in the background applied to the anterior abdominal wall; (B) a large indirect hernial sac being dissected off the cord structures after ligation and division by teasing out the PPF; CL, Cooper’s ligament; CV, venous corona mortis; CA, arterial corona mortis; CAV, arterial-venous corona mortis; 1, blue polypropylene ligature end; (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Intraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

The plane of dissection between the two fasciae, namely, the preperitoneal fascia and the transversalis fascia was easily fissile and practically avascular due to almost total absence of any criss-crossing neurovascular supplies of the two distinct fascias. This avascular plane was referred in the surgical discourse by the author as the “surgical preperitoneal plane” to differentiate it from the ‘true anatomic preperitoneal space’, which lies between the preperitoneal fascia/fat and the parietal peritoneum.

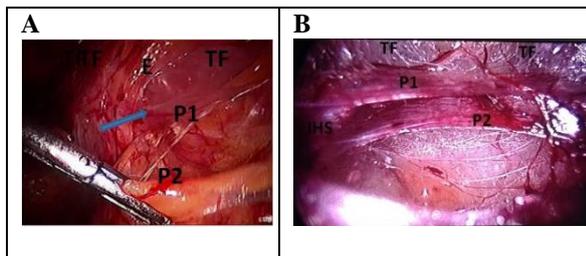


Figure 8: Right TEPPs: (A) showing a double membranous preperitoneal fascia (PPF-DM); P1, outer thin membranous preperitoneal fascia; P2, inner membranous preperitoneal fascia still closely applied around the cord structures and indirect hernial sac; TF, well-defined transversalis fascia; E, superior lateral fascial extension (SLEXT) forming the superomedial crura of the primary internal ring present in the TF; Arrow (↓) shows the secondary internal ring (SR) in the PPF which is extending beyond the SR; (B) showing a double membranous preperitoneal fascia in another patient; (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Infraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

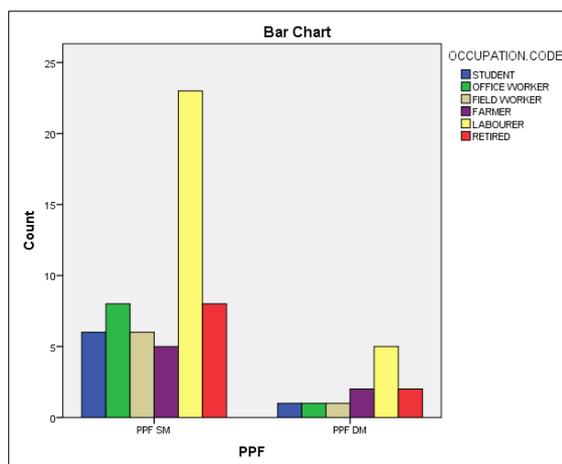


Figure 9: Correlation between Preperitoneal Fascia (PPF) and Patients' Occupation: SM, single membranous; DM, double membranous; (Adapted with permission from Ansari, MM. Thesis for PhD (Surgery) titled - “A Study of Laparoscopic Surgical Anatomy of Infraumbilical Posterior Rectus Sheath, Fascia Transversalis & Pre-Peritoneal Fat/Fascia during TEPP Mesh Hernioplasty for Inguinal Hernia”, Aligarh Muslim University, Aligarh, India, 2016)

The avascular plane outside the preperitoneal fascia was always found easy to extend into the inguinal canal with the preperitoneal fascia continued into the inguinal canal around the spermatic cord structures as their innermost covering, the internal spermatic fascia. This internal spermatic fascia was always required to be teased out to visualize and dissect the indirect hernial sac off the cord structures [Figure 4]. Moreover, parietalization of the cord structures always required the teasing out of the preperitoneal fascia which ensheaths these structures [Figure 7]. The mean age and BMI of the patients with single membranous was not different significantly from those of patients with the double-layer PPF ($p > 0.05$) [Table 6 and 7]. Moreover, the incidence of single-layer and double-layer PPF was comparable across the different types of the profession of the individuals with insignificant correlations (Pearson CHISQ CC, $R = 0.987$, $df 5$, $Sig. 0.964$, $p > 0.05$) [Figure 9]. The anatomy of the preperitoneal fascia was mirror image on the two sides of the body in all 8 cases with the bilateral hernia [Table 3].

To summarize the results of the present study, it was observed in all patients studied during the operation of the TEPP hernioplasty that the Transversalis fascia and Preperitoneal fascia were definite anatomic entities not only distinctly separate from each other with an easily fissile avascular plane in between them but also quite distinct from the Rectus fascia (thickened posterior epimysium of the rectus muscle) lying anterior to the posterior rectus sheath/fascia (when present), lying anterior to the Transversalis fascia. The preperitoneal fascia was found unilaminar in majority (83%) and bilaminar in a minority of patients (17%), while the transversalis fascia was always found unilaminar but often diaphanous (64%) and sometimes thin membranous (13%) or thin flimsy (23%).

DISCUSSION

Way back in 1804, Sir Astley Paston Cooper stated prophetically that “No disease of the human body belonging to the province of the surgeon, requires in its treatment, a greater combination of accurate anatomic knowledge with surgical skill than hernia in all its varieties”,^[31] the essence of which was endorsed in the later part of the 20th century by Cleland et al,^[50] and Read.^[51] The Cooperian philosophy is still timely and rather more true in the current laparoscopic era for safe and successful outcome as emphasized recently by Annibali et al and Bhatia,^[52,53] and it demands crisp precise flawless anatomical knowledge,^[16,26,53] long strenuous laparoscopic learning,^[16,21] and significant laparoscopic experience of >30-80 cases,^[27,55-59] for the seamless surgery, and that it also poses new

dangers of modern technological approaches, warranting more anatomic research.^[28,33] Anecdotal experiences published in the literature indicate that the fascial arrangements and relationships of structures near the deep inguinal ring are unfamiliar from the laparoscopic perspectives and are not generally known to most of the laparoscopic hernia surgeons.^[60] A definite need to define accurately groin anatomy as visualized by the preperitoneal approach cannot be really overemphasized.^[61]

Confusions and misunderstandings are continued regarding the extraperitoneal fascial tissues among the practicing surgeons and anatomists alike since the time (1804) of Sir Astley Paston Cooper.^[22,24,31,32,49,62] Even direct examination of the live surgical anatomy under excellent perspective and high magnification with clear definition of the various fascial planes under the focused bright lighting of the intraperitoneal and preperitoneal laparoscopy did not help much to alleviate the ever prevailing confusions and misunderstandings/misinterpretations, and little/no agreement exists among the practicing surgeons and anatomists regarding the interparietoperitoneal fascial tissues, especially the transversalis fascia and the preperitoneal fascia.^[22,49] In 1997, Maurice Arregui lamented that 'Unlike the anterior anatomy of the inguinal abdominal wall, little in the current English literature exists about the preperitoneal fascia and conflicting information abounds regarding the transversalis fascia. In contemporary literature, there remains not only little understanding but also little interest.'^[22] Since 1997, little has changed over the last two decades as the same poor understanding and little interest is still reflected by the scanty/sparse dedicated research work reported on the extraperitoneal tissue planes in which laparoscopic hernia surgeon makes dissections for space creation and mesh placement for the posterior preperitoneal repair of the inguinal hernia, despite a lot of discussions and deliberations in the live surgical forums and workshops.

'Endoscopic totally extraperitoneal inguinal hernioplasty, TEP, has become an established technique for repair of inguinal hernia.'^[17] A longer learning curve is one of the three major reasons for such a low ratio of laparoscopic hernioplasty globally in addition to the increased operating times and the increased costs, despite the clear advantages, including less acute and chronic postoperative pain, shorter convalescence, and earlier return to work,^[11] notwithstanding certain drawbacks and small but definite risk of complications.^[14,15,27] In addition to the need of the sound technical learning and hands-on training, it is mandatory to acquire precise anatomical knowledge before performing the technically demanding TEPP hernioplasty.^[21,27,55,59,63-65] In addition to the technical dexterity, there are some drawbacks for the common adoption of this technique including

increased operative times, complications during the early learning curve, and almost absolute necessity for general anaesthesia.^[14,15]

The easily fissile plane of the preperitoneal surgical dissection was found avascular as long as both fascia & fat was visible on either side of the dissection plane - anteriorly the diaphanous transversalis fascia and posteriorly the preperitoneal fascia covering the preperitoneal fat, suggesting separate embryonic origin of the transversalis fascia (outermost layer) and preperitoneal fascia (intermediate layer), as also documented by Mark Hayes in terms of the outermost layer (transversalis fascia),^[66] the intermediate layer (preperitoneal or extraperitoneal fascia) and the innermost layer (peritoneum).

Preperitoneal Fascia

In the first clinical laparoscopic study of preperitoneal anatomy in 1997, Maurice Arregui lamented that "Most authors also consider the fascial planes posterior to the epigastric vessels as the tela subserosa or the preperitoneal fascia. There continues to remain much confusion, little agreement, and less understanding of these layers of tissue behind the inferior epigastric tissues".^[22] The concept of a diaphanous preperitoneal fascia (i.e., the preperitoneal fascia together with the preperitoneal fat) was emphasized in one of the author's interim reports,^[30] which was in full tune with the first laparoscopic observations of the preperitoneal fascia reported by Arregui.^[22] However, with greater understanding and evolution of the anatomic knowledge at completion of the present study, the two structures, i.e., the preperitoneal fascia (PPF) and the preperitoneal fat (EPF) have been delinked in order to explore their detailed characteristics individually, and this division was found more logical and appropriate for the sake of discussion and further anatomic stratification.

Presence of a thin membranous preperitoneal fascia was first reported in a large cadaveric study (500 body halves) in 1960 by Anson et al.^[67] Anson's observations were strongly supported by Lampe.^[68] The preperitoneal fascia was called as the 'Fascia of Anson' by Redman or 'Fascia of Lampe' by Condon and Memon et al.^[47-49] Presence of the preperitoneal fascia was undeniably confirmed in two clinical studies of live surgical anatomy by Australian Paediatric surgeon Dr. Robert Fowler in 1975 and Arkansas Urologist Dr. John Redman in 1996.^[5,47] Fowler observed that there is 'a loose fissile plane' between the preperitoneal fascia and the transversalis fascia,^[25] and that the deep inferior epigastric vessels 'serve as a guide to the recognition and separation of the preperitoneal fascia from the transversalis fascia' (which contain the vessels). Fowler's exact description with illustrations of the special features of the preperitoneal fascia in the inguinal region is really interesting - "In the inguen, the preperitoneal fascia is usually thicker and stronger than it is

elsewhere in the abdomen, particularly behind the posterior wall of the inguinal canal and in the vicinity of the internal ring. In this region the membranous layer forms a veritable felt work of fibres, which for descriptive purposes can be somewhat artificially subdivided into superficial and deeper groups [Figure 1]. The most interior of these superficial membranous fibres roof over and surround the spermatic cord structures where they enter the transversalis fascial ring, or internal ring proper. Here they blend with the transversalis fascia and internal spermatic fascia, but elsewhere the preperitoneal fascia and transversalis fascia are separate. These fairly tough anterior fibres have to be deliberately disrupted in order to fully expose a hernial sac by the preperitoneal route [Figure 1, upper].

The deeper main membranous sheet of the preperitoneal fascia displays a circumferential arrangement of fibres surrounding the vas, spermatic vessels, and any patent processus vaginalis when present, forming what is here called the “secondary internal inguinal ring” [Figure I, lower]. These circular fibres have a particularly strong inferomedial lip, around which hooks the vas deferens, as it changes course abruptly from its upward and outward path to a downward and medial one. Surgical disruption of this secondary internal ring opens up an additional fissile plane or little “cave” of loose areolar tissue leading to the retroperitoneal plane.”

Moreover, Fowler supported the observations of Condon that considerable individual variations might occur in the morphology and relative strength of the fascial layers and in the amount of fatty accumulation between the layers.^[25,69] The present study also recorded three morphological types of transversalis (Diaphanous, thin membranous and flimsy) and two types of the preperitoneal fascia (single membranous and double membranous).

In 1996, Redman also described three well-defined fascial layers in the inguino-pelvic region: inner stratum,^[47] the supportive connective tissue of the peritoneum; intermediate stratum, the bilaminar extraperitoneal fascia (fatty layer and membranous stroma); and outer stratum, the transversalis fascia, supporting the observations of Mark Hayes.^[66] Redman also documented a ‘secondary internal ring’ in the plane of the preperitoneal fascia,^[47] and credited Browne for the first description of a secondary internal inguinal ring,^[70] who described in 1933 his clear understanding of the secondary internal inguinal ring along with a beautiful illustration. However, Browne did not name the fibrous plane of the secondary internal inguinal ring.^[70,71]

In 1998, Colborn and Skandalakis documented the constant presence of a tissue-paper like membrane covering the preperitoneal fat in their innumerable cadaveric and surgical dissections,^[46] and this was

found fairly tough at times, although they did not capitalize on the term ‘preperitoneal fascia’. Regular presence of the preperitoneal fascia was strongly supported by Memon and associates,^[49,73] who emphatically cautioned against common mistake of its interpretation as the ‘posterior lamina of transversalis fascia’. Preperitoneal fascia was recognized as the ‘extraserosal’ fascia by the Terminologia Anatomica (1998) as a definite anatomical entity distinct from the innermost layer (transversalis fascia) of the parietal wall.^[49]

Moreover, Amid and Hiatt documented in 2008 that Read and Skandalakis frequently referred to this fascia as the dividing membrane in the preperitoneal space between the transversalis fascia and the peritoneum, but this layer remained largely unknown to surgeons not familiar with the older literature.^[74]

In 2000, Folscher et al described this fascia as the urogenital fascia.^[75] The thin membranous preperitoneal fascia of the groin is quite distinct from the transversalis fascia, although often mistaken for it.^[25,51,67,68,72] This distinction, and other special features of this fascia in the groin, was more readily appreciated in the course of the preperitoneal approach than by either the conventional transinguinal approach or the transabdominal laparoscopic approach. Philosophy of Davies^[46] that the extraperitoneal connective tissue (preperitoneal fascia and fat) and the peritoneum are a reflection of the anatomic disposition of the superficial fascial layers and the skin of the anterior abdominal wall in reverse order, was supported by Colborn and Skandalakis.^[75] In 2000, Kingsnorth et al stated that “Davies suggested that the inner linings of the peritoneal cavity are comparable with the outer coverings of the abdominal wall but reversed in orientation, so the skin (i.e., peritoneum) lies on an adipose layer of Camper (i.e., extraperitoneal fat), which is succeeded by the membranous layer of the fascia of Scarpa (i.e., the membranous layer of extraperitoneal fascia), and this by the muscle fascia of Gallaudet (i.e., transversalis fascia), beneath which is external oblique musculature (i.e., transversus abdominis). This is probably a terrible oversimplification of a highly complex structure, but the authors still find it interesting.”^[75,76]

Robert Fowler observed that “But if the peritoneal relationships are preserved, then additional aspects of the fascia related to the internal ring become apparent,^[25] and are of particular relevance to operations performed by the suprainguinal preperitoneal approach (Nyhus, 1964).^[77] Closely associated with the transversalis fascia, and often mistaken for it (Lampe, 1964),^[68] but clearly separable, is the less well known preperitoneal fascia,^[67] which has certain specialized features of its own in the inguinal region.” Fowler’s ‘Increased opportunities for observations on this preperitoneal fascia and for appreciation of its surgical significance’ with the open supra-inguinal

preperitoneal approach were immensely enhanced through the preperitoneal laparoscopy, in particular by the total extraperitoneal approach with intact peritoneum as was evidenced during our study. Preperitoneal laparoscopy in the present study not only confirmed the regular presence of membranous preperitoneal fascia quite distinct from the transversalis fascia with an easily fissile avascular plane of dissection in between them, the 'Surgical Preperitoneal space' (cf. True anatomical preperitoneal space), but also revealed the presence of a double-layer preperitoneal fascia in 17% of our patients, confirming the observations of Redman that Anson's thicker preperitoneal fascia in the inguinal region is often bi-laminar and easily separable from the transversalis fascia.^[47]

In 2002, Lange et al (2002),^[24] documented the preperitoneal fascia as a 'double-layer preperitoneal fascia complex', supporting the observations of Annibali et al,^[78] although their two layers of the 'preperitoneal fascia complex' really lie in the same anatomical plane, forming the 'internal spermatic fascia' around the cord structures as described by Arregui in 1997 or the conical 'spermatic sheath' reported by Stoppa et al.^[22,79] Present study confirmed the formation of the 'internal spermatic fascia' by the preperitoneal fascia as its extension analog. This is in contradiction to the conventional textbook teaching that the 'internal spermatic fascia' is formed by the transversalis fascia.^[52,80-88] Way back in 1946, Tobin et al documented for the first time that the innermost covering of the spermatic cord,^[89] the internal spermatic fascia, was really derived from the preperitoneal fascia instead of the transversalis fascia. Moreover in 1945, Lytle documented a middle inguinal ring,^[90] a secondary internal inguinal ring, formed by a separate fascial sling in addition to the deep/internal inguinal formed in the transversalis fascia. Anson et al and Fowler concurred with Lytle for the presence of a secondary internal inguinal ring deep to the primary (true) internal inguinal ring (of the transversalis fascia),^[22,25,90] and confirmed its formation by a well-defined preperitoneal fascia distinct from the transversalis fascia. Present laparoscopic study fully supported the observations of Anson et al and Fowler and recorded in all 60 indirect inguinal hernias that a secondary internal inguinal ring was formed at the junction of 'conical spermatic sheath',^[22,25] the first part of the innermost covering of the spermatic cord (internal spermatic fascia) and the preperitoneal fascia covering the general parietal peritoneum. This was evident more clearly with smaller indirect inguinal hernias as was also documented by Arregui.^[22] In 1948, Mark Allan Hayes documented with illustration two fascias related to the intermediate layer/stratum of the extraperitoneal connective tissue,^[66] namely, (1) the umbilical prevesical fascia and (2) the umbilical vesical fascia. This gives credence to the double-

layer preperitoneal fascia observed in the present study.

Transversalis Fascia

Recently in 2001, Robert Bendavid declared that 'The transversalis fascia is the least understood of all the structures that make up the inguinal region.'^[91] Contradictory accounts of anatomy and morphology are attributed to the Transversalis fascia in the literature (Hayes, 1948),^[66] with continued confusions and misinterpretations of the multi-laminar fascial anatomy of the inguinal region,^[22,92] despite the great importance accorded to the transversalis fascia in the prevention of inguinal hernia.^[93-95] The term 'Transversalis Fascia' was coined in 1804 by Sir Astley Cooper,^[31] to the part of endoabdominal fascia that covered the undersurface of transversus abdominis muscle and aponeurosis, separating them from the underlying extra-peritoneal fat and peritoneum. This definition was accepted by a number of investigators including Condon.^[22] However, in 1921, Braus termed all the tissues between the transversus abdominis and the peritoneum as the transversalis fascia. Use of the term 'transversalis fascia' was later extended to "...the entire connective tissue sheet lining the musculature of the (whole) abdominal cavity" by Lampe and others,^[92,95-98] and this is the most popular definition used in the current surgical practice,^[52,88,99-102] although various parts of this transversalis fascia are often designated in relation to the respective musculature.^[92,103]

The bi-laminar description of the Transversalis fascia by Sir Astley Cooper,^[31,32,104] has been hotly contested with a number of stalwarts of the field on either side of the debate.^[49,102] Cooper's bi-laminar concept of transversalis fascia was supported by stalwart investigators including Morton (1841)^[105] Mackay (1889),^[106] Little (1945),^[90] and Read (1992),^[51] but other equally reputed researchers including McVay and Anson (1940),^[107] Condon (1995),^[48] and Mirilas (2008 and 2012)^[71,108] maintained emphatically that the transversalis fascia consisted simply of a single layer. Confusions and misinterpretations of the cadaveric inguinal anatomy are continued even today despite two laparoscopic studies reported in the literature: the first study on the laparoscopic cadaveric anatomy of groin by Colborn & Skandalakis (1998),^[46] in soft unfixed cadavers, and the second study on the laparoscopic live surgical anatomy of groin by Maurice Arregui (1997),^[22] in patients of inguinal hernia undergoing laparoscopic hernioplasty, mainly by total extraperitoneal approach. No other study is available in the literature except the ones reported recently by the author.^[29,30,38,42] The classical review of controversies and confusions about the transversalis fascia by Memon and associates reported in 1999 is a real treat and worth reading for the hernia surgeons and anatomists alike.^[49]

Bilaminar concept of the transversalis fascia did not gain the support of those who would perpetuate it.^[49] The term 'posterior lamina of the transversalis fascia' was not endorsed either by the consensus document of the Nomina Anatomica (12th International Congress of Anatomists, 1989) or in the standard textbooks of anatomy,^[49] including Moore's Clinically Oriented Anatomy,^[85,109] Woodburne and Burkel's Essentials of Human Anatomy,^[83,110] Hollingshead's Textbook of Anatomy,^[111] and Gray's Anatomy.^[100,112-113] In the opinion of Robert Bendavid (2013), the problem arose when Sir Astley Cooper called the transversus muscle as the transversalis muscle, and labelled its inferior continuation as the transversalis aponeurosis or transversalis fascia, although he should have been called it the transversus aponeurosis or transversus fascia that also contributes to the posterior wall of the inguinal canal.^[102] In 1999, Memon et al,^[49] suggested two possible reasons for disparity in description of the transversalis fascia, viz., firstly an actual occurrence of the anatomic variations in formation of the fascial layers in the inguinal region, and secondly the hardening and/or fusions of different fascial layers during cadaver embalming as initially suggested in 1995 by Condon.^[48] Read believed that the "preperitoneal fascia of Lampe" represents the Cooper's posterior lamina of the transversalis fascia as documented by Condon.^[48] Memon and associates emphasized after meticulous dissections, laparoscopic as well as cadaveric (fresh and embalmed) that it is more prudent to treat the 'preperitoneal fascia' distinct and separate from the transversalis fascia. In 2012, Petros Mirilas, the noted surgeon-anatomist of Georgia, categorically declared that 'the concept of the bi-laminar fascia transversalis is outdated',^[108] based on his own exhaustive work reported earlier.^[71] Our observations confirmed that the transversalis fascia is invariably uni-laminar with its own neurovascular supply shared with the transversus abdominis muscle, and the transversalis fascia is quite distinct from the preperitoneal fascia, with an easily fissile plane for avascular surgical dissection in between them, which has made the effective preperitoneal hernia repair (open or laparoscopic) a seamless technical feasibility.

Last but not the least, the author strongly feels that to tackle the baffling situation of current raging confusions and partial interpretations/misinterpretations of interparietoperitoneal fascial tissues based on the different gross dissection/surgical techniques, methods and surgical philosophy, analogous to the famous fable of 'The Blind Men and The Elephant',^[114,115] there is an urgent need of developing an idealistic model of the preperitoneal inguinal anatomy wherein all observations made by every investigator in the past are incorporated, along with a rider that considerable

individual variations do occur frequently in each and every musculo-fascial layer.^[25,88,93] The author intends to report such an anatomic model separately in near future.

CONCLUSION

Present study documented clearly that the 'transversalis fascia' is invariably uni-laminar and it may be diaphanous (60%), thin membranous (15%) or thin flimsy (25%). A well-defined membranous 'preperitoneal fascia' was always present and quite distinct from the transversalis fascia, with their separate neurovascular supply and with an easily fissile avascular plane in between them. Preperitoneal fascia was single layer in majority of patients (83%) and double-layer in a minority of patients (17%). Present study also confirmed that the preperitoneal fascia formed the innermost covering of the spermatic cord, the 'internal spermatic fascia', with formation of a 'secondary internal inguinal ring' at its beginning. The observation of George Posta^[116] that "Besides, performing the preperitoneal laparoscopic hernia repair affords a fascinating and beautiful anatomic dissection," was well illustrated in the present study, and the multiple fascial layers were clearly observed with finer details during the preperitoneal laparoscopy, but which demanded astute understanding and interpretation due to their complex anatomic dispositions coupled with wide morphological variations in each and every musculo-fascial layer as was seen in the present study and also reported by others.^[25,88,93] More laparoscopic research studies in larger population sample may help in further stratification and easy understanding of the anatomic entities, and involvement of a dedicated anatomist may make our efforts easier to expunge the erroneous descriptions and interpretations from the literature. The famous axiom of Thomas Henry Huxley - 'Irrationally held truths may be more harmful than reasoned errors' is really befitting the laparoscopic hernia surgeons to remember all the time,^[117] and may be a paramount reason for the apparently demanding nature of TEPP hernioplasty and hence its unpopularity. Author strongly affirms the opinion of Gupta and associates that a sound knowledge and understanding of the laparoscopic preperitoneal anatomy will render the apparently difficult TEPP hernioplasty an easily achievable target.^[27]

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