Arcuate Line of Douglas: A Prospective Study of Laparoscopic Live Surgical Anatomy during TEPP Hernioplasty

Running Title: Arcuate Line: Laparoscopic Live Surgical Anatomy

Maulana M. Ansari

MBBS, MS (Gen. Surgery), PhD (Surgery)#, Ex-Professor of General Surgery, Department of Surgery
J. N. Medical College, Aligarh Muslim University, Aligarh, UP, India

E-mail: mmansari.amy[at]gmail.com ; mma_amu[at]yahoo.com

Abstract: ***Contrary to traditional textbook teaching, arcuate line anatomy, currently an important landmark during laparoscopic total extraperitoneal preperitoneal (TEPP) hernioplasty had been known to vary frequently in various cadaveric studies reported over the last century. Sixty eight TEPP hernia repair was performed in 60 adult patients through posterior rectus sheath approach, utilizing 3-midline-port technique and only telescopic dissection. The so-called classical arcuate line (normal-sited single sharp well-defined) was observed in only 46% of the 68 successful TEPP hernioplasties in adult male patients with primary inguinal hernia, and in the remaining 54%, arcuate line was of 6 variant types which included the high single sharp well-defined (4.4%), low single sharp well-defined (4.4%), normal-sited single ill-defined (14.7%), low single ill-defined (5.9%), multiple, i.e., both primary and secondary (4.4%), and absent (20.6%). In patients with incomplete posterior rectus sheath, arcuate line was found situated, in general, at the 1/3rd of the umbilico-pubic distance. Secondary arcuate line was also documented in 50% of the cases with complete posterior rectus sheath. Arcuate line had non-mirror anatomy on the two sides of the body in 62.5% of patients with bilateral inguinal hernias. Arcuate line did not represent termination of posterior rectus sheath in 14.7% of our cases.***

Keywords: Arcuate line, Arcuate line of Douglas, posterior rectus sheath, TEPP anatomy, TEPP hernioplasty

1. Introduction

Laparoscopic surgery is revolutionary in the sense that the whole team shares the operative field and makes collective judgments to perform the specific procedure, which is open to even outside observers.[1] The development of laparoscopic surgery has changed how surgeons perceive and manouvre among the various tissue planes and landmarks of the human anatomy[2], and moreover, it has generated an acute need of a new field of study, laparoscopic live surgical anatomy, or laparoscopic anatomy in short.[3] The cadaveric description of the inguinal anatomy, still taught in our anatomy classrooms, often proves counterproductive for instant recognition of the unique individual anatomy that warrants indigenization of judicious surgical dissection required during the laparoscopic surgery.[4,5]

Contrary to traditional textbook teaching, Arcuate line of Douglas, is known to frequently vary in morphology, number and level since long in the cadaveric studies.[6-15] This transition zone (arcuate line) in the posterior rectus sheath has assumed immense importance during the laparoscopic total extraperitoneal preperitoneal (TEPP) hernioplasty. However, research work on the laparoscopic live surgical anatomy of the TEPP access anatomy is sparse and scanty[4,5], and there is no research work reported in the literature with respect to the live surgical anatomy of the Arcuate anatomy to the best of our knowledge. Present study's interim report of the laparoscopic live surgical anatomy of the Arcuate anatomy was received with great interest and enthusiasm by the surgeons and anatomists alike.[16] Hence, the full report with final data confirmation and analysis in the larger sample of 68 TEPP hernioplasties is now presented here in order to help the surgical fraternity for better understanding of the Arcuate line anatomy, the knowledge of which is the key for the TEPP hernioplasty.[17]

2. Materials and Methods

The present study was designed and carried out prospectively in the Department of Surgery, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, India in the form of a doctoral research for award of PhD in Surgery. TEPP hernioplasty for inguinal hernia was performed under the Institutional Ethics Committee's clearance and patients' written informed consent. Period of study was from April, 2010 to November, 2016. Recruitment criteria for the present study were four, namely, (1) Patient's choice of laparoscopic hernia repair under the written informed consent, (2) Patient's good financial support for the increased cost of surgery and larger mesh, (3) patient's fitness for general anaesthesia as declared under pre-anaesthetic check-up, and (4) Availability of functioning laparoscopic equipment and instruments.

Patient was included in the study if he/she was aged 18 years or more, the physiological score was ASA Grade I & II (American Society of Anesthesiologists), he/she has uncomplicated fully reducible primary inguinal hernia, and has underwent successful laparoscopic total extra-peritoneal pre-peritoneal (TEPP) hernioplasty. Exclusion criteria were patients <18 years of age, patients with ASA Grade III - V, patients with recurrent inguinal hernia,

patients with complicated inguinal hernia, patients with femoral hernia, patients with history of lower abdominal surgery, and patient's refusal for laparoscopic repair.
Patient's age, weight (measured without footwear), height, and occupation were documented. Body mass index (BMI) was calculated by the Deurenberg's formula.[18] After pre-anaesthetic check-up, patients were admitted one day before the operation as part of the general policy of our hospital. Standard 3-midline-port technique was utilized under general anaesthesia with patient supine as has been practiced consistently and reported earlier by the author.[16,19-21]

Arcuate line was observed in terms of its existence, morphology, number, level, shape and symmetry in all the patients. For the purpose of discussion and future reference, the level of the arcuate line was arbitrarily categorized into normal-sited (classical), low and high based on two criteria, namely, our current anatomic understanding that the arcuate line is generally situated at about 1/3rd of the distance from umbilicus to the pubic symphysis (U-PS)[13,16,22] , and the maximum U-PS of 18.0 cm recorded in the present study. Thus an arcuate line was labelled as 'normal-sited' when the its distance from the umbilicus (U-AL) was found between 3-6 cm, while it was labelled as 'high' when U-AL distance was <3 cm and 'low' when U-AL distance was found >6cm. The primary arcuate line (cf. secondary arcuate line) was considered as absent when U-AL distance was found equal to the U-PS distance, i.e., when the posterior rectus sheath was found complete extending upto the pubic bone.

The present study adopted the definition of primary and secondary arcuate line as described by Mackay (1889)[23] and Walmsley (1937)[6]. An arcuate line (of Douglas) formed by shifting of most of the aponeurotic fibres from the posterior to the anterior rectus sheath was termed the 'typical' arcuate line or 'true fold' by Walmsley (1937)[6], to differentiate it from the secondary arcuate line (Henle's Band) that at times formed in the continued thin fascial posterior rectus sheath between 'true fold' and pubic bone as defined by Mackay (1889) [23].

Statistical Package for Social Sciences (SPSS v. 21) was used for data analysis. All data were computed as Mean±SD (Standard Deviation) and a p-value of <0.05 was considered as significant.

3. Results

A total of 66 adult patients with primary inguinal hernia consented for the laparoscopic hernia repair during the study period. Three female patients with primary inguinal hernia could not be recruited into the study due to one or more exclusion criteria. Thus a total of 63 adult male patients with primary inguinal hernia were posted for TEPP hernioplasty which proved successful in only 60 out of 63 patients.

a. Demographic Characteristics of Patients

In the 60 patients, 68 TEPP hernioplasties were carried – Unilateral TEPP in 52 cases (right side 17; left side 35) and Bilateral TEPP in 8 cases (simultaneous 5; interval 3). Three male patients were excluded from the study because of forced early conversion. Two patients were converted to open mesh repair – excessive CO_2 retention with anaesthetic problems (1) and shearing injury to deep inferior epigastric vessels by the roughened joint of Maryland Dissection before placement of the second working port (1). Conversion to Total Extraperitoneal Preperitoneal (TAPP) repair was performed in one patient in whom peritoneal injury occurred during the placement of the first 11-mm blunt trocar itself. In this patient, peritoneal laparoscopy documented presence of a very short posterior rectus sheath below the umbilicus with formation of a high arcuate line, and inadvertent angulation by the assistant easily perforated the unsupported transversalis fascia and peritoneum, leading to frank pneumoperitoneum.

Therefore data analysis was carried out for 68 TEPP hernioplasties (unilateral 52; bilateral 8) performed successfully in the 60 patients. Mean age of the patients was 50.1±17.2 years (range 18-80 years). Their mean BMI (Body mass index) was 22.6±2.0 kg/m^2 (range 19.5-31.2 kg/m^2). Forty nine and 11 out of 60 patients were in ASA grade I and II respectively. 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). Observations of the Arcuate line (AL) were documented in terms of its morphology, level, number and symmetry as described in the following paragraphs.

b. Existence of Arcuate Line

Traditional Arcuate line of Douglas was found present in only 54 out of 68 cases of TEPP hernioplasty, i.e., the posterior rectus sheath ended before reaching to the pubic bone with formation of an arcuate line **(Fig. 1).** Moreover, tendinous bands often called the secondary arcuate lines (Mackay, 1889; Walmsley, 1937)[6,23] were also observed within the incomplete posterior rectus sheath in addition to the terminal primary arcuate line in 3 out of these 54 cases, leading to double/multiple arcuate lines (DAL) (Double in 2 cases, and Triple in 1 case) **(Fig. 3).**

However, in the remaining 14 cases, the traditional arcuate line was found absent because the posterior rectus sheath extended upto the pubic bone **(Fig. 2),** but secondary arcuate lines were observed within the posterior rectus sheath in 7 out of these 14 cases, (Single in 4 cases, Double in 1 case, and Triple in 2 cases) **(Fig. 4, 5 and 6).**

c. Nature of Arcuate Line

In terms of the arcuate line definitions of Mackay (1889)[23] and Walmsley (1937)[6], the present study documented the primary arcuate (traditional Arcuate line of Douglas) in 54 out of 68 cases of TEPP hernia repair **(Fig. 1),** and the secondary arcuate lines in 10 cases including 3 cases of secondary arcuate line along with the primary arcuate line in the incomplete posterior rectus sheath and 7 cases of secondary arcuate line in the posterior rectus sheath with absent primary arcuate line (single 4, double 1, and triple

2) **(Fig. 4, 5 and 6)**. In other words, 3 cases of incomplete posterior rectus sheath and one half cases of the complete posterior rectus sheath (N=14) had the secondary arcuate lines.

d. Number of Arcuate Line

Present study recorded presence of a single arcuate line in a total of 55 out of 68 cases, and they included single primary arcuate line in 53 out of 54 cases of the incomplete posterior rectus sheath **(Fig. 1 and 7)** and single secondary arcuate line in 4 out of 14 cases of the complete posterior rectus sheath **(Fig. 4).** Double arcuate lines were recorded in only 3 cases including 2 instances in the incomplete posterior rectus sheath and 1 instance in the complete posterior rectus sheath. Triple arcuate lines were also seen in another 3 cases including 1 instance in the incomplete posterior rectus sheath **(Fig. 3.)** and 2 instances in the complete posterior rectus sheath **(Fig. 6)**.

e. Morphology of Arcuate Line

Present study documented basically 4 types of arcuate line morphology – (1) single sharp well-defined primary arcuate line (SWD) in 37 out of 68 cases of successful TEPP hernia repair **(Fig. 1),** (2) single ill-defined primary arcuate line (SID) in the 14 cases **(Fig. 7),** (3) combination of well-defined and ill-defined (DAL, double/ triple secondary arcuate line) in 3 cases **(Fig. 3)** when secondary arcuate line was also present in addition to the primary arcuate line, (4) Absent primary arcuate line (AAL) in the remaining 14 cases **(Fig. 2).**

3.1.1 Relation of AL Morphology with Age

Mean age of the patients did not did not differ significantly ($p>0.05$) among the 4 types of primary arcuate line morphology (single well-defined, single ill-defined, double/triple, and absent) **(Table 1).** Tukey HSD Post-hoc Tests were also statistically insignificant ($p >0.05$). Pearson Correlation was also not significant (R, -0.20745; Sig. 0.903; $p >0.05$). In other words, morphology of the primary arcuate line did not tend to vary with respect to the age of the patients in our study.

3.1.2 Relation of AL Morphology with BMI

Mean BMI of the patients did not did not differ significantly ($p>0.05$) among the 4 types of primary arcuate line morphology (single well-defined, single ill-defined, double/triple, and absent) **(Table 2).** Pearson Correlation was also not significant (R, -0.02404; Sig. 0.8459; $p >0.05$). In other words, arcuate line morphology did not tend to vary with respect to the BMI of the patients in our study.

3.1.3 Relation of AL Morphology with Profession

Occupation of the patients did not significantly affect the morphology of the primary arcuate line among the 4 types of primary arcuate line morphology (single well-defined, single ill-defined, double/triple, and absent) (Pearson Correlation: $r = -0.01587$, Sig. 0.9034, $p >0.05$). In other words, morphology of primary arcuate line did not tend to vary with respect to the professional occupation of the patients in our study.

3.1.4 Symmetry of AL Morphology in Bilateral Hernias

The morphology of the primary arcuate line was found symmetrical on the two sides of body in only 5 out of the 8 cases studied and asymmetrical in the remaining 3 patients **(Table 3).** The mean age and BMI of the patients did not affect the symmetry of primary arcuate line morphology significantly ($p>0.05$) **(Table 4 and 5).**

f. Level/ Position of Arcuate Line

In terms of our definition outlined in the 'materials and methods', present study recorded presence of 5 levels of the arcuate line, namely, (1) normal-sited primary arcuate line (NAL) in 47 out of 68 cases of TEPP hernioplasties **(Fig. 1 and 6)**, (2) high primary arcuate line (HAL) in 3 cases out of 68 cases, (3) low primary arcuate line (LAL) in 10 out of 68 cases, **(Fig. 8),** (4) arcuate line at pubis, i.e., absent primary arcuate line (AAL) in 14 cases **(Fig. 2),** and (5) others like double/triple arcuate line (DAL) in the remaining 3 cases **(Fig. 3).**

3.1.5 Measurement of Level of Arcuate Line

In the 54 instances of the incomplete posterior rectus sheath with formation of a primary arcuate line (AL), the mean distance from the umbilicus to the primary arcuate line (U-AL) was 5.37±1.62 cm (range 2.5-11.5 cm). The primary arcuate line was found situated at the $1/3^{rd}$ of the distance from the umbilicus to the pubic symphysis (Mean 15.74±s.d 1.41 cm; range 13.0 to 18.0 cm) and at the $2/3^{rd}$ of the distance from the xiphisternum to the pubic symphysis (Mean 30.25±s.d 1.93 cm; range 19.0 to 34.0 cm).

The positions of the primary arcuate line observed during the 68 TEPP hernioplasties are diagrammatically illustrated in the **Fig. 9.** Majority of the primary arcuate lines (N=41) belonged to the classical normal group (**Fig. 1**) as defined earlier (U-Al distance 3-6 cm); the AL was high in 3 cases, and it was low (**Fig. 7**) in 10 cases.

Secondary arcuate line(s) observed in the present study were not included here for data analysis for seven reasons, namely, firstly they are secondary in nature, secondly they are often multiple, thirdly they occurred in both the incomplete and complete posterior rectus sheaths, fourthly their position was highly variable, fifthly their incidence was quite low in the present study, sixthly which one of the double/multiple secondary arcuate lines should be considered for target measurement, and seventhly their documentation here is likely to create severe constraints and confusion in data analysis of the primary arcuate line, and hence require separate data analysis sometime later.

3.1.6 Relation of AL Level with Age

The level of the primary arcuate line did not differ significantly with respect to the age of the patients **(Table**

6). Pearson Chi Square correlation was also not found significant among the three age groups (r = 0.062, n = 54, Sig. 0.657, p >0.05).

Mean age of the patients with three different levels of the primary arcuate line (classical, high and low) was not statistically different (ANOVA, $F_{2\,51}$ = 0.347, Sig. 0.708, p >0.05), and Pearson Chi-Square correlations were also not different significantly (*Pearson CHISQ CC:* R=36.907, df 48, Sig. 0.878, p >0.05; *Likelihood Ratio:* R=29.467, df 48, Sig. 0.984, p >0.05; *Linear-by-Linear Association:* R=0.712, df 1, Sig. 0.399, p >0.05).

3.1.7 Relation of AL Level with BMI

Level of the primary arcuate line was different significantly (p<0.001) in patients with overweight/obesity as compared to patients with normal weight **(Table 12) (Table 7).** Pearson Chi Square Correlations were also significantly different between the two groups (r = -0.443, n = 46, Sig. 0.002, p <0.01). Primary Arcuate line was found situated high (U-AL <3 cm) in 3 out of 4 overweight/obese patients, and there was no instance of high arcuate line in patients with normal weight.

Mean BMI of the patients with the three positions of the primary arcuate line (classical, high and low) was also found significantly different (ANOVA, $F_{2\,51}$ = 28.350, Sig. 0.000, p <0.001). Post Hoc Tests (Scheffe and Tukey HSD) confirmed that that the patients with high arcuate line had significantly higher BMI as compared to those with the classical or low arcuate line, and the difference between the latter two was not significant (p >0.05). In other words, the high arcuate line used to occur in the overweight/obese patients.

3.1.8 Relation of AL Level with Occupation

The nature of patient's occupation did not affect significantly the level of the primary arcuate line and the Pearson correlation tests were also not statistically significant (*Pearson CHISQ CC:* R=6.649, df 10, Sig. 0.758, p >0.05; *Likelihood Ratio:* R=8.443, df 10, Sig. 0.586, p >0.05; *Linear-by-Linear Association:* R=0.532, df 1, Sig. 0.553, p >0.05). Moreover, Contingency Coefficient and Spearman correlation were also not significant (p >0.05).

3.1.9 Symmetry of AL Level in Bilateral Hernias

The level of primary Arcuate line was found symmetrical on the two sides of body in only 4 out of the 8 cases studied and asymmetrical in the remaining 4 patients **(Table 6) (Table 3).** The mean age of the patients was significantly different (p <0.05) between the mirror and non-mirror levels of the primary arcuate line **(Table 4),** and patients with non-mirror levels of the primary arcuate line were significantly much older in age than those with the mirror levels of the primary arcuate line. However, BMI of the patients was not different significantly between the two groups of primary arcuate line level **(Table 5),** i.e., the patients' BMI did not affect the level of the primary arcuate line alone, if not combined with its morphology (*vide infra*).

g. Combined Morphology & Level of Arcuate Line

For more clarity of understanding and data analysis, features of morphology and level of arcuate line were combined. In only 31 out of 68 instances, the classical arcuate line, i.e., single sharp well-defined arcuate line situated within 3-6 cm of the umbilicus was documented in the present study and was abbreviated as NS-SWD **(Fig. 1) (Table 8** and **10).**

Variant forms of the primary arcuate line (Variant-AL) were observed in 37 out of 68 cases, and included 6 subtypes, namely, (1) normal-sited single ill-defined (NS-SID) in 10 cases **(Fig. 7),** (2) high single sharp well-defined (H-SWD) in 3 cases, (3) low single sharp well-defined (L-SWD) in 3 cases **(Fig. 8)**, (4) low-sited single ill-defined (L-SID) in 4 cases, (5) double or multiple (DAL) in 3 cases **(Fig. 3)**, (6) absent (A) in 14 cases **(Fig. 2) (Table 9** and **11).**

3.1.10 Relation of Combined AL Morphology/Level with Age/BMI

Mean age and BMI of the patients in 2 groups of the normal and variant AL were found comparable without statistical difference (p>0.05) **(Table 8** and **10).** In other words, variations of the primary arcuate line were independent of the age or BMI of the individuals.

Among the 6 subgroups of variant primary arcuate line (Variant-AL), the patient's age did not affect the morphology of primary arcuate line **(Table 9)**, but the high level of the primary arcuate line was found to occur in only the overweight/obese individuals with a high statistical significance (p<0.001) **(Table 11),** although sample size in this was rather small.

3.1.11 Correlation of Combined AL Morphology/Level with Profession

Occupation of the patients did not significantly affect the morphology of the primary arcuate line either between the two major groups (classical and variant) of the primary arcuate line (Pearson Chi-Square Correlation: R = 4.618, df 5, Sig. 0.464, p >0.05) or among the seven subtypes (1 classical and 6 variants) of the primary arcuate line (Pearson Chi-Square Correlation: R = 22.235, df 30, Sig. 0.845, p >0.05).

3.1.12 Correlation of Combined AL Morphology/Level with PRS Morphology

The whole tendinous (WT) morphology of the posterior rectus sheath (PRS) was found associated with the classically described single sharp well-defined (SWD) primary arcuate line, irrespective of its level (normal, high or low) **(Table 12).** The partly tendinous (PT) and thinned-out (TO) morphology of the PRS were mainly associated with formation of the single ill-defined (SID) and double/multiple primary arcuate line (DAL). The Absent-

AL was observed in relation all types of PRS morphology in varying proportions **(Table 12).**

3.1.13 Symmetry of AL Morphology & Level in Bilateral Hernias

With respect to the twin features of morphology and level, the primary arcuate line had mirror anatomy in only 3 out of the 8 patients who underwent Bilateral TEPP hernioplasty, and non-mirror anatomy in the remaining 5 patients **(Table 3).**

Age of the patients affected the combined feature of morphology and level of the primary arcuate line significantly (p <0.01) with arcuate line variations of symmetry occurring more in the older age group **(Table 13).** However, patients' BMI did not significantly affect the arcuate line variations of symmetry of the combined feature of morphology and level of the primary arcuate line **(Table 14).**

h. Shape of the Arcuate Line

Arcuate line was found distorted due to pressure effects (overstretching, straightening and anterior curvaturing, etc.) of the CO_2 insufflation even at the low pressure of 12 mmHg, and hence in general, the primary arcuate line appeared almost straight, with its lateral end variable (lower in 18 cases, equal in 25 cases and higher in 11 cases) with respect to its medial end in patients with the incomplete posterior rectus sheath (n=54) **(Fig. 9)**. In 14 patients with complete posterior rectus sheath, the primary arcuate line was absent, supposing the lateral end of the posterior rectus sheath touching the pubic bone **(Fig. 9)**.

4. Discussion

Although the rectus sheath has been described well in cadavers[13,15], but the literature on the arcuate line is sparse and scanty and that too only cadaveric in nature. Herein we would like to discuss the our live observations of the arcuate line in terms of its existence, morphology, number, level, shape and symmetry and try to corroborate with the cadaveric observations reported in the literature because there is no report on live surgical anatomy of the arcuate line available in the English literature to the best of our knowledge.

a. Existence of Arcuate Line

Arcuate line variations have been often reported in past since the time of Mackay (1889)[23] by various investigators in cadaveric studies.[6-12,15,23-26] These studies described one or more of the four variations of primary arcuate line (AL) reported in literature, which include (1) the classical single sharp well-define AL (SWD-AL), (2) indistinct/ill-defined AL (SID-AL)), (3) double/multiple AL (DAL), and (4) Absent AL (AAL). The present study documented all the four types of these arcuate line variations in *54.4%, 20.6%, 4.4%, and 20.6% of our cases respectively.*

Incidence of primary arcuate line existence has been reported in 80-100% of the cadaveric dissections.[12,14,15,26] Our observation of presence of the primary arcuate line in 79 % of the hernia repairs is in tune with these cadaveric findings. However, Loukas et al (2008)[13] reported a lower incidence of primary arcuate line existence in only 35% of the subjects. Contrary to the above observations, Rizk (1991)[10] found that the formation of primary arcuate line was a rare phenomenon, occurring in only 1.25% of his cadaveric dissections, and supported the observation of Askar (1977)[27] that *"A real arcuate line could not be identified in the material examined (40 cadavers)"*, i.e., the arcuate line was absent in 100% of Askar's cases. Observations of Rizk (1991)[10] and Askar (1977)[27] were strongly supported by the studies of Arregui (1997)[4] and Spitz and Arregui (2001)[28]. Cunningham et al (2004)[12] reported the absence of primary arcuate line in only 5% of the cadaveric specimens. Our observation of absent primary arcuate line in 21% is in full agreement with that of 20% reported by Mwachaka et al (2010)[15].

It is of interest to recall the gender variation in the occurrence of the arcuate line documented by Mwachaka and associates (2010)[15], viz., the arcuate line was absent in only 7% of male cadavers but it was found absent in about 1/3rd of the female cadavers, a phenomenon not yet reported in the English literature. *Present study had limitation of gender differentiation due to non-recruitment of the female patients because of exclusion criteria.*

Arregui (1997)[4] found in many dissections that the posterior rectus sheath used to get attenuated in its lower part and almost always continued in the attenuated fashion below the arcuate line if one is present, extending upto the pubic bone. Later, it was confirmed by Spitz and Arregui (2001)[28] that the arcuate line, if one is present, was not an absolute point of termination of the posterior rectus sheath but it represents a point of gradual transition, with the posterior rectus sheath being continued below it an attenuated form upto the pubic bone. They supported the earlier observation of Walmsley (1937)[6] that *"In the human subject also, the proper posterior wall of the sheath is represented below the arcuate line (linea semicircularis) by a thin delicate fascial sheet which is distinct from the fascia transversalis.*" Moreover, the observations of Spitz and Arregui (2001)[28] also supported the opinion of some anatomists including Moffat (1989)[29] and Rizk (1991)[10] that the arcuate line often seen in the dissection hall is, in reality, artificially created by removing the lower attenuated part of the posterior rectus sheath, simply considering it as the underlying transversalis fascia. Present study also documented this phenomenon of gradual transition not only in 50% of the complete posterior rectus sheath (n=14) when Henle's band was also considered as secondary arcuate line (*vide infra*) **(Fig. 4, 5 and 6)**, but also in 5.6% of the incomplete posterior rectus sheath **(Fig. 3**). In other words, either this phenomenon of gradual transition in the posterior rectus sheath may not be an universal phenomenon, leading to discrepancy in the anatomic descriptions by the various investigators, or this phenomenon of gradual transition is masked by the hardening and fusion of lower attenuated posterior rectus sheath and underling transversalis fascia in the fixed cadavers, or this may be a reflection of poor surgical dissection technique despite improved optics, or this may be the rupture artifact effect of the blind balloon dissection (often used during TEPP hernioplasty) when lower attenuated part of the posterior rectus sheath is blown out and missing, with the upper margin of the rent in the posterior rectus sheath representing the arcuate line.

In the present study, an *artificial arcuate* line was created surgically in presence of the complete posterior rectus sheath (n=14) at about the level of middle port in order to reach the requisite preperitoneal space for further definitive dissection **(Fig. 10),** as was also reported earlier by the author.[21,30] Similarly, in presence of a long posterior rectus sheath with low arcuate line (n=10), a *secondary arcuate line* has to be created more proximally at about the level of middle port in order to reach the requisite preperitoneal plane for further definitive dissection and space creation as has been reported earlier by the author.[30]

b. Number and Nature of Arcuate Line

Traditional textbook teaching dictates presence of a single arcuate line (SAL); however, sporadic cases of the double and multiple arcuate lines (DAL) had been often reported in the literature.[7-9,13] Loukas et al (2008)[13] documented a single arcuate line in only 25% and double arcuate line in 10% of the 200 cadaveric specimens, while the arcuate line was absent in remaining 65%. Present study recorded presence of a single primary arcuate line in 75% of 68 successful TEPP hernia repair, double arcuate line (1 primary and 1 secondary) in incomplete posterior rectus sheath in 2.9%, double arcuate line (both secondary) in complete posterior rectus sheath in 1.5%, triple arcuate line (1 primary and 2 secondary) in incomplete posterior rectus sheath in 1.5%, triple arcuate line (all three secondary) in incomplete posterior rectus sheath in 2.9%, and totally absent arcuate line in the remaining 16.2% of 68 successful TEPP hernia repair performed in the present study.

Below the arcuate line of Douglas, a thin fascial layer always forms the deep wall of the rectus sheath with a constant arrangement of fibres which may be well-developed at place(s) to form the secondary arcuate line (Henle’s Band) between the true fold (primary arcuate line) and pubis.[6,23] In the present study, the primary arcuate line was documented in 79.4% of 68 successful TEPP hernioplasties, all being related to the incomplete posterior rectus sheath; however, the secondary arcuate lines were observed in relation to both incomplete posterior rectus sheath (5.6%) and complete posterior rectus sheath (21.4%). There was no formation of arcuate line of any sort in the remaining 78.6% of the cases, which had complete posterior rectus sheath, extending upto the pubic bone.

After the classical exhaustive work of Askar (1977)[27] and Rizk (1980)[31], all three aponeuroses of the anterior abdominal wall (external oblique, internal oblique and transversus abdominis) are now accepted to be bi-laminar in nature.[22] Thus the posterior rectus sheath is now generally regarded as tri-laminar in nature (formed by internal lamina of the internal oblique aponeurosis and two laminae of the transversus aponeurosis), although a number of variations in its formation had been reported in the literature.[6,7,27,31,26,32] *Differential termination of the layers of internal oblique and transversus aponeuroses that form the tri-laminar posterior rectus sheath has been regarded as the cause for the formation of the double or multiple arcuate lines,*[7,9] although this concept was wishfully prophesied way back in 1937 by Robert Walmsley[6]**.**

c. Level of Arcuate Line

Traditional textbook teaching described the position of the primary arcuate line at half of the distance from the umbilicus to the pubic symphysis (U-PS),[12,33-35] although a lot of variations had been reported in the literature,[12,24-26,36] making its typical location debatable.[37] Present study documented the average position of the primary arcuate line at 1/3rd of the U-PS distance, which is in full agreement with the observations of Loukas et al (2008)[13] and ratified recently by Rosen et al (2016)[22] in the 41st edition of the Gray’s Anatomy. *However, the arcuate line level was found variable beyond the average position in 24% of our patients, when absent arcuate lines are excluded from consideration* **(Fig. 11).**

Monkhouse and Khalique (1986)[26] observed that symmetrical disposition of the arcuate line on the two sides of the body was rare. Loukas et al (2008)[13] also documented a high degree of asymmetry in the arcuate line position (60-96%), and the arcuate line level did not have any correlation with the age, gender or race of their subjects. Present study recorded non-mirror position of the primary arcuate line on two sides of the body in 50% of TEPP hernia repair – the low vs. the classical position in 25% of our cases, and the classical position vs. the absent-AL in another 25% of our cases. Similar to the observation of Monkhouse and Khalique (1986)[26], the present study also did not find any significant correlation between the arcuate line positions on the two sides of the body and the age, BMI or occupation of the patients.

d. Morphology of Arcuate Line

Loukas et al (2008)[13] described three morphological types of the arcuate line, namely, Type I, indistinct/absent arcuate line (65%), Type II, sharp well-defined arcuate line (25%), and Type III, double arcuate line (10%). Based on Loukas classification[13], the morphological types of the arcuate line in the present study may be grouped in five categories for the sake of comparative analysis and understanding, namely, (1) Indistinct single primary arcuate line (Type I) in 20.6%, (2) Well-defined single primary arcuate line (Type II) in 54.4%, (3) double arcuate line in incomplete posterior rectus sheath (say, Type IIIA) in 4.4%, (4) double arcuate line in complete posterior rectus sheath (say, Type IIIB) in 4.4% of TEPP hernioplasties (n=68), (5) Absence of both primary and secondary arcuate lines (say, Type IVB) in 16.2% of all the TEPP hernia repairs performed in the present study (n=68).

e. Symmetry of Arcuate Line Morphology

Loukas et al (2008)[13] documented asymmetry in the arcuate line morphology in 4-40% of cases depending upon its type, which did not have any significant correlation with the age, gender or race of their subjects ($p > 0.05$). We did not find any other study in the literature that might have highlighted the correlation between the arcuate line morphology and the demographic characteristics of the individuals. Our observations are also in tune with those of Loukas et al (2008)[13]**.** Present study recorded asymmetry of the arcuate line morphology in 37.5% of patients with bilateral hernia (n=8), and no significant collation was found between arcuate line morphology and the age, BMI or occupation of the patients ($p > 0.05$).

f. Relation of Arcuate Line Morphological with Posterior Rectus Sheath (PRS)

Present study observed exclusive association of single sharp well-defined arcuate line (SWD) with the whole-tendinous posterior rectus sheath (WT-PRS), irrespective of the arcuate line position. On the other hand, the single ill-defined (SID) and double arcuate line (DAL) were found almost exclusively in the partly-tendinous posterior rectus sheath (PT-PRS) and thinned-out posterior rectus sheath (TO-PRS). However, the absent arcuate line was recorded in all types of the PRS morphology. No study on correlation between the AL and PRS morphology is reported in literature, to the best of our knowledge, for the comparative analysis.

g. Shape of Arcuate Line

Contrary to the common belief about the classical transverse concave shape of the arcuate line, Monkhouse and Khalique (1986) documented the highly variable shape of the arcuate line and beautifully illustrated with a line diagram **(Fig. 11).**[26] During the clinical setting of the laparoscopic TEPP hernioplasty, we could not ascertain the actual shape of the arcuate line in our patients because of the pressure effects of CO_2 insufflation. However, the lateral end of arcuate line was found almost at level with its medial end in majority of our patients (46.3%), while the lateral end was found a little lower or higher in 33.3% and 20.4% respectively **(Fig. 9).** Our observations are in tune with those of Monkhouse and Khalique (1986) **(Fig. 11).**[26]

h. Combined Anatomy of the AL-Level and AL-Morphology in the Bilateral Hernias

Monkhouse and Khalique (1986)[26] reported that symmetrical disposition of the arcuate line on the two sides of the body is a rare phenomenon. Asymmetry of arcuate line morphology and level was recorded in 62.5% of our 8 patients with bilateral hernias. Loukas et al (2008)[13] also reported arcuate line asymmetry in a high percentage of 79% of the 100 cadavers (200 sides) examined, and they found no correlation between the arcuate line asymmetry and the age, sex or race of the subjects ($p > 0.05$). In the present study, incidence of the arcuate line asymmetry was significantly higher in our older patients ($p < 0.05$), although patients' BMI or profession made no significant difference ($p > 0.05$).

5. Conclusions

The so-called classical arcuate line (normal-sited single sharp well-defined) was observed in only 46% of the 68 successful TEPP hernioplasties in adult male patients with primary inguinal hernia, and in the remaining 54%, the primary arcuate line was of 6 variant types which included the high single sharp well-defined (4.4%), low single sharp well-defined (4.4%), normal-sited single ill-defined (14.7%), low single ill-defined (5.9%), multiple, i.e., primary associated with secondary arcuate line (4.4%), and absent primary arcuate line (20.6%). The primary arcuate line was found situated, in general, at the 1/3rd of the umbilico-pubic distance. The primary arcuate line had non-mirror anatomy on the two sides of the body in 62.5% of patients with bilateral inguinal hernias. Secondary arcuate line was also documented in 50% of the cases with the complete posterior rectus sheath.

Thus present study confirmed the wide anatomic variations in the Arcuate line of Douglas reported sparingly in the literature.[4,10-15,22,24-26,28] Moreover, present study also confirmed the opinion that the arcuate line may not always represent the termination of the posterior rectus sheath.[19,28,29] Lastly, use of laparoscopy for the inguinal hernia repair created a positive effect on the surgeons to necessarily learn the surgical anatomy of the region from a new posterior perspective beyond the traditional textbook teaching,[38-40] as was the experience of the author himself. The author strongly recommends the observations of Claude Avisse and colleagues (2000)[5] that the laparoscopic approach provides new vision of structures known for centuries, and the anatomic research is still useful as well as acutely needed to realize the full the potential of the minimal access laparoscopic surgery under the current crisp precise scientific knowledge and to parallel revolution of the minimal access laparoscopic surgery with the open surgery. Many of the previous observations reported in the older literature but not mentioned in the textbooks of anatomy and surgery are proved correct as also emphasized by Condon (1996).

6. Future Scope

Present study documented new features of surgical anatomy of the arcuate line and wide variations in its position and morphology. However, the present study had two basic limitations, namely, small sample size and absence of female subjects. The study has generated a number of potential areas for future research, some of which are listed as under:

1. Need of creating a sub-speciality of 'Laparoscopic Surgical Anatomy, preferably with involvement of an interested anatomist;
2. Need of more Laparoscopic Research-Based Studies
3. Need of large-sample studies with induction of both male & female patients;

4. Utilization of definition or high resolution ultrasonography (HD-USG), dynamic MRI and multi-detector CT (MDCT) for pre-operative detection of anatomic variations (Coulier, 2007);
5. Utilization of High Definition Endoscopic Vision for better perspective, lighting and magnification in order to timely detect the anatomic variations and judicious surgical dissection for seamless laparoscopic surgery;
6. Development of a computerized anatomic model may enhance our anatomic knowledge and understanding;
7. Last but not least, anatomic research in laparoscopic live surgical anatomy is not only still useful but also warranted in the current era of laparoscopic revolution.

7. Conflict of Interest: None

8. Funding: Nil

9. References

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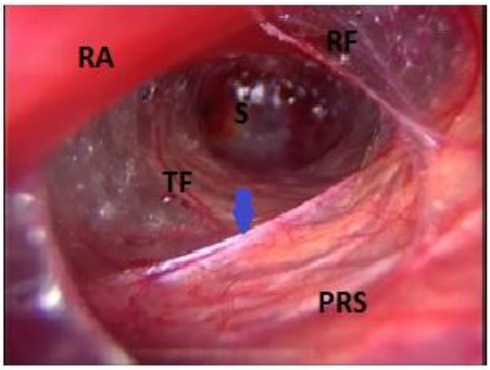


Figure 1: Classical Single Sharp Well-defined Primary Arcuate Line (blue arrow) in the Incomplete Posterior Rectus Sheath: PRS, posterior rectus sheath; **RA,** rectus abdominis muscle; **RF,** rectusial fascia; **TF,** transversalis fascia; **S,** sign of light in the depth of posterior rectus canal;

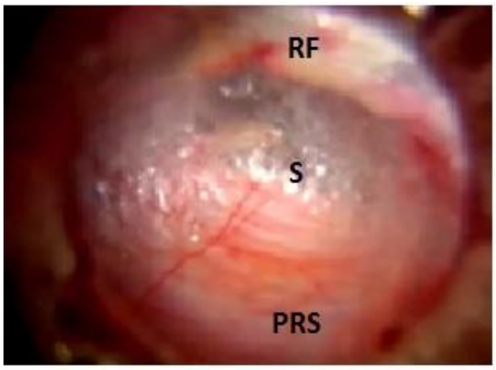


Figure 2: Absence of Primary Arcuate Line in Complete Posterior Rectus Sheath (Whole Tendinous): PRS, posterior rectus sheath; **RF,** rectusial fascia covering the rectus abdominis muscle; **S,** sign of light in the depth of posterior rectus canal;

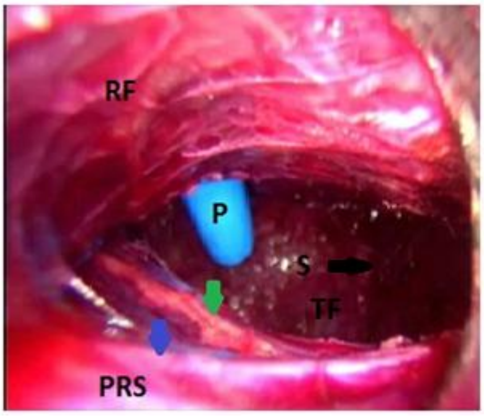


Figure 3: Triple Arcuate Line in the Long Incomplete Posterior Rectus Sheath: Black arrow, low primary arcuate line; **Blue arrow,** well-defined first secondary arcuate; **Green arrow,** second secondary arcuate line: **PRS,** posterior rectus sheath; **RF,** rectusial fascia covering the rectus abdominis muscle; **S,** sign of light in the depth of posterior rectus canal; **P,** plastic 5-mm working port;

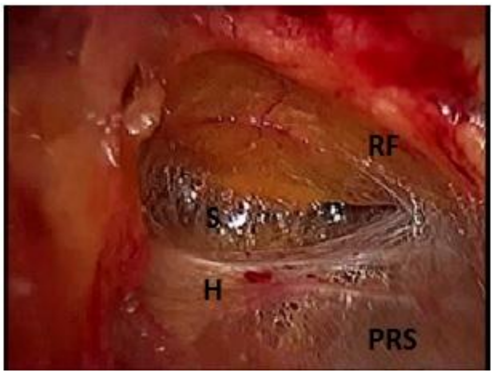


Figure 4: Secondary Arcuate Line (Henle's Band) in Complete Posterior Rectus Sheath (Grossly Attenuated): PRS, posterior rectus sheath; **RF,** rectusial fascia covering the rectus abdominis muscle; **H,** Henle's Band; **S,** sign of light in the depth of posterior rectus canal;

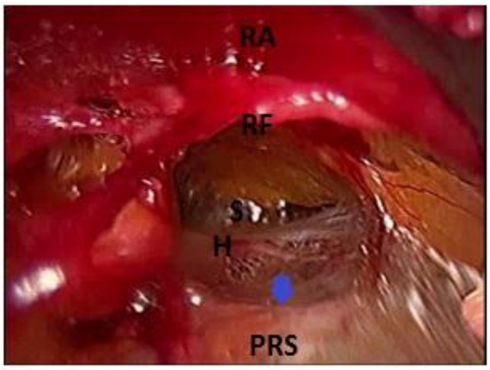


Figure 5: Double Arcuate Lines in Complete Posterior Rectus Sheath: Blue arrow, well-defined first secondary arcuate line; **H,** Henle's Band (second secondary arcuate line); **PRS,** posterior rectus sheath; **RF,** rectusial fascia; **RA,** rectus abdominis muscle; **S,** sign of light in the depth of posterior rectus canal;

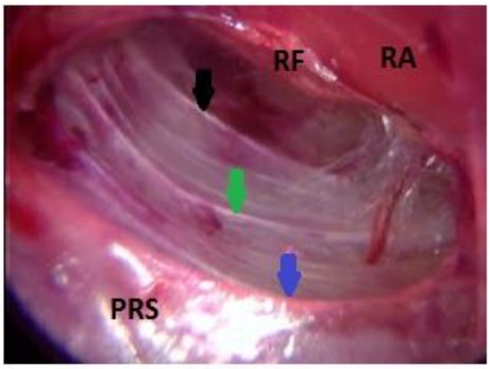


Figure 6: Triple Arcuate Line in Complete Posterior Rectus Sheath (partly tendinous): Blue arrow, well-defined first secondary arcuate line; **Green arrow**, second secondary arcuate line; **Black arrow**, third secondary arcuate line; **PRS**, posterior rectus sheath; **RF**, rectusial fascia; **RA**, rectus abdominis muscle; **S**, sign of light in the depth of posterior rectus canal;

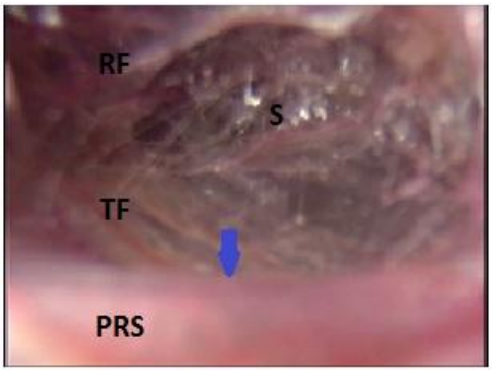


Figure 7: Single ill-defined Primary Arcuate Line in Incomplete Posterior Rectus Sheath: Blue arrow, ill-defined primary arcuate line; **PRS,** posterior rectus sheath; **TF,** transversalis fascia; **RF,** rectusial fascia covering the rectus abdominis muscle; **S,** sign of light in the depth of posterior rectus canal;

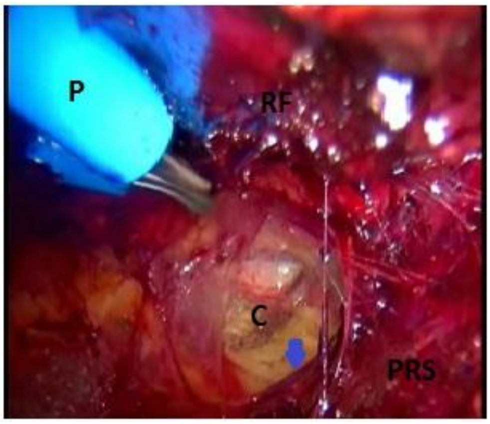


Figure 8: Low Well-defined Primary Arcuate Line in Long Incomplete Posterior Rectus Sheath (same patient as in Fig. 3): **Blue arrow,** well-defined primary arcuate line; **PRS,** posterior rectus sheath; **RF,** rectusial fascia covering the rectus abdominis muscle; **S,** sign of light in the depth of posterior rectus canal; **P,** plastic 5-mm working port;

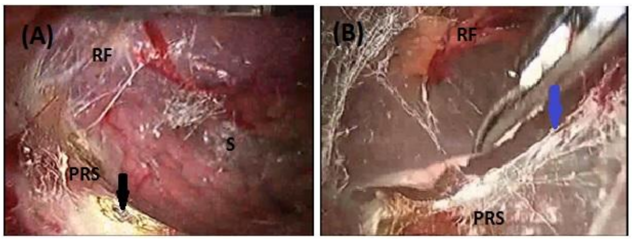


Figure 10: Creation of Artificial Arcuate Line in Complete Posterior Rectus Sheath (Thinned-Out): (A) showing start of creation of artificial arcuate line in the posterior rectus sheath by slight cauterization at one place (black arrow); **(B)** showing completion of artificial arcuate line (blue arrow); **PRS,** posterior rectus sheath; **RF,** rectusial fascia; **S,** sign of lighthouse in the depth of the posterior rectus canal;

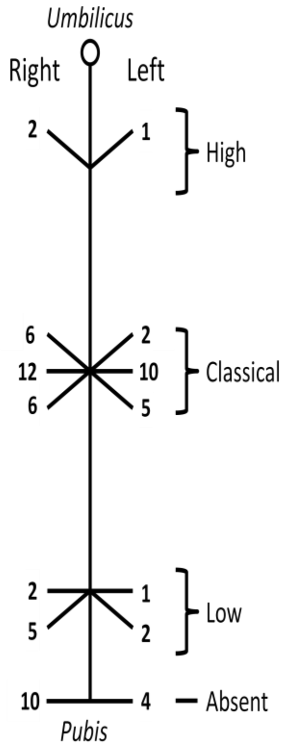
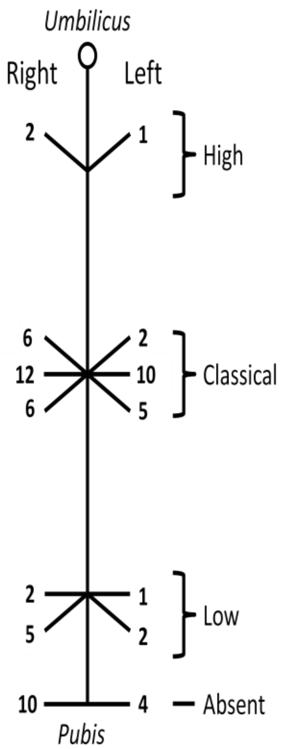


Figure 9: Diagrammatic representation of the 4 Groups of the Primary Arcuate Line Levels (Classical, High, Low and Absent) with the Relative Positions of their Medial and Lateral Ends, and their Comparative Evaluation with those of Monkhouse and Khalique (1986): **Number** on the arcuate line indicates its count/frequency; **U-PS**, distance between umbilicus to pubic symphysis; **High**, arcuate line at <3 cm of U-PS distance; **Classical**, arcuate line at 3-6 cm of U-PS distance; **Low**, arcuate line at >6 cm of U-PS distance; **Absent,** arcuate line situated at pubic bone *(i.e., the posterior rectus sheath was complete, extending upto the pubic bone).*

Present Study **Monkhouse & Khalique (1986)**

(A)



(B)

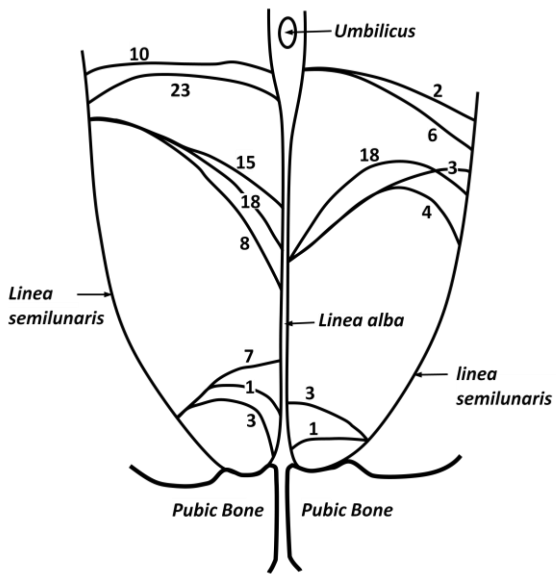


Figure 11: Comparative Diagrammatic Representations of Primary Arcuate Lines: A, Present study's diagrammatic representation of the 4 groups of the Arcuate Line Levels (Classical, High, Low and Absent) with the Relative Positions of their Medial and Lateral Ends; **Number** on the arcuate line indicates its count/frequency; **U-PS**, distance between umbilicus to

pubic symphysis; **High**, arcuate line at <3 cm of U-PS distance; **Classical**, arcuate line at 3-6 cm of U-PS distance; **Low**, arcuate line at >6 cm of U-PS distance; **Absent,** arcuate line situated at pubic bone *(i.e., the posterior rectus sheath was complete, extending upto the pubic bone);* **B,** Actual line diagram of arcuate lines reported by Monkhouse and Khalique (1986); ***Note:*** Arcuate line shape in the present study was distorted due to the pressure effect and hence its diagrammatic representation cannot be compared with the exact shapes documented by Monkhouse and Khalique (1986) (redrawn with permission).

Table 1: Age Distribution of Patients with Various Morphology of Primary Arcuate Line

(N=68)

S. No	Variant Arcuate Line	Hernias		Patients		Age Mean±S.D. (Range)	Variance	F-Value	Sig. (2-Tailed)	p-Value
	Type	N	%	N	%	Years				
1.	**SWD**	37	54.4	31	51.7	52.8±15.3 (18-80)	262.9841 & 280.1531	$F_{3\ 64}$ = 0.9387	0.4273	>0.05
2.	**SID**	14	20.6	13	21.7	53.0±18.8 (21-80)				
3.	**DAL**	3	4.4	3	5.0	48.3±7.6 (40-55)				
4.	**AAL**	14	20.6	13	21.7	44.5±19.2 (19-72)				
	Total	68	100	60	100	50.1±17.2 (18-80)				

SWD, single sharp well-defined; SID, single ill-defined; DAL, double/ multiple arcuate line;
AAL, absent arcuate line; SD, standard deviation; F, analysis of variance (ANOVA) value;
Sig., significance value; p>0.05, not significant;

Table 2: Body Mass Index (BMI) of Patients with Four Morphology Subtypes of Primary Arcuate Line

(N=68)

S. No.	Variant Arcuate Line	Hernias		Patients		BMI Mean±S.D. (Range)	Variance	F-Value	Sig. (2-Tailed)	p-Value
	Type	N	%	N	%	Kg/m^2				
1.	**SWD**	37	54.4	31	51.7	22.7±2.4 (19.3-31.2)	2.9743 & 3.8403	$F_{3\ 64}$ = 0.7745	0.5125	>0.05
2.	**SID**	14	20.6	13	21.7	21.8±1.3 (19.5-23.8)				
3.	**DAL**	3	4.4	3	5.0	22.6±0.6 (22.1-23.2)				
4.	**AAL**	14	20.6	13	21.7	22.7±1.1 (21.5-24.3)				
	Total	68	100	60	100	22.6±2.0 (19.3-31.2)				

SWD, single sharp well-defined; SID, single ill-defined; DAL, double/ multiple arcuate line;
AAL, absent arcuate line; SD, standard deviation; F, analysis of variance (ANOVA) value;
Sig., significance value; p>0.05, not significant;

Table 3: Bilateral Anatomy of Primary Arcuate Line (AL) In Patients with Bilateral Hernias

(N=8)

S. No.	Level of Arcuate Line		Morphology of Arcuate Line		Both Level & Morphology of Arcuate Line	
	Left Side	**Right Side**	**Left Side**	**Right Side**	**Left Side**	**Right 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.	NS	A*	SWD	A*	NS-SWD	A*
5.	NS	A*	SWD	A*	NS-SWD	A*
6.	NS	LS*	SWD	SWD	NS-SWD	L-SWD*
7.	NS	NS	SWD	SID*	NS-SWD	NS-SID*
8.	NS	LS*	SWD	SWD	NS-SWD	L-SWD*

§One case of bilateral absence of AL was excluded for comparative analysis;
NS, classical normal-sited; LS, low-sited; A, absent; SID, single ill-defined;
NS-SWD, classical, normal-sited single sharp well-defined arcuate line;

SWD, sharp well-defined; NS-SID, normal-sited single ill-defined;
LSWD, low sharp well-defined; Star (*) indicates asymmetry on two sides;

Table 4: Age of Patients with Mirror and Non-Mirror Anatomy of Primary Arcuate Line on Two Sides of Body in Bilateral Hernias

(N=8)

S. No.	AL-Anatomy	AL-Type	N	%	Age Mean±SD (Range) Years	C.I.D	t-Value	Sig. (2-Tailed)	p-Value
1.	Level of Arcuate Line	**Mirror**	4	50	47.50±10.41 (35-60)	-31.561 to -1.9386	2.7672	0.0325	<0.05
		Non-Mirror	4	50	64.25±6.18 (57-72)				
		Total	8	100	55.88±11.96 (35-72)				
2.	Morphology* of Arcuate Line	**Mirror**	4	57.1	54.25±8.69 (45-65)	-26.070 To 4.5695	1.8038	0.1311	>0.05
		Non-Mirror	3	42.9	65.00±6.24 (-)				
		Total	8	100	55.88±11.96 (45-65)				

*One case of bilateral absence of arcuate line (AL) was excluded for comparative analysis; SD, standard deviation;
CID, confidence interval of difference; t, independent-sample t-test value; Sig., significance value;
p >0.05, not significant;

Table 5: Body Mass Index (BMI) of Patients with Mirror and Non-Mirror Anatomy of Primary Arcuate Line on Two Sides of Body in Bilateral Hernias

S. No.	AL-Anatomy	AL-Type	N	%	BMI Mean±SD (Range) Kg/m^2	C.I.D	t- Value	Sig. (2-Tailed)	p-Value
1.	Level of Arcuate Line	**Mirror**	4	50	21.38±0.80 (20.5-22.4)	-3.285 To 1.4453	0.9517	0.3780	>0.05
		Non-Mirror	4	50	22.30±1.76 (20.2-24.4)				
		Total	8	100	22.05±0.67 (20.2-24.4)				
2.	Morphology* of Arcuate Line	**Mirror**	4	57.1	22.30±1.69 (20.5-24.4)	-2.104 To 3.7642	0.7272	0.4997	>0.05
		Non-Mirror	3	42.9	21.47±1.14 (20.2-22.4)				
		Total	8	100	22.05±0.67 (20.2-24.4)				

AL, arcuate line; *One case of bilateral absence of arcuate line was excluded for comparative analysis;
CID, confidence interval of difference; t, independent-sample t-test value; Sig., significance value;
P >0.05, not significant;

Table 6: Umbilicus-to-Primary-Arcuate-Line Distance in Different Age Groups of Patients (N=47) with Incomplete Posterior Rectus Sheath

S. No.	Age Groups (Years)	*N_{AL}	%	U-AL** Mean±SD (Range) cm	F-value¶	Sig. (2-tailed)	p-value
1.	**18-40**	14	25.9	5.2±1.1 (2.5-6.5)	$F_{2\ 51}$ = 0.139	0.871	>0.05
2.	**41-60**	23	42.6	5.4±1.6 (2.5-10.5)			
3.	**60-80**	17	31.5	5.5±2.1 (2.5-11.5)			
	TOTAL	54	100	5.4±1.6 (2.5-11.5)			

*N_{AL}, number of arcuate lines including the opposite sides (7); **U-AL= distance from umbilicus to arcuate; ¶F, ANOVA value; Sig., significance value; p>0.05, insignificant;

Table 7: Umbilicus-to-Primary-Arcuate-Line Distance in Patients (N=47) with Incomplete Posterior Rectus Sheath with respect to Body Mass Index

S. No.	BMI*	N	%	U-AL** Mean±SD (Range) cm	C.I.D	t-value	Sig. (2-tailed)	p-value
1.	Normal BMI (<25Kg/m²)	43	91.5	5.68±1.52 (3.5-11.5)	1.5024 To 4.5976	3.969	0.000	<0.001
2.	High BMI (>25 Kg/m²)	4	8.5	2.63±0.25 (2.5-3.0)				
	TOTAL	47	100	5.37±1.62 (2.5-11.5)				

*BMI = Body mass index; N, number of patients with incomplete posterior rectus sheath;
**U-AL = distance from umbilicus to arcuate line; t, independent-sample t-test value;
Sig., significance value; p<0.001, highly significant;

Table 8: Age Distribution of Patients with Two Major Types of Primary Arcuate Line (AL) According to the Combined Features of Morphology and Level (N=68)

S. No	Arcuate Line Type	Hernias		Patients		Age Mean±S.D. (Range)	C.I.D	t- Value	Sig. (2-Tailed)	p-Value
		N	%	N	%	Years				
1.	AL-Classical	31	45.59	26	43.33	50.62±17.20 (18-80)	-8.10 To 9.981	t = 0.2081	0.8359	>0.05
2.	AL-Variant	37	54.41	34	56.67	49.68±17.44 (19-80)				
	TOTAL	68	100	60	100	50.1±17.2 (18-80)				

AL-Classical, normal-sited single sharp well-defined arcuate line (NS-SWD); AL-Variant, variant arcuate line;
SD, standard deviation; CID, confidence interval of difference; t, independent-sample t-test value;
Sig., significance value; p>0.05, not significant;

Table 9: Age Distribution of Patients with Various Subtypes of Variant Primary Arcuate Line According to the Combined Features of Morphology and Level (N=37)

S. No	Variant Arcuate Line	Hernias		Patients		Age Mean±S.D. (Range)	C.I.D	t- or F-Value	Sig. (2-Tailed)	p-Value
	Type	N	%	N	%	Years				
1.	HSWD	3	8.11	3	5.00	54.00±12.17 (40-62)	-	$F_{5\ 28}$ = 0.608	0.694	>0.05
2.	LSWD	3	8.11	2	3.33	53.5±4.95 (50-57)				
3.	NS-SID	10	27.03	9	15.00	50.22±21.01 (21-80)				
4.	LSID	4	10.81	4	6.67	61.25±14.68 (40-72)				
5.	DAL	3	8.11	3	5.00	48.33±7.64 (40-55)				
6.	AAL	14	37.84	13	21.67	44.46±19.23 (19-72)				
	Total	37	100	34	100	50.44±16.80 (19-80)				

AL-Classical, normal-sited single sharp well-defined arcuate line (NS-SWD); AL-Variant, variant arcuate line;
HSWD, high single sharp well-defined; LSWD, low single sharp well-defined; NS-SID, normal-sited single ill-defined;
LSID, low single ill-defined; DAL, double/ multiple arcuate line; AAL, absent arcuate line; SD, standard deviation;
CID, confidence interval of difference; F, one way analysis of variance value;
Sig., significance value; p>0.05, not significant

Table 10: Body Mass Index (BMI) of Patients with Two Major Types of Primary Arcuate Line (N=68)

S. No.	Arcuate Line	Hernias		Patients		BMI Mean±S.D. (Range) Kg/m^2	C.I.D	t- Value	Sig. (2-Tailed)	p-Value
	Type	N	%	N	%					
1.	AL-Classical	31	45.6	26	43.3	22.24±1.71 (19.3-27.5)	-1.658 To 0.4579	t = 1.1353	0.2609	>0.05
2.	AL-Variant	37	54.4	34	56.7	22.84±2.24 (19.5-31.2)				
	Total	68	100	60	100	22.58±2.03 (19.3-31.2)				

AL-Classical, normal-sited single sharp well-defined arcuate line (NS-SWD); AL-Variant, variant arcuate line;
SD, standard deviation; CID, confidence interval of difference; t, independent-sample t-test value;
Sig., significance value; p>0.05, not significant;

Table 11: Body Mass Index (BMI) of Patients with Six Subtypes of Variant Primary Arcuate Line (N=37)

S. No.	Variant Arcuate Line	Hernias		Patients		BMI Mean±S.D. (Range) Kg/m^2	C.I.D	F-Value	Sig. (2-Tailed)	p-Value
	Type	N	%	N	%					
1.	HSWD	3	8.1	3	5.0	28.63±2.38 (26.5-31.2)	-	$F_{5\ 28}$ = 14.668	0.000	<0.001
2.	LSWD	3	8.1	2	3.3	21.55±0.07 (21.5-21.6)				
3.	NS-SID	10	8.4	9	15.0	22.14±1.46 (19.5-23.8)				
4.	LSID	4	10.8	4	6.7	21.35±0.42 (20.9-21.8)				
5.	DAL	3	8.1	3	5.0	22.60±0.56 (22.1-23.2)				
6.	Absent (A)	14	37.8	13	21.7	22.73±1.13 (21.5-24.3)				
	Total	37	100	34	100	22.53±1.95 (19.5-31.2)				

AL-Classical, normal-sited single sharp well-defined arcuate line (NS-SWD); AL-Variant, variant arcuate line;
HSWD, high single sharp well-defined; LSWD, low single sharp well-defined; NS-SID, normal-sited single ill-defined;
LSID, low single ill-defined; DAL, double/ multiple arcuate line; A, absent arcuate line; SD, standard deviation;
CID, confidence interval of difference; F, one way analysis of variance value; Sig., significance value;
P >0.05, not significant;

Table 12: Correlation between Primary Arcuate Line Type and Morphology of Posterior Rectus Sheath (N=68)

S. No.	Arcuate Line	Morphology of Posterior Rectus Sheath										Total	
		WT-PRS		MT-PRS		PT-PRS		TO-PRS		GA-PRS			
	Type	N	%	N	%	N	%	N	%	N	%	N	%
1.	NS-SWD	30	96.8	0	-	0	-	0	-	1	3.2	31	45.6
2.	L-SWD	3	100	0	-	0	-	0	-	0	-	3	4.4
3.	H-SWD	3	100	0	-	0	-	0	-	0	-	3	4.4
4.	NS-SID	1	10	0	-	8	80	1	10	0	-	10	14.7
5.	L-SID	0	-	0	-	4	100	0	-	0	-	4	5.9
6.	DAL	0	-	0	-	3	100	0	-	0	-	3	4.4
7.	AAL	6	42.9	1	7.1	1	7.1	3	21.4	3	21.4	14	20.6
	Total	43	63.2	1	1.47	16	23.5	4	5.9	4	5.9	68	100

NS-SWD, classical, normal-sited single sharp well-defined arcuate line; HSWD, high single sharp well-defined;
LSWD, low single sharp well-defined; NS-SID, normal-sited single ill-defined; LSID, low single ill-defined;
DAL, double/multiple arcuate line; AAL, absent arcuate line; PRS, posterior rectus sheath; WT, whole tendinous PRS;
MT, musculo-tendinous PRS; PT, partly tendinous PRS; TO, thinned-out PRS; GA, grossly attenuated PRS;
SD, standard deviation; CID, confidence interval of difference; t, independent-sample t-test value;
F, one way analysis of variance value; Sig., significance value; p>0.05, not significant;

Table 13: Age Distribution of Patients (N=8) with Mirror and Non-Mirror Anatomy of Primary Arcuate Line with respect Twin Features of Extent & Morphology

AL – Twin Features	AL-Anatomy	N	%	AGE Mean±SD (Range) Years	C.I.D	t- Value	Sig. (2-Tailed)	p-Value
AL Level & Morphology	Mirror	3	37.5	43.33±7.64 (35-50)	-31.517 To -8.633	4.2938	0.0051	<0.01
	Non-Mirror	5	62.5	63.40±5.68 (57-72)				
	Total	8	100	55.88±11.95 (35-72)				

AL, arcuate line; SD, standard deviation; CID, confidence interval of difference; t, independent-sample t-test value; Sig., significance value; p<0.01, very significant;

Table 14: Body Mass Index of Patients (N=8) with Mirror and Non-Mirror Anatomy of Primary Arcuate Line with respect Twin Features of Extent & Morphology

AL – Twin Features	AL – Anatomy	N	%	BMI Mean±S.D (Range) Kg/m^2	C.I.D	t- Value	Sig. (2-Tailed)	p-Value
AL Level & Morphology¶	Mirror	3	37.5	21.03±0.50 (20.5-21.5)	-3.581 To 1.0012	1.3777	0.2175	>0.05
	Non-Mirror	5	62.5	22.32±1.53 (20.2-24.4)				
	Total	8	100	22.05±0.67 (20.2-24.4)				

AL, arcuate line; BMI, body mass index; SD, standard deviation; CID, confidence interval of difference; t, independent-sample t-test value; Sig., significance value; p>0.05, not significant;