InScienz Open Access

Journal of Surgery and Clinical Interventions

Research Article | Volume: 1.1 | Open Access

Arcuate Line Variations: Surgical Significance and Clinical Implications during TEPP Hernioplasty

Maulana M Ansari*

Department of Surgery, J. N. Medical College, Aligarh Muslim University, Aligarh, UP, India

Abstract

Knowledge of arcuate line of Douglas is a crucial key for the success of laparoscopic hernia surgery through total extraperitoneal preperitoneal (TEPP) approach. Literature on the arcuate line (AL) is scanty and mainly cadaveric in nature. Laparoscopic live surgical anatomy of the Arcuate line of Douglas was reported by author for the first time (Ansari MM. Int J Sci Res 2017; 6(6): 2348-2363.). Surgical significance and clinical implications of arcuate line variations are now presented herein.

Sixty adult male patients underwent a total of 68 TEPP hernioplasty successfully. Their mean age and BMI were 50.1 ± 17.2 years and 22.6 ± 2.0 kg/m² respectively. Ratio of ASA grades I and II was 4.5:1. By occupation, patients were manual labourers (N=24), retired persons (N=9), office workers (N=8), students (N=7), farmers (N=6) and field workers (N=6). Present study recorded seven types of arcuate line anatomy. Primary arcuate line, when present, was situated, in general, at 1/3rd of the umbilico-pubic distance. AL anatomy was non-mirror on two sides of body in 62.5% of bilateral hernias.

Overall incidence of conversion to Open/TAPP hernioplasty was 4.3%, but conversion secondary to the anatomic variation (of a high arcuate line) was seen in only 1.4%. In presence of low (10.3%) and absent (20.6%) primary arcuate line, an artificial arcuate line had to be created at about the level of middle working port. Endovision, ease of procedure, operation time and peritoneal injury were significantly affected in an adverse manner by the anatomic variations of arcuate line. Surgical emphysema, postoperative seroma, infection and chronic pain were not affected significantly by anatomic variations of arcuate line.

Keen observation, timely recognition of anatomic variations and judicious dissection are essential to perform TEPP hernioplasty with ease, safety, rapidity and better results.

Keywords: Laparoscopic anatomy; TEPP anatomy; TEP anatomy; Arcuate line; Arcuate line of Douglas; Anatomic variations; Surgical significance; Clinical implication

Introduction

Traditional description of the inguinal anatomy is oversimplified and stereotyped [1,2], and the same is still taught in our anatomy classrooms although 'The study of anatomy has changed enormously in the last few decades' [3]. The anatomy learned in the early days of our medical career gets imprinted, leading to a fixed mindset that often proves counterproductive even under the excellent internal perspective and magnified view of the modern day laparoscopy [4] for instant recognition and precise dissection of the anatomical structures, especially the variant anatomy often reported in the literature [5] which are of paramount surgical importance during the laparoscopic inguinal hernioplasty [6]. Moreover, gross anatomy is often not translated into the surgical anatomy observed on the operation table [7], especially in the unfamiliar laparoscopic posterior perspective [8,9].

Received date: 31 Jul 2017; **Accepted date:** 14 Sep 2017; **Published date:** 19 Sep 2017.

***Corresponding Author:** Maulana M Ansari, Department of Surgery, J. N. Medical College, Aligarh Muslim University, Aligarh, UP, India, Tel: 0091-9557449212; **E-mail:** mmansari.amu@gmail.com

Citation: Ansari MM (2017) Arcuate Line Variations: Surgical Significance and Clinical Implications during TEPP Hernioplasty. J Surg Clin Interventions. 1(1)

Laparoscopic surgery warrants 'crisp precise anatomic knowledge' [10] of not only the target inguinal region but also the adjacent access areas [10-12]. Poor understanding of the level of entry into and maintenance of the surgical pre-peritoneal plane is now regarded as the main cause of surgical difficulties during total extraperitoneal preperitoneal (TEPP) hernioplasty for inguinal hernia with a long learning curve and poor clinical outcomes despite its proven efficacy and better results documented by a number of investigators [13-15]. Knowledge of the Arcuate line of Douglas, the lower border of the posterior rectus sheath, is a crucial key for the success of the laparoscopic hernia surgery through the total extraperitoneal preperitoneal (TEPP) approach [16]. Literature on the arcuate line is scanty and mainly cadaveric in nature, and that too rarely reported in the preperitoneal perspective [17]. Because of its extensive nature, the laparoscopic live surgical anatomy of the arcuate line of Douglas has been published separately by the author [18]. Herein, the surgical significance and clinical implications of the arcuate line variations observed during the total extraperitoneal preperitoneal (TEPP) hernioplasty but not yet discussed in the literature are presented in the present study.

Materials and Methods

A prospective clinical study on laparoscopic live surgical anatomy was designed in April, 2010 and was approved by the Faculty of Medicine, Aligarh Muslim University, Aligarh, and cleared by the Institutional Ethics Committee. The study recruited all consecutive adult patients with primary inguinal hernia who consented for laparoscopic hernia repair and underwent the TEPP hernioplasty after fulfilling the inclusion and exclusion criteria. All patients were operated by a single senior surgeon (the author), the In-Charge of the Surgical Unit 6 of the Department of

Surgery. First case of TEPP hernioplasty was performed in February, 2011 in the Department of Surgery, J. N. Medical College and Hospital, AMU, Aligarh, and the study was completed in November, 2015.

The inclusion criteria for the study comprised: (1) adult patients with uncomplicated primary inguinal hernia, (2) adult patients of age 18 years and above, and (3) adult patients with ASA Grade I & II only of American Society of Anesthesiologists. Exclusion criteria in the study were children and young patients less than 18 years, adult patients in ASA grade III and IV, adult patients with past history of lower abdominal operation, adult patients with complicated inguinal hernia, adult patients with recurrent inguinal hernia, adult patients with femoral/other groin hernia, and adult patients refusing for the laparoscopic repair. Demographic data of the patients were recorded in terms of age, gender, weight (measured without footwear), height, and profession/occupation of the patients. Body mass index (BMI) was calculated by the Deurenberg's formula [19]. In the present study, the Arcuate line variation was considered as a focussed independent variable for all the functional outcomes in the intra-operative and post-operative periods.

Standard 3-midline-port surgical technique through the posterior rectus sheath approach was adopted to perform the total extraperitoneal preperitoneal (TEPP) hernioplasty, and the method was consistently the same as reported earlier by the author [20-24]. Lower border of Xiphisternum, upper border of pubic symphysis and the two anterior superior iliac spines were first marked. Umbilico pubic distance was measured from the centre of the umbilicus to the upper border of the pubic symphysis. After placement of the first 11-mm optical port in the infraumbilical position, unhurried controlled telescopic dissection was carried out within the posterior rectus canal in each and every patient in order to carefully observe for the arcuate line position and morphology of the arcuate line. Percutaneous needle confirmation was done for both placement of the 5-mm working ports and for ascertaining the position of the arcuate line (Figures 1A and 1B). Entry into the preperitoneal space was made at about the level of the middle working port for definitive dissection and mesh placement. Early conversion protocol was adopted in case of any exigency that might risk the safety and survival of the patient.

Outcome measures of the study were endoscopic vision (measured in visual analog score of 1-10), ease of procedure (measured in visual analog score of 1-10), operation time, peritoneal injury, surgical emphysema seroma, infection, chronic pain and recurrence, and their correlations with the arcuate line anatomy. Statistical Package for Social Sciences (SPSS v. 21) was used for all statistical computations. Data were analysed in terms of Mean±SD (standard deviation) with a p-value <0.05 taken as significant.

Observations and Results

Sixty eight uncomplicated primary inguinal hernias (52 unilateral hernias (Left side 35; Right side 17) and 8 bilateral hernias) were successfully repaired laparoscopically in 60 adult male patients through the TEPP approach during the present study period. Only three female patients presented during the study period but could not be recruited into the study because of one or more exclusion criteria. Three male patients had early conversion to TAPP (Transabdominal Pre-Peritoneal) /Open repair. In one patient, conversion to the open pre-peritoneal repair was done due to instrument injury to the deep inferior epigastric vessels. In another patient, conversion to the open anterior repair was performed because the patient developed severe hypercarbia due to excessive CO_2 retention. In the third patient, conversion to the TAPP repair was carried out because frank pneumoperitoneum occurred just after the placement of the first optical 11-mm trocar at the infra-umbilical port when a high arcuate line was detected on trans-abdominal laparoscopy with a 5-mm telescope passed through the lateral working port.

Present study recorded seven types of arcuate line anatomy, namely, (1) NSWD, normal-sited single sharp well-defined (Classical) arcuate line (46%), (2) HSWD, high single sharp well-defined (4.4%), (3) LSWD, low single sharp well-defined arcuate line (4.4%), (4) NSID, normal-sited single ill-defined arcuate line (14.7%), (5) LSID, low single ill-defined arcuate line (5.9%), (6) Multiple arcuate line (4.4%), and (7) Absent arcuate line (20.6%) (Table 1). For the primary arcuate line when present, the mean U-AL distance (distance from the umbilicus to the arcuate line) was 5.37 ± SD1.62 cm (Range 2.5 to 11.5). Primary arcuate line was found situated, in general, at 1/3rd of the umbilico-pubic distance (U-PS). Only 24.1% of the primary arcuate lines were located at or within 2 cm of the mid-point of the U-PS distance. AL anatomy was non-mirror on two sides of body in 62.5% of bilateral hernias (Table 2). Secondary arcuate line was seen in 14.7% of cases. Details of these anatomic variations of the arcuate line have been already reported separately by the author because of their exhaustive nature in themselves [18], and only their surgical significance and clinical implications during and after the TEPP hernia repair are presented herein.

Demographic characteristics of patients

A total of 68 TEPP hernioplasties were successfully completed that include Unilateral TEPP (N=52), Simultaneous Bilateral TEPP (N=5) and Interval Bilateral TEPP (N=3). Patients' age ranged from 18 to 80 years with a mean of 50.1 ± SD17.2 years, and their BMI ranged from 19.5 to 31.2 kg/m² with a mean of 22.6 ± SD2.0 kg/m². By occupation, the study included manual labourers (n=24), retired persons (n=9), office workers (n=8), students (n=7), farmers (n=6) and field workers (n=6).

The arcuate line (AL) anatomy did not vary with respect to the age and profession of the patients but the high sharp well-defined (H-SWD) arcuate line had significantly higher BMI as compared to the other AL variants (p<<0.001), the details of which has been reported elsewhere [18].

Table 1: Distribution of Various Subtypes of Arcuate Line according to the Combined Features of its Level/Position and Morphology in Patients (N=60) Undergoing TEPP Hernioplasty (N=68)

S. No.	Arcuate Line Type (Level + Morphology)	Hernias		Patients	
		N	%	N	%
1.	AL-Classical	31	45.59	26	43.33
2.	AL-Variant	37	54.41	34	56.67
	Total	68	100	60	100
	AL-Variant Subtypes	N	%	N	%
1	HSWD	3	8.11	3	5.00
2	LSWD	3	8.11	2	3.33
3	NS-SID	10	27.03	9	15.00
4	LSID	4	10.81	4	6.67
5	DAL	3	8.11	3	5.00
6	A	14	37.84	13	21.67
	Total	37	100	34	100
	Total	37	100	33	100

TEPP: Total Extraperitoneal Preperitoneal; AL-Classical: Normal-Sited Single Sharp Well-Defined arcuate line (NS-SWD); AL-Variant: Arcuate Line Variant; HSWD: High Sharp Well-Defined arcuate line; LSWD: Low Single Sharp Well-Defined arcuate line; NS-SID: Normal-Sited Single Ill-Defined arcuate line; LSID: Low Single Ill-Defined arcuate line; DAL: Double/Triple Arcuate Line; A: Absent arcuate line; *(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)*

Table 2: Anatomy of Arcuate Line (AL) in Patients with Bilateral Inguinal Hernias (N=8) who Underwent Bilateral TEPP Hernioplasty

S. No.	AL Level		AL Morphology		Arcuate Line Type & Morphology	
	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side
1.	NS	NS	SID	SID	NS-SID	NS-SID
2.	NS	NS	SWD	SWD	NS-SWD	NS-SWD
3.	A§	A§	A§	A§	A§	A§
4.	A	NS*	A	SWD*	A	NS-SWD*
5.	A	NS*	A	SWD*	A	NS-SWD*
6.	LS	NS*	SWD	SWD	L-SWD	NS-SWD*
7.	NS	NS	SID	SWD*	NS-SID	NS-SWD*
8.	LS	NS*	SWD	SWD	L-SWD	NS-SWD*

NS: Classical Normal-Sited; LS: Low-Sited; A: Absent; SID: Single Ill-Defined; SWD: Sharp Well-Defined; NS-SWD: Classical, Normal-Sited Single Sharp Well-Defined Arcuate Line; NS-SID: Normal-Sited Single Ill-Defined; LSWD: Low Sharp Well-Defined; Star (*) Indicates Asymmetry On The Two Sides With Different AL Type On Contralateral Side; *(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)*

Modification in surgical technique

In the current standard technique of TEPP hernioplasty with 3 midline ports, direct-vision telescopic dissection is preferred to the blind balloon dissection in the posterior rectus canal and the surgeon is advised to enter the avascular preperitoneal space just below the arcuate line of Douglas, keeping in mind the traditional teaching of arcuate line being normally located at about half of the umbilico-pubic distance. However, modification of the surgical technique was warranted in the situation of either low (10%) or absent arcuate line (21%). Modification of the surgical technique was also demanded in the arcuate line was located >2 cm above/below the mid-point of the umbilico-pubic distance. Moreover, caution was required while operation was taken up on the opposite side at the same sitting or after an interval because non-mirror anatomy of the arcuate line was present on the contra-lateral side in a high percentage of the cases (63%).

Creation of artificial arcuate line in case of absent arcuate line: In absence of the primary arcuate line, i.e., when the posterior rectus sheath extended upto the pubic bone, an artificial arcuate had to be created surgically at about the level of the middle working port, i.e., at about half way down the umbilico-pubic distance for entry into the requisite avascular preperitoneal space for further definitive dissection and creation of adequate space from midline to the anterior superior iliac spine for mesh placement (Figure 1).

Creation of artificial secondary arcuate line in presence of low arcuate line: Low arcuate line in a long posterior rectus sheath, when present, posed two problems. Firstly, the effective rectus sheath canal got increased with wide fulcrum effects and severe ergonomic disability of working as reported earlier by the author [20]. Secondly, going below the low arcuate line, as is generally recommended, meant very small working space down for manoeuvring and adequate space creation for mesh placement. Thus presence of a low arcuate line warranted creation of a secondary arcuate line more proximally by the surgical dissection for an optimal entry into the avascular preperitoneal space and its maintenance (Figure 1), mimicking a scenario similar to that seen in case of the absent arcuate line (vide supra).

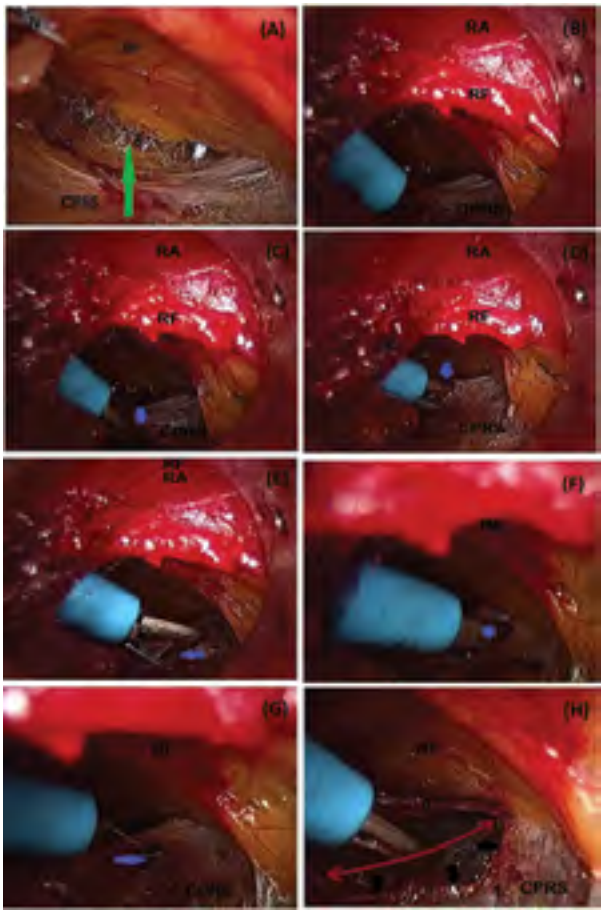

Figure 1: Creation of Artificial Arcuate Line in Complete Posterior Rectus Sheath (C-PRS):
(A) Needle Confirmation before Port Placement with Green Arrow indicating posterior rectus canal; (B-G) Artificial arcuate line created surgically in the C-PRS at the level of middle working port; (H) Artificial arcuate line completed; Double-Headed Red Arrow indicates the rent created surgically in the C-PRS; Single-Headed Black Arrows, indicate lower border of the artificial arcuate line; 1, proximal part of C-PRS; 2, distal part of C-PRS; RA, rectus abdominis muscle visible partly; RF, rectusial fascia covering the rectus abdominis muscle; S, sign of lighthouse faintly visible in the depth of the posterior rectus canal;
(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)

Entry into preperitoneal space in presence of high/classical arcuate line: In the present study, the mid-point of the umbilico-pubic distance in the patients undergoing TEPP hernioplasty was located at a mean of 7.9 ± 0.7 cm (Range 6.5 - 9.25), and the middle working port used to be placed at about this mid-point of the umbilico-pubic distance. In 50% of the hernias (N=68) operated in the present study, the arcuate line (High and Classical) was located at >2.5 cm above the mid-point of the umbilico-pubic distance (MP-UPS), and in these cases, the concept of entry into the preperitoneal space just below the arcuate line was difficult to follow. Therefore, the entry into the preperitoneal space was made at or just below the level of the middle port, i.e., the mid-point of the umbilico-pubic distance for the smooth ergonomic forward working. That means the entry into the preperitoneal space was made at ≥ 2.5 cm below the arcuate line in the cases of High and Classical arcuate line to facilitate the forward downward dissection in the preperitoneal space.

False sense of security for contralateral surgery: In the present study, individually the arcuate line position and morphology were dissimilar on two sides of the body in 50% and 37.5% respectively; however, with both features together, non-mirror anatomy of arcuate line was found in 62.5% because of the overlap as reported earlier [18]. However, traditional textbook teaching do not mention the asymmetry of the arcuate line on the two sides of the body, and hence the TEPP surgeon who feels confident of now having the experience and knowledge of the arcuate line anatomy on one side of the body after performing TEPP hernioplasty, often lands up in difficulties while operating on the opposite side due to presence of the variant anatomy. The surgical technique was not required to be modified due to the asymmetry of the arcuate line anatomy but in view of the high incidence of the asymmetry, extreme caution for the unhurried methodical telescopic dissection was adopted during operation on the contra-lateral side which proved fruitful.

Conversion

Present study recorded conversion in 3 out 71 hernias taken up for the TEPP repair, resulting in a conversion rate of 4.2%. However, only 1 out of the 3 conversions (33.3%) was secondary to an anatomic variation, resulting in an incidence of 1 out of 71 hernias (1.4%). This conversion occurred just after placement of the first optical 11-mm blunt trocar at the infraumbilical site in a patient having a high arcuate line with a short infraumbilical posterior rectus sheath which was detected on conversion to the TAPP approach.

Endoscopic vision (Endovision)

Present study recorded a mean score of 8.20 ± SD1.33 VAS (Range 4.0-9.5 VAS) for the endoscopic vision (endovision) during the 68 TEPP hernia repairs. The endovision score was less in presence of the variant arcuate line as compared to the classical arcuate line, and the statistical difference between them was highly significant (p <0.001) (Table 3).

Difference in endovision between the classical single sharp well-defined (SWD) arcuate line and its variants (SID, DAL and Absent-AL) was highly significant (p <0.001) (Table 3). Further Post-Hoc Tests (Tukey) analysis showed highly significant difference in endovision between the SWD and its two variants of Double-AL (p <0.01) and Absent-AL, while the difference in endovision was insignificant (p >0.05) between the SWD and its variant of single ill-defined AL (SID). Moreover, the Absent-Al was found significantly different from Double-AL but not from the SID-AL. However, the SID-AL group was comparable (p >0.05) not only to the Double-AL but also to the SWD group. Pearson Chi Square correlations were also highly significant with strong association among the 7 groups of the AL anatomy (p <0.001) (Figure 2).

Ease of procedure (EOP)

Present study recorded a mean score of 7.27 ± 2.05 VAS (Range 4.0-9.5 VAS) for the ease of procedure (EOP) during the 68 TEPP hernia repairs. The EOP score was less in presence of the variant arcuate line as compared to the classical arcuate line, and the statistical difference between them was highly significant (p <0.001) (Table 3).

Post Hoc Tests (Tukey HSD) analysis revealed significant difference between SWD and the Absent-AL (p <0.001) or the Double-AL (p <0.01), but not between the SWD and SID-AL (p >0.05). The EOP was significantly different among the variant subgroups, except between the Double-Al vs. Absent-AL or the Double-Al vs. SID-AL. The Pearson Chi Square tests also found highly significant correlations of the EOP (p <0.001) with strong Likelihood Ratio and Linear-by-Linear Association for the 7 groups of the AL anatomy (Figure 3).

Operation time (OT)

Present study recorded mean operation time of 1.87 ± 0.59 hours (Range 0.75-3.25 hours) during the 68 TEPP hernia repairs. The duration of the operation time was much more in presence of the any of variant subtypes (SID/DAL/A) of the arcuate line as compared to the classical arcuate line, and the statistical difference between them was also highly significant (p <0.001) (Table 3).

Post Hoc Tests (Tukey HSD) showed that the difference in operation time between the subgroups 'A' and SID or between the subgroups SID and DAL was insignificant statistically, while the difference between the subgroups 'A' and DAL was significant. The Pearson Chi-Square Correlations were also significant (p<0.05) between the operation time and the 7 subgroups of the arcuate line anatomy with strong association (Figure 4).

Peritoneal injury (PI)

Present study recorded 28.3% incidence of peritoneal injury during the 68 TEPP hernia repairs. Incidence of peritoneal injury was significantly more in presence of the variant anatomy of the arcuate line (p <0.05) (Table 3) (Figure 5). Moreover, no significant differences were found among the 3 variant subgroups of the arcuate line morphology (Single ill-defined AL (SID), Double-AL and Absent-AL) on Post Hoc Tests (Tukey HSD) analysis. The Pearson Chi-Square Correlations were also not significant between the peritoneal injury and the seven subgroups of arcuate line anatomy, although a significant association was present (Figure 6).

Surgical emphysema, post-operative seroma and infection

Present study recorded surgical emphysema, post-operative seroma and superficial surgical site infection in 16.2%, 10.3% and 5.9% respectively, and their incidence did not differ significantly between the classical and variant groups of the arcuate line (p >0.05) (Table 3). No patient developed mesh infection if the study.

Post-operative chronic inguinal pain

Chronic groin pain suggestive of an injury to the genital branch of the genito-femoral nerve was observed in one patient after 2/3rd of the study

Table 3: Functional Effects of Anatomical Variations of Arcuate Line during TEPP Hernioplasty (N = 68)

S.No	Variable	Arcuate Line Types		¨CID	††t-value	††Sig. (2-tailed)	p-value
		¶AL Classical (N=37)	¶AL Variant (N=31)				
1	**Endovision Mean ± S.D* (VAS)§**	8.57 ± 1.34	6.10 ± 1.67	1.74 To 3.20	6.770	0.000	**<0.001**
2	**EOP Mean ± S.D* (VAS)§**	8.61 ± 1.52	5.66 ± 1.31	2.2666 To 3.6540	8.520	0.000	**<0.001**
3	**OT Mean ± S.D* (Hours)**	1.56 ± 0.38	2.24 ± 0.59	-0.924 To -0.451	-5.812	0.000	**<0.001**
4	**PI Mean ± S.D* (N)**	0.14 ± 0.35	0.39 ± 0.50	-0.456 To -0.047	-2.460	0.017	**<0.05**
5	**Emphysema Mean ± S.D* (N)**	0.11 ± 0.32	0.23 ± 0.43	-0.297 To 0.062	-1.310	0.195	>0.05
6	**Seroma Mean ± S.D* (N)**	0.05 ± 0.23	0.16 ± 0.37	-0.255 To 0.040	-1.450	0.152	>0.05

TEPP: Total Extraperitoneal Preperitoneal; ¶AL: Arcuate Line; *SD: Standard Deviation; §VAS: Visual Analog Score (1-10); **CID: 95% Confidence Interval Of The Difference; †T: Independent-Sample Student t-Test Value; ††Sig: Significance;

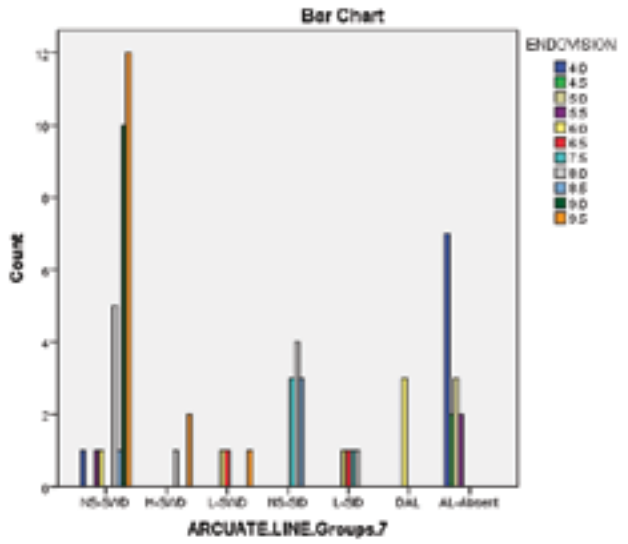

Figure 2: Correlation between Endovision and Types of Arcuate Line (AL): NS-SWD: Normal-Sited Single Well-Defined; H-SWD: High Single Well-Defined; L-SWD: Low Single Well-Defined; NS-SID: Normal-Sited Single Ill-Defined; L-SID: Low Single Ill-Defined; DAL: Double/Triple Arcuate Line; *Pearson CHISQ CC:* (R = 158.757, df 60, Sig. 0.000, p <0.001); *Likelihood Ratio:* (R=129.208, df 60, Sig. 0.000, p <0.001); *Linear-by-Linear Association:*R=43.410, df 1; Sig. 0.000, p<0.001;
(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)

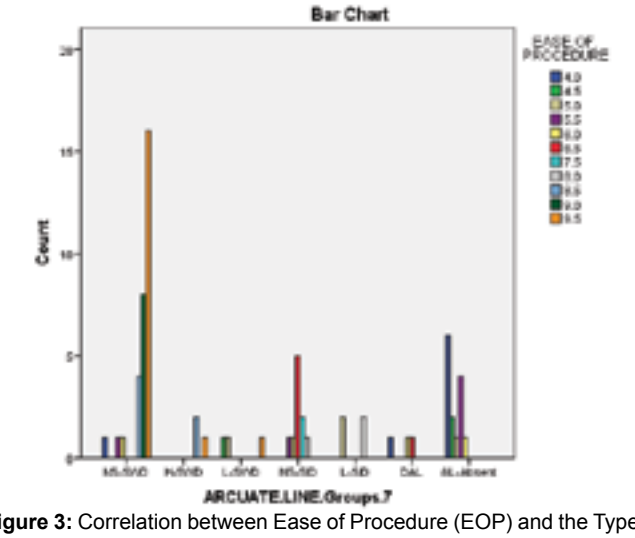

Figure 3: Correlation between Ease of Procedure (EOP) and the Types of Arcuate Line (AL):
NS-SWD: Normal-Sited Single Well-Defined; H-SWD: High Single Well-Defined; L-SWD: Low Single Well-Defined; NS-SID: Normal-Sited Single ill-Defined; L-SID: Low Single ill-Defined; DAL: Double/Triple Arcuate Line; AL-Absent: Absent Arcuate Line;
Pearson CHISQ CC: R = 161.327, df 60, Sig. 0.000, p <0.001); *Likelihood Ratio:* R=132.533, df 60: Sig. 0.000, p <0.001); *Linear-by-Linear Association:* R=43.961, df 1; Sig. 0.000, p<0.001)
(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)

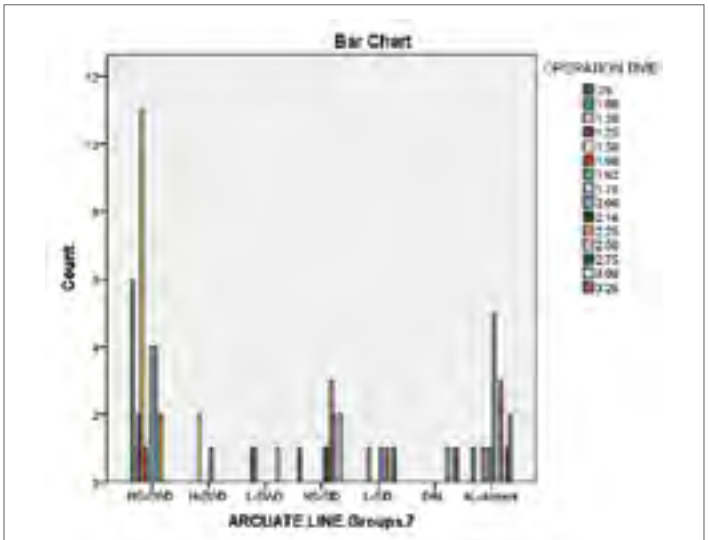

Figure 4: Correlation between Operation Time (OT) and the Types of Arcuate Line (AL):
NS-SWD: Normal-Sited Single Well-Defined; H-SWD: High Single Well-Defined; L-SWD: Low Single Well-Defined; NS-SID: Normal-Sited Single Ill-Defined; L-SID: Low Single Ill-Defined; DAL: Double/Triple Arcuate Line; AL-Absent: Absent Arcuate Line;
Pearson CHISQ CC: R=108.136, df 84, Sig. 0.039, p <0.05); *Likelihood Ratio:* (R=89.691, df 84, Sig. 0.315, p >0.05); *Linear-by-Linear Association:* R=18.645, df 1; Sig. 0.000, p<0.001)
(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)

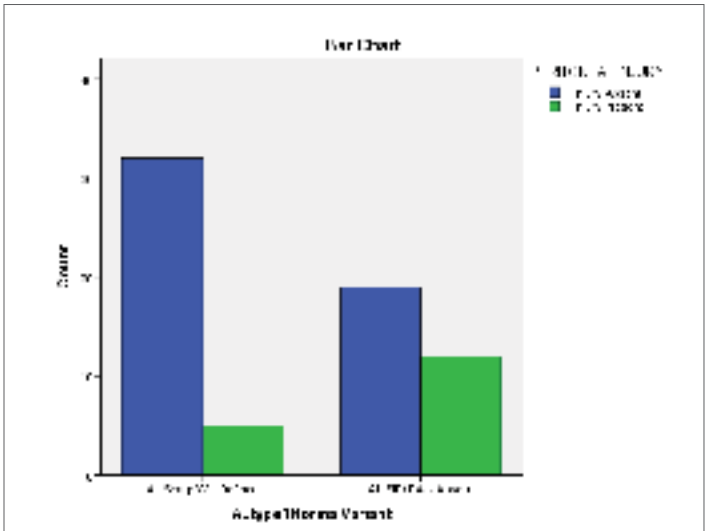

Figure 5: Correlation between the Peritoneal Injury (P. Injury) and the Classical/Variant Anatomy of the Arcuate Line:
SID: Single Ill-Defined; DAL: Double/Triple Arcuate Line;
Pearson CHISQ CC: R = 5.711, df 1, Sig. 0.017, p <0.05; *Likelihood Ratio:* R=5.790, df 1, Sig. 0.016, p <0.05; *Linear-by-Linear Association:* R=5.627, df 1, Sig. 0.018, p <0.05; *Fisher's Exact Test:* Sig. (2-tailed) 0.024, p <0.05; Sig. (1-tailed) 0.017, 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)

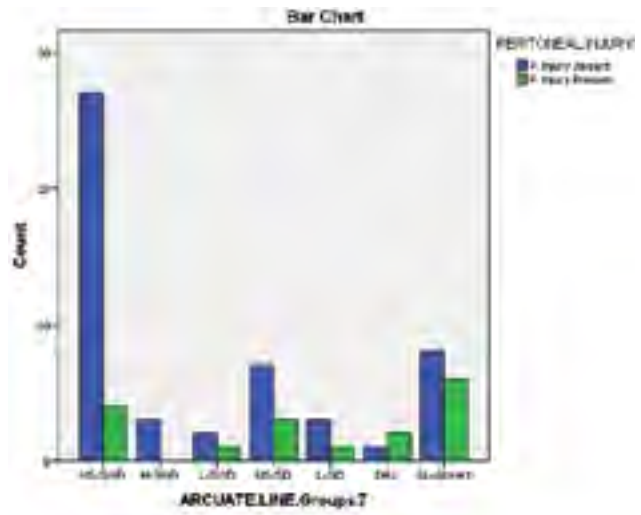

Figure 6: Correlation between the Peritoneal Injury and 7 subtypes of the Arcuate Line:
NS-SWD: Normal-Sited Single Well-Defined; H-SWD: High Single Well-Defined; L-SWD: Low Single Well-Defined; NS-SID: Normal-Sited Single ill-Defined; L-SID: Low Single ill-Defined; DAL: Double/Triple Arcuate Line; AL-Absent: Absent Arcuate Line;
Pearson CHISQ CC: R= 8.823, df 6: Sig. 0.184, p >0.05; *Likelihood Ratio:* R=9.160, df 6, Sig. 0.165, p >0.05; *Linear-by-Linear Association:*R=6.663, df 1; Sig. 0.010, 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)

was completed. The pain persisted for about 9 months and resolved fully with conservative management. This patient had a variant arcuate line in terms of the normal-sited single *ill-defined* arcuate line.

Recurrence of hernia

Follow-up of the patients was carried out in the present study for a mean period of 33 ± SD 17 months (Range 5-61 months). Recurrence of inguinal hernia was not detected in any of our patients.

Discussion

Anatomic variations in the arcuate line were known since long through the gross cadaveric studies [1,25-33], but somehow their descriptions could not translate into the textbook teaching and hence generally out of bounds for the medical students and upcoming young surgeons, who are really the prospective backbone of the current laparoscopic revolution but become handicapped if they do not happen to have an opportunity to read the older literature.

It is rather strange to mention that even in the current booming trend of the laparoscopic approach to the inguinal hernia, online literature search did not find any clinical study correlating the effects of anatomic variations of the arcuate line and the intraoperative &/or postoperative functional outcomes. This rather confirms the opinion of Maurice Arregui [4] that there is not only little interest but also little understanding of the preperitoneal hernia anatomy among the surgeons and anatomists alike. The present study appears to be the first research work on the surgical significance and the clinical implications secondary to the anatomic variations of the arcuate line. Therefore, the discussion is largely limited to the data of the present study and the author's data on the significance of anatomic variations of the posterior rectus sheath reported elsewhere [34].

The endovision, ease of procedure and operation time were adversely affected in presence of the variant anatomy of the arcuate line, and the incidence of the peritoneal injury was also significantly more in presence of the variant arcuate line as compared to the classical type (Tables 3 and 4) (Figures 7 and 8). There was no adverse effect of the variant anatomy of the arcuate line on the incidence of surgical emphysema, postoperative seroma and infection (Tables 3 and 4) (Figures 7 and 8). Endoscopic vision was very significantly lower in presence of the variant anatomy of the arcuate line, particularly Double-AL and Absent-AL, in comparison to that observed with the classical AL ($p<0.001$). The normally-situated classical arcuate line (NS-SWD), low arcuate line (L-SWD/L-SID), high-

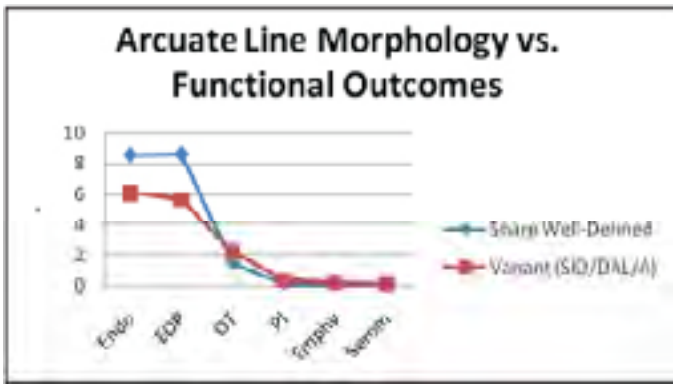

Figure 7: Correlation between the Morphology of Arcuate Line (AL) and the Functional Outcomes: Endo: Endovision; EOP: Ease Of Procedure; OT: Operation Time; PI: Peritoneal Injury; Emphy: Surgical Emphysema; Serom: Postoperative Seroma; SID: Single Ill-Defined Arcuate Line; DAL: Double/Triple Arcuate Line; A: Absent Arcuate Line; *(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)*

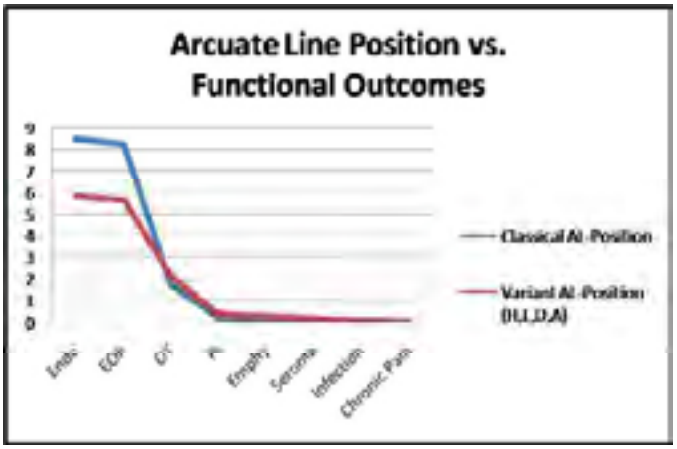

Figure 8: Correlation between the Position of Arcuate Line (AL-Position) and the Functional Outcomes: Endo: Endoscopic Vision; EOP: Ease Of The Procedure; OT: Operation Time; PI: Peritoneal Injury; Emphy: Surgical Emphysema; Seroma: Postoperative Seroma; Classical: Normal-Sited Arcuate Line; H: High Arcuate Line; L: Low Arcuate Line; D: Double/Triple Arcuate Line; A: Absent Arcuate Line; *(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)*

Table 4: Correlations (p-values) between Arcuate Line Anatomy and Functional Outcomes during TEPP Hernioplasty (N = 68)

S. No	Anatomy	Subgroups	N	Endo	EOP	OT	PI	Emphy	Serom
	Arcuate Line	Classical Variant	37 31	**<0.001**	**<0.001**	**<0.001**	**<0.05**	>0.05	>0.05

TEPP: Total Extra-Peritoneal Preperitoneal Hernioplasty; Endo: Endovision; EOP: Ease of Procedure; OT: Operation Time; PI: Peritoneal Injury; Emphy: Surgical Emphysema; Serom: Postoperative Seroma

situated arcuate line (H-SWD) and absent arcuate line (Absent-AL) corresponded to the NIC, LIC, SIC and C types of the posterior rectus sheath (PRS) with similar characteristics of the endovision reported elsewhere by the author [34].

Prior knowledge and awareness of the anatomic variations based on the older cadaveric literature and unhurried controlled telescopic initial dissection proved highly successful and fruitful in terms of three major aspects, namely, no conversion secondary to the so-called difficult dissection, absence of any major complication except one episode of injury to the genital branch of the genito-femoral nerve and highly satisfactory postoperative recovery except one instance of temporary chronic groin pain due to the aforesaid nerve injury.

The two limitations of the present study cannot be overemphasized. Firstly, the sample size is definitely small in view of the fact that inguinal hernia repair inclusive of both laparoscopic and open techniques is the most common general surgical procedure performed globally [35-37]. This scenario is really a reflection of poor public awareness of newer technology techniques and peer resistance for adopting the newer technology techniques for various reasons including little understanding, little interest and demanding procedure, especially in a developing country like India. This may be true even for the developed countries because only 15-20% of the inguinal hernias are operated by the laparoscopic approach in America and around the world [38]**.** The second limitation of the present study is the absence of female patients, although a few presented during the study period but unfortunately could not be recruited due to the exclusion criteria.

Conclusions

Arcuate line variants adversely impacted endoscopic vision, ease of procedure, operation time and peritoneal injury, and can require special technical gestures, such as the creation of a new arcuate line. Prior knowledge, dedicated keen observation and timely recognition of the arcuate line variant proved fruitful for judicious surgical dissection to achieve seamless total extraperitoneal preperitoneal hernia repair [4,6,8,9,15,16]. Further increase in the anatomic knowledge beyond the cadaveric dissections is still possible with newer techniques of laparoscopy in the evolution of the laparoscopic surgery with safety and efficacy at par with that of the open procedures [11,38-40].

Award of Degree of PhD (Surgery)

This article encompasses a part of the exhaustive observations made during the doctoral research for award of degree of PhD (Surgery) to the author for year 2016 by the Aligarh Muslim University, Aligarh, UP, India - 202002.

Conflict of Interest

None

Funding

Nil

References

1. McVay CB, Anson BJ (1940) Composition of the rectus sheath. Anat Rec 77(2): 213-225.
2. Monkhouse W S, Khalique A (1986) Variations in the composition of the human rectus sheath: a study of the anterior abdominal wall. J Anat 145: 61-66.
3. Faiz O, Moffat D (2011) Preface. In: Omar Faiz, David Moffat (eds.) Anatomy at a Glance. 1st Edition, Oxford: Blackwell Science, p 5.
4. Arregui ME (1997) Surgical anatomy of the preperitoneal fasciae and posterior transversalis fasciae in the inguinal region. Hernia 1: 101-110.
5. Rizk NN (1980) A new description of the anterior abdominal wall in man and mammals. J Anat 131(3): 373-385.
6. Rao MKG, Ramana V, Vincent R (2009) A rare case of occurrence of fleshy muscle fibers in the anterior wall of rectus sheath. Int J Anat Var 1: 31-32.
7. Condon RE (1996) Reassessment of the groin anatomy during the evolution of preperitoneal hernia repair. Am J Surg 172: 5-8.
8. Spaw AT, Ennis BW, Spaw LP (1991) Laparoscopic hernia repair: the anatomic basis. J Laparoendosc Surg 1: 269-277.
9. Marks SC Jr, Gilroy Am, Page DW (1996) The clinical anatomy of laparoscopic inguinal hernia repair. Singapore Med J 37(5): 519521.
10. Rosser J (1994) The anatomical basis for laparoscopic hernia repair revisited. Surg Laparosc Endosc 4(1): 36-44.
11. Avisse C, Delattre JF, Flament JB (2000) The inguinofemoral area from a laparoscopic standpoint. History, anatomy, and surgical applications. Surg Clin North Am 80(1): 35-48.
12. Li LJ, Zheng XM, Jiang DZ, Zhang W, Shen HL, et al. (2010) Progress in Laparoscopic Anatomy Research: A Review of the Chinese Literature. World J Gastroenterol 16(19): 2341-2347.
13. Liem MS, van Steensel CJ, Boelhouwer RU, Weidema WF, Clevers G J, et al. (1996) The learning curve of totally extraperitoneal laparoscopic hernia repair. Am J Surg 171: 281-285.
14. Lange JF, Rooijens PPGM, Koppert S, Kleinrensink GJ (2002) The preperitoneal tissue dilemma in totally extraperitoneal (TEP) laparoscopic hernia repair: an anatomo-surgical study. Surg Endosc 16: 927-930.
15. Faure JP, Doucet C, Rigourd PH, Richer JP, Scepi M (2006) Anatomical pitfalls in the technique for total extra peritoneal laparoscopic repair for inguinal hernias. Surg Radiol Anat 28(5): 486-493.
16. Katkhouda N (1998) (ed.) Advanced Laparoscopic Surgery: Techniques and Tips. 2nd Edition, Chapter 10, Berlin Heidelberg: Springer-Verlag, 149-168.
17. Quin TH, Annibali R, Dalley AF II, Fitzgibbons RJ Jr (1995) Dissection of the anterior abdominal wall and the deep inguinal region from a laparoscopic perspective. Clin Anat 8(4): 245251.
18. Ansari MM (2017a) Arcuate Line of Douglas: A Prospective Study of Laparoscopic Live Surgical Anatomy during TEPP Hernioplasty. Int J Sci Res 6(6): 2348-2363.
19. Deurenberg P, Weststrate JA, Seidell JC (1991) Body mass index as a measure of fatness: age- and sex-specific prediction formulas. Br J Nutr 65: 105-114.

20. Ansari MM (2013) Effective Rectus Sheath Canal: Does It Affect TEP Approach for Inguinal Mesh Hernioplasty. J Exp Integr Med 3(1): 73-76.

21. Ansari MM (2014) Complete posterior rectus sheath and total extra-peritoneal hernioplasty. Saudi Surg J 2(4): 80-83.

22. Ansari MM (2015) Arcuate Line Variations: Are they important for TEP surgeons? Kuwait Med J 47(4): 313-316.

23. Ansari MM (2017b) Rectusial Fascia: A New Entity of Laparoscopic Live Surgical Anatomy. Open Access J Surg 3(4): pp 1-5.

24. Ansari MM (2017c) Surgical significance of rectusial fascia during TEPP hernioplasty. Int J Sci Appl Res 4(7): 13-21.

25. Walmsley R (1937) The sheath of the rectus abdominis. J Anat 71: 404-414.

26. Lung-Chin Y (1965) Constitution of the rectus sheath. Acta Anatomica Sinica 8(2): 234-238.

27. Woodburne RT, Burkel WE (1988) In: Essentials of Human Anatomy, 8th ed., pp. 411-417. New York, Oxford: Oxford University Press.

28. Rizk NN (1991) The arcuate line of the rectus sheath–does it exist? J Anat 175: 1-6.

29. Schaefer EA, Dancer G (1894) In: Quain's Elements of Anatomy, 10th ed., vol. II. London: Longmans, Green & Co.

30. Cunningham SC, Rosson GD, Lee RH, Williams JZ, Lustman CA, et al. (2004) Localization of the arcuate line from surface anatomic landmarks: a cadaveric study. Ann Plast Surg 53(2): 129-131.

31. Loukas M, Myers C, Shah R, Tubbs RS, Wartmann C, et al. (2008) Arcuate line of the rectus sheath: clinical approach. Anat Sci Int 83(3): 140-144.

32. Mwachaka P, Odula P, Awori K, Kaisha (2009) Variations in the Pattern of Formation of the Abdominis Rectus Muscle Sheath among Kenyans. Int J Morphol 27(4): 1025-1029.

33. Mwachaka PM, Saidi HS, Odula PQ, Awori KO, Kaisha WO (2010) Locating the arcuate line of Douglas: is it of surgical relevance. Clin Anat 23(1): 84-86.

34. Ansari MM (2017f) Posterior Rectus Sheath: A Prospective Study of Laparoscopic Live Surgical Anatomy during TEPP Hernioplasty. World J Lap Surg (In Press).

35. Bittner R, Arregui ME, Bisgaard T, Dudai M, Ferzli GS, et al. (2011) Guidelines for laparoscopic (TAPP) and endoscopic (TEP) treatment of inguinal Hernia [International Endohernia Society (IEHS)]. Surg Endosc 25(9): 2773-2843.

36. Putnis S, Berney CR (2012) Totally extraperitoneal repair of inguinal hernia: techniques and pitfalls of a challenging procedure. Langenbecks Arch Surg 397: 1343.

37. Berger D (2016) Evidence-Based Hernia Treatment in Adults. Dtsch Arztebl Int 113: 150-158.

38. Davis CJ, Arregui ME (2003) Laparoscopic repair for groin hernias. Surg Clin North Am 83(5): 1141-1161.

39. Spitz JD, Arregui ME (2001) Fascial anatomy of the inguinal region. In: Robert Bendavid, Jack Abrahamson, Maurice E. Arregui, Jean B. Flament, Edward H. Phillips (eds.) Abdominal Wall Hernias: Principles and Management, 1st Edition (Reprint), Chapter 8, Springer Science-Business Media, New York, pp. 86-91.

40. Mirilas P, Colborn GL, McClusky-III DA, Skandalakis LJ, Skandalakis PN, et al. (2005)The history of anatomy and surgery of the preperitoneal space. Arch Surg 140: 90-94.