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Original Research Article

Patent umbilical artery in medial umbilical fold: Cadaveric study and clinical implications

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ABSTRACT

Background: Minimally invasive surgery has become one of the most accepted surgical options across the globe. In most laparoscopic surgeries, medial umbilical fold (MUF) containing the umbilical artery (UA) serves as an important landmark for creation of peritoneal flap. 50% of gynaecological laparoscopic injuries occur at the time of entry into the anterior abdominal wall, as it involves blind insertion of the trochar or veress needle in the peritoneal cavity. Any variation in the structures of the anterior abdominal wall may affect the placement location of the trocar, which is a crucial aspect to ease the surgeon's ability to manoeuvre the abdominal cavity. The presence of cords and/or dense ligamentous structures in the anterior abdominal wall may complicate trocar insertion and restrict the probe movement during laparoscopic procedures. Hence, the aim of the present study was to classify and observe the variations in the MUF in the anterior abdominal wall.

Methods and Results: The cadavers in the study were formalin fixed through femoral artery perfusion method. Out of the 35 (23 males; 12 female) cadavers (70 MUF), studied, 34 cadavers (69 MUF) followed the pattern of the existing classification proposed by Tokar and Yucel, (2009). However, the right MUF of one male cadaver presented, patent umbilical artery (PUA) associated with a long mesentery. Based on safe presentations for laparoscopic exploration, MUF was given grades. Grades 0 and 1 were categorised as safe as compared to grade 2 and the novel variant observed, based on the morphology of MUF. No significant difference was noted in the occurrence of safe presentations of MUF amongst males and females.

Conclusion: MUF with a patent vessel and a mesentery may cause technical difficulties to the surgeon by decreasing the laparoscopic port work space and obscuring the view of lateral pelvic wall during surgeries. Furthermore, persistent UA can compress the ureter and vas deferens resulting in myriad of symptoms ranging from unexplainable flank pain, hydronephrosis to male infertility. Awareness of such variants is of relevance to urologists in determining the cause of these unexplained symptoms and to surgeons in determining the site of safe trocar insertion. The findings also, highlight the fact that anterior abdominal wall anatomy is not mirror image on both the sides.

1. Introduction

Knowledge of anatomical variations with respect to persistence of aberrant ligamentous and vascular structures on the anterior abdominal wall has often been underestimated. Medial umbilical fold (MUF) is the fold of peritoneum raised bilaterally by the obliterated umbilical arteries (OUA).[1] The MUF serves as an important landmark for creation of peritoneal flap during transabdominal preperitoneal (TAPP) inguinal hernia repair.

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The peritoneum is incised on the lateral aspect and, the flap cut runs horizontally (lateral to medial) to reach the MUF, then, there is a change in direction of cut, so that it runs parallel to MUF (resembling a hockey stick).[2] Hence, the knowledge of variation in the anatomy of MUF is of immense clinical significance during laparoscopic exploration of the abdominal cavity, especially now as minimal access surgery (MAS) are being preferred over conventional open surgeries. Although, MAS has become one of the best options amongst doctors as well as patients due to its numerous advantages such as minimal access, minimal post-operative morbidity, shorter hospital stay and easy return to daily activities; however, efficacy of the surgery is directly and closely related to the surgeon's anatomical knowledge, skill, and experience.[3] Presence of fibrous cord with web or a long mesentery may cause technical difficulties to the operating surgeon by decreasing the work space, obscuring the view of lateral pelvic wall and confusion in identification of the peritoneal folds. Furthermore, patent UA in the MUF could also form the basis of unexplainable lower flank pain, ureteral compression, hydronephrosis and/or male infertility as both, the ureter and vas deferens are crossed by MUF.[4–6] Although a few studies have classified the umbilical ring based on the arrangement of various ligamentous structures in the umbilical region,[7,8] very few studies have focussed on the morphology of the MUF. Hence, the aim of the present study was to classify and observe the variations in the MUF structure within the anterior abdominal wall.

2. Materials and Methods

MUFs (70) of 35 cadavers (23 males and 12 females) were observed during educational cadaveric dissection of the undergraduate medical students, at the All India Institute of Medical Sciences, New Delhi, India, over a period of three years. The institutional guidelines for procurement of human cadavers and their use for medical teaching and research were strictly adhered to. All the cadavers used in the study were donated for teaching and research. Hence, the need for clearance from the Ethics Committee was precluded in this study.

The dissection was carried out according to the Cunningham's manual of dissection volume II.[9] Morphology of theMUF was classified according to Tokar and Yucel,[10] classification. According to this classification, Grade 0 was described as MUF with no visible ligament, Grade1 was designated where MUF was seen as a fibrous cord and Grade 2 MUF was described to present a fibrous cord with a visible mesentery. The fold of mesentery was designated as web by these workers. Presence of MUF grade 0 and 1 was considered relatively safe for laparoscopic exploration, while MUF grade 2 was considered liable to complications.

Any deviation from the normal was noted and photographed. For paraffin embedding and haematoxylin and eosin (H & E) staining, MUF was fixed in 10% formalin. For paraffin embedding tissue was dehydrated in ascending grades of ethanol. Following clearing in cedar-wood oil, paraffin blocks were made keeping in mind the orientation of the tissue. H & E staining was carried out on 7 μm thick sections (Rotary microtome- Shandon AS325). The sections were dewaxed in xylene and subjected to decreasing concentrations of ethanol and hydrated by immersion in distilled water. The sections were stained in haematoxylin stain and counterstained with eosin. Then they were dehydrated by passing through increasing grades of ethanol and cleared in xylene, mounted in DPX and cover slipped.[11] The slides with the stained sections were examined under the light microscope (Nikon E 600 mounted with DS cooled camera) and photographed.

Statistical analysis was done using Stata Corp LP, Texas, USA. Data was presented as numbers and percentages. The classification of the MUF was reported as percentage (%) with 95% confidence interval on each side separately. The presence (%) of relatively safe (grade 0 and 1) MUF presentations between male and female was compared using Fishers exact test. The p value less than 0.05 was considered statistically significant.

3. Results

Table 1 shows the distribution of various grades of MUF observed in the present study. No significant difference was noted in the occurrence of safe presentations of MUF amongst males and females [p=0.709 (Right side), p=1.000 (Left side)]. 69 MUF presented obliterated UA with normal MUF anatomy, falling into the classification by Tokar and Yucel.[10] In one elderly male cadaver, we observed PUA associated with a long mesentery in the right MUF (Figure 1 A). Both the UA and superior vesicle arteries were seen as two separate branches of the anterior division of the internal iliac artery (IIA) (Figure 1 B). The length of the UA from the origin was 37 cm and it crossed the ureter near its origin and the vas deferens after emerging from the deep inguinal ring. The H & E staining of the MUF tissue obtained from this cadaver, confirmed the presence of lumen in the UA by revealing arterial tissue present in between the fibrous tissue of the ligament. The lumen (*) of the artery was lined by endothelial cells (→) (Figure 2 A, B).

4. Discussion

PUA observed in this study (in one of the MUF) could be due to failure of complete obliteration of the UA. The functional obliteration of the UA occurs within few minutes of birth due to factors such as thrombosis in the lumen after ligation of the umbilical cord and reduced oxygen tension through the vessel; however, the anatomical obliteration of

Table 1: Showing the distribution of MUF observed on 35 cadavers according to Tokar & Yucel[10] classification.

	Right Side (n=35)				Left side (n=35)			
	Grade 0	Grade 1	Grade 2	Novel finding	Grade 0	Grade 1	Grade 2	Novel finding
Male (n=23)	3 (4.2%)	12 (17.14%)	7 (10%)	1 (1.42%)	4 (5.71%)	11 (15.71%)	8 (11.42%)	0
Female (n=12)	1 (1.42%)	8 (11.42%)	3 (4.2%)	0	1 (1.42%)	7 (10%)	4 (5.71%)	0
P value		0.709*			1.000*			

*Comparison between relatively safe presentation of MUL between males and females using Fisher's exact test.

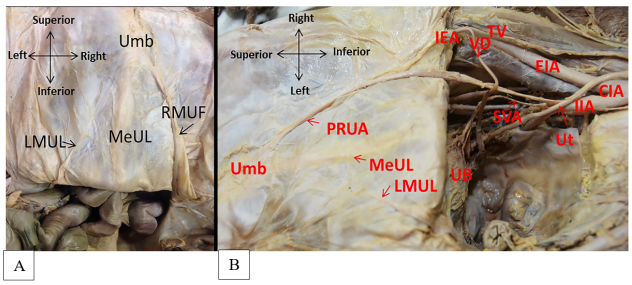

Fig. 1: Posterior aspect of the anterior abdominal wall showing the median (MeUL), left (LMUL) and right medial umbilical fold (RMUF) converging superomedially towards the umbilicus (Umb). Note the mesentery in the RMUF. B Origin of Superior vesicle (SVA) and patent right umbilical artery (PRUA) from the internal iliac artery (IIA) which in turn is seen coming from the common iliac artery (CIA). The ureter (Ut) and vas deferens (VD) are seen in relation to the PRUA. EIA: external iliac artery; IEA: inferior epigastric artery; UB: urinary bladder; TV: testicular vein.

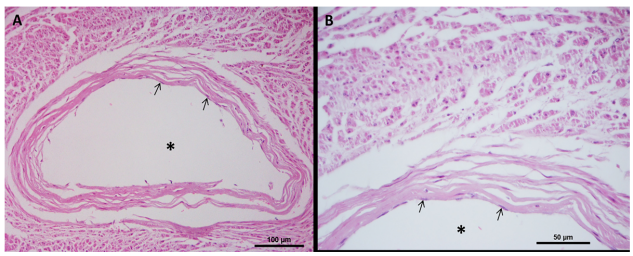

Fig. 2: A & B): Photomicrograph of the H & E stained section of the right medial umbilical fold showing the umbilical artery with clear lumen (*) and lined by endothelium (→) embedded in the fibrous tissue

the lumen takes 2-3 months due to fibrous proliferation. The closure of these arteries is accomplished by contraction of the smooth musculature in their walls, which is postulated to occur due to thermal and mechanical stimuli and change in oxygen tension.[16] The UA is structurally different from other arteries of the same calibre, as it has very few elastic fibres in its wall. The wall has only circularly oriented smooth muscles as the outer layer (tunica adventitia) while the inner layer (tunica intima) is rich in ground substance. After birth, when the circular smooth muscles contract, due to scarce elastic fibres, the wall tension overcomes the transmural pressure, resulting in irreversible closure of the vessel lumen.[17]

During fetal life, UAs are direct caudal continuation of the primitive dorsal aortae. After fusion of the dorsal aortae, they arise from its ventrolateral aspects and pass lateral to the allantois in the connecting stalk. Later the proximal part of each UA is joined by a new vessel which leaves the aorta at its termination and passes lateral to the allantois. This, is regarded as the fifth lumbar intersegmental artery, and constitutes the dorsal root of the UA. The dorsal root gives off the axial artery of the lower limb, branches to the pelvic viscera and more proximally gives the external iliac artery. The ventral root disappears entirely, such that the UA now arises from the IIA. During fetal life, the UAs carry deoxygenated blood to the placenta for oxygenation. After birth, the distal part of the UA usually obliterates and is seen in the MUF while the proximal part remains patent as the IIA, the superior vesicle artery (which supplies the superior surface of the urinary bladder)[1] or in few cases gives contribution to the uterine artery.[18,19] Depending on the extensive process of formation and regression of blood vessels, various branching patterns of the IIA have been described.[20,21] In the adults, UA is usually seen arising from the anterior division of the IIA. UAs of both the sides ascend along the side of the urinary bladder [where they are related to the ureter & vas deferens (in the male)] and run superomedially on the posterior aspect of the anterior abdominal wall to converge at the umbilicus and enter the umbilical cord to reach the placenta in the fetus.[1]

Hydronephrosis is the dilation of renal pelvis and calyces, due to obstruction in the flow of urine. It can be unilateral or bilateral. Depending on the site of obstruction of the ureter, it can be upper or lower ureteric obstruction. Various causes of ureteric constriction have been described in the literature such as calculi, pelvi-uretric junction obstruction, obstructing ureteric clot, obstructing ureteric transitional cell carcinoma or extra ureteric compression by blood vessels, tumours, granulomas, lymph nodes etc.[22] Timely diagnoses of this condition is extremely crucial as prolonged cases of hydronephrosis may present with irreversible renal damage due to tubular atrophy and interstitial fibrosis.[23] On review of literature, we came

Table 2: Showing the review of literature, highlighting the role of umbilical artery in ureteric compression

Investigators	Subject of study	Number of case (s)	Age group/ sex	Symptoms	Procedure carried out	Results after procedure	Histology (if done)
Young & Kiser [12]	Patients	Case report (5)	1-36 years/ males	Hydroureteronephrosis; hydroureter; some dilation of pelvices & calyces	UA resection with or without resection & reimplantation of ureter in the bladder	Obstruction of ureter at pelviureteric junction by umbilical artery (UA)	No
Read et al. [13]	Patients	Case report (6)	6 months -6 years 5 boys ; 1 girl	Hematuria in 4 cases; Left ureter obstruction in 4 cases Right ureter obstructed in 1 case Both ureters obstructed in 1 case	In 3 cases only division of obstructing vessel In 4 cases ureteroneocystostomy was also done	In 4 cases obstruction was by aberrant umbilical arteries. In 3 cases obstruction was by vesical arteries	No
Mackie et al. [14]	Patient	Case report (1)	2 years/ male	Persistent drainage at umbilicus	Surgical removal of the fibrous tract	No umbilical discharge	Fibrous cord with lumen
Quattlebaum & Anderson [4]	Patient	Case report (1)	79 years/ male	Left flank pain	Partial ureterectomy & ureteroureterostomy	Ureteral compression by patent UA	No
Kurimoto et al. [6]	Patient	Case report (1)	14 years/ male	Intermittent flank pain with right hydronephrosis	Excision of the cord as well as the dilated part of ureter, followed by end to end anastomosis	Ureteral compression by remnant of UA	Excised cord was of arterial origin
Grifoni et al. [5]	Patient	Case report (1)	37 years/ male	Left flank pain and hydronephrosis due to extrinsic obstruction of left ureter	Partial left terminal ureterectomy with ureteroneocystostomy	Ureteral compression by residue of UA	No
Gupta et al. [15]	Patient	Case report (1)	32 years/ female	Primary infertility & recurrent left flank pain	Ligation of UA along with partial ureterectomy & reimplantation of ureter into the bladder	Ureteral compression by persistent UA	No
Tokar & Yucel [10]	During laparoscopy	126	28 days – 17 years	-	-	Proposed classification of MUF into grade 0, 1, 2	No
	Cadaveric dissection	1	NA				

across a few interesting clinical cases, which reported persistence of UA as the basis of hydronephrosis and flank pain. A comprehensive review of literature has been shown in Table 2.[12–15] Anatomical basis of these symptoms has been explained by the course followed by the UA and its relation with the ureter. The aberrant UA on its way to the anterior abdominal wall crosses the ureter, which turns medially to terminate in the urinary bladder. Since, UA also crosses the vas deferens (carrying spermatozoa in the males), as it turns medially to form the ejaculatory duct on the posterior wall of the urinary bladder, the possibility of persistent UA compressing vas deferens and presenting as male infertility cannot be ruled out. Hence, prior acquaintance of such variants of MUF may assist the surgeons in planning surgical procedures; urologists and gynaecologists in resolving unexplained flank pain, hydronephrosis and infertility.

Tokar and Yucel[10] in their extensive study on variation of MUF in paediatric age groups highlighted the importance of the knowledge of these variations in laparoscopic exploration especially in children with small abdominal cavities. A preliminary grading scale based on the anatomical appearance of MUF during laparoscopy was proposed by these authors following their investigations in 126 patients of paediatric ages (28 days to 17 years), in which they classified the MUF into three types. Grade 0 was described as MUF with no visible ligament and was noted in 11% cases, when MUF was seen as a fibrous cord it was described as grade 1 and was noted in 50% cases while 39% cases presented a fibrous cord with small mesentery in MUF which was denoted as grade 2. These investigators have highlighted that MUF with fibrous cord and a mesentery (grade 2) may cause technical difficulties and narrow working space during laparoscopic exploration. Hence, presence of MUL grade 0 and 1 was considered safe for laparoscopic exploration as compared to grade 2. The results of the present work followed the pattern observed by these investigators; however, one of the right sided MUF of an elderly male cadaver did not correspond to the grading proposed by these investigators. This could be associated with the difference in the age of the study group (paediatric versus adult). MUF observed was associated with a long mesentery and exhibited a patent UA with distinct lumen. This novel presentation of MUF could lead to technical difficulties during laparoscopic exploration and hence, the operating surgeons should be aware of variations in the bilateral ligamentous anatomy of the anterior abdominal wall. The findings of the present study also highlight the fact that left and right anterior abdominal wall ligamentous anatomy are not necessarily mirror images. Asymmetry in anatomy of MUF was also observed by Tokar and Yucel[10] in one case which they associated with urogenital abnormality; however, we did not observe any such anomaly in the cadaver. Our study has few limitations such as limited sample size and lack of data, whether the artery was pulsatile and/or was the deceased suffering from hydronephrosis or flank pain when alive. Despite these limitations, we believe that the knowledge of the variant patterns of the MUF is of interest to surgeons and interventional radiologists to improve the quality and safety during various surgical procedures in the abdominal region with an anterior approach.

5. Conclusion

The results from the present study suggest that MUF does not present a uniform morphology. It may not be visible as a separate structure on the inner aspect of the abdominal wall or it may just be a fibrous cord or a fibrous cord with small mesentery or a cord with patent umbilical artery along with a long mesentery. Out of all the presentations the latter two are the perilous grades as they may cause technical exertions to the operating surgeon by decreasing the work space and obscuring the view of lateral pelvic wall during surgeries. Knowledge of this variation by a paediatric surgeon may prevent unnecessary complication haemorrhage while using MUF as a reinforcing flap to cover the internal ring during laparoscopic herniorrhaphy in children with indirect inguinal hernia.[24] Furthermore, persistent UAs may compress the ureter and vas deferens resulting in myriad of symptoms ranging from unexplainable flank pain, hydronephrosis to male infertility. Awareness of such variants is of relevance to urologists in determining the cause of these unexplained symptoms and to surgeons in determining the site of safe trocar insertion.

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None.

7. Conflict of Interest

None.

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