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Morphometric Analysis of the Ureter with Respect to Lateral Lumbar Interbody Fusion Using Contrast-Enhanced Computed Tomography

Chunneng Huang, Zhenyu Bian, Liulong Zhu

Department of Orthopedics, Affiliated Hangzhou First People's Hospital, Zhejiang University School of Medicine, Hangzhou, China

Objective : To analyze the anatomical location of the ureter in relation to lateral lumbar interbody fusion and evaluate the potential risk of ureteral injury.

Methods : One hundred eight patients who performed contrast-enhanced computed tomographic scans were enrolled in this study. The location of the ureter from L2-L3 to L4-L5 was evaluated. The distances between the ureter and psoas muscle, intervertebral disc, and retroperitoneal vessels were also recorded bilaterally.

Results : Over 30% of the ureters were close to the working corridor of extreme lumbar interbody fusion at L2-L3. Most of the ureters were close to working corridor of oblique lumbar interbody fusion, especially at L4-L5. The distance from the ureter to the great vessels on the left side was significantly narrowing from L2-L3 to L4-L5 (28.8±9.5 mm, 22.0±8.0 mm, 15.5±8.4 mm), and it was significantly larger than that on the right side (12.3±6.1 mm, 7.4±5.7 mm, 5.4±4.4 mm).

Conclusion : Our findings indicate that the location of the ureter varies widely among individuals. To avoid unexpected damage to the ureter, it is imperative to directly visualize it and verify the ureter is not in the surgical pathway during lateral lumbar interbody fusion.

Key Words : Lateral lumbar interbody fusion · Extreme lumbar interbody fusion · Oblique lumbar interbody fusion · Ureteral injury · Complication.

INTRODUCTION

Lateral lumbar interbody fusion (LLIF), including oblique lumbar interbody fusion (OLIF) and extreme lumbar interbody fusion (XLIF), has gained its popularity for the advantages of smaller incisions, less blood loss and faster recovery comparing to traditional posterior approach[6,13]. This technique utilizes the retroperitoneal space between great vessels and lumbar plexus as a surgical corridor to access the intervertebral disc. Therefore, it has a potential risk of causing direct injury to surrounding structures such as lumbar plexus, aorta, segmental arteries as well as sympathetic trunk as previously reported[4,5,10].

Recently, several studies have described the ureteral injury

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• Address for correspondence : **Liulong Zhu**
Department of Orthopedics, Affiliated Hangzhou First People's Hospital, Zhejiang University School of Medicine, Huansha Road 261#, Hangzhou, Zhejiang Province 310000, China
Tel : +86-18768115463, Fax : +86-18768115463, E-mail : zhuliulong2566@126.com, ORCID : https://orcid.org/0000-0002-1750-0314

due to lateral fusion techniques[7,8,14]. Ureteral injury is a devastating complication that can lead to postoperative abdominal pain, hematuria, or even renal atrophy. The ureter runs laterally to the vertebral body and psoas major. Hence, it can theoretically be injured at any time during procedure, including retraction and psoas muscle mobilization[1]. Therefore, it is necessary to become familiar with the course of the ureter and relationships between the ureter and adjacent structures to avoid this adverse event.

In this study, contrast-enhanced computed tomographic scan was used to visualize and identify the ureter. We aimed to analyze the anatomical location of the ureter in relation to LLIF and evaluate the potential risk during this approach.

MATERIALS AND METHODS

Subjects and materials

After acquiring the approval from the Institutional Review Board (IRB) of Hangzhou First People's Hospital (IRB No. HZSY202101102001), we retrospectively reviewed imaging data from patients who had undergone contrast-enhanced computed tomography (CT) between January 2020 and October 2021 in our hospital. Patients who had hydronephrosis, ureteral dilatation, insufficient ureteral enhancement, spinal deformity and history of abdominal, spinal or ureteral surgery were excluded. Finally, a total of 108 patients were included, consisting of 60 males (average age, 54.7±15.9 years) and 48 females (average age, 54.5±11.2 years). All images were performed on 64 multi-detector rows CT scanners (GE Medical Systems, Milwaukee, WI, USA). All patients were administered 400–500 mL of water orally 20 minutes before the examination. Unenhanced CT scans of the abdomen and pelvis were performed. Excretory phase images of the abdomen and pelvis were obtained 8 minutes after the injection of contrast material (Omnipaque; Daiichi Pharmacy, Tokyo, Japan). The scanning parameters were 240 mA tube current, 120 kV tube voltage, 1.25-mm collimation and 1.5 mm slice intervals.

Radiographic evaluation

All axial excretory phase images were analyzed by the measurement tools in Synapse PACS software (Fujifilm Medical Systems, Milwaukee, WI, USA). The ureters were identified bilaterally at L2-L3, L3-L4 and L4-L5 intervertebral disc levels. The anatomical location of the ureter was classified using the psoas muscle and intervertebral disc as reference structures. The intervertebral disc area was divided into four zones (Fig. 1A). The area between the anterior and middle line of the intervertebral disc was divided equally into two zones II-v, III-v. The area anterior to the anterior edge and the area posterior to the middle line of the intervertebral disc were defined as zone I-v and zone IV-v, respectively. In addition, the psoas area was also divided into four zones (Fig. 1B). The area between the lateral edge of the intervertebral disc and lateral edge of the psoas was divided equally into two zones II-p, III-p. The areas on the two sides of this zone are defined as I-p and IV-p, respectively.

The distances between the ureter and psoas muscle (UPD),

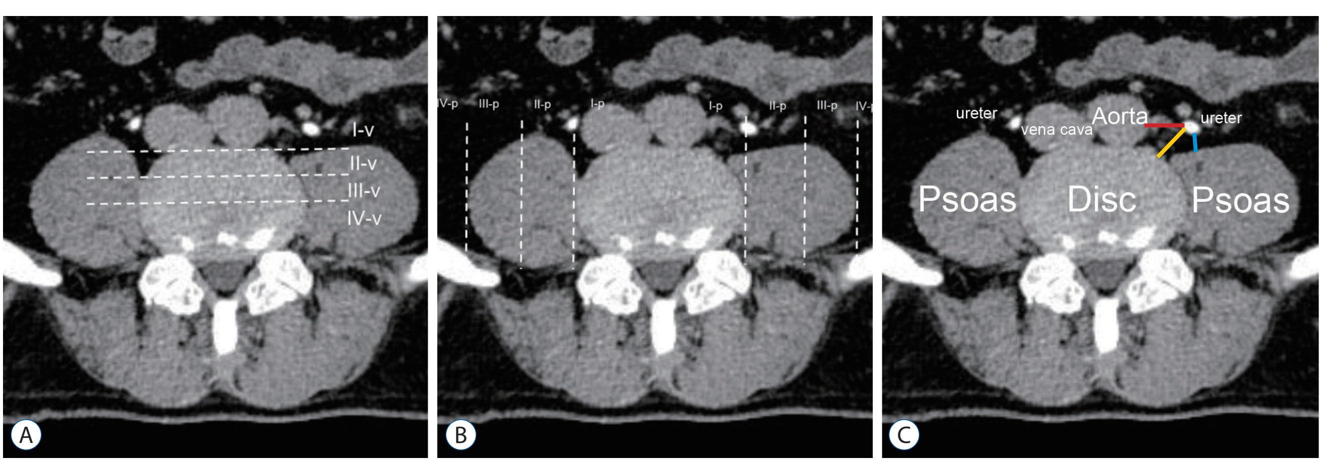

Fig. 1. Evaluation of anatomical location of the ureter from contrast-enhanced computed tomography images. A : The axial plane of intervertebral discs was divided into four zones. B : The psoas area was also divided into four zones. C : Measurements of relevant parameters, ureter-vessel distance (UVD), ureter-psoas distance (UPD), and ureter-disc distance (UDD), at L2-L3, L3-L4, and L4-L5. Red line : UVD; blue line : UPD; yellow line : UDD.

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ureter and intervertebral disc (UDD), as well as ureter and the aorta or common iliac vessels (UVD) were also recorded (Fig. 1C). Psoas dimensions in both the antero-posterior and latero-lateral measured directions were also measured at each level bilaterally.

Statistical analyses

Continuous variables were presented as mean±standard deviation (SD). Independent-samples t-test, one-way analysis of variance following Bonferroni's *post-hoc* test and linear regression with Pearson's correlation coefficient were performed using SPSS version 22 (IBM, Armonk, NY, USA). $p<0.05$ was considered statistically significant.

RESULTS

Location of the ureter according to zone classification systems

According to classification of the intervertebral disc zone, the position of the ureter was variable at L2/3. On the left side, the ureter located in zone I-v 19 subjects (17.6%), zone II-v 38 subjects (35.8%), zone III-v 34 subjects (31.5%), and zone IV-v seven subjects (6.5%) at L2/3. Besides, 10 ureters (9.3%) could not be detected at this level, indicating the ureteropelvic junction was lower. The ureter went anteriorly as it migrated down to the bladder. Most of the ureters located in zone I-v (72 subjects, 66.7%) and zone II-v (33 subjects, 30.6%) at L4/5. Similar results were also found on the right side (Fig. 2A and B).

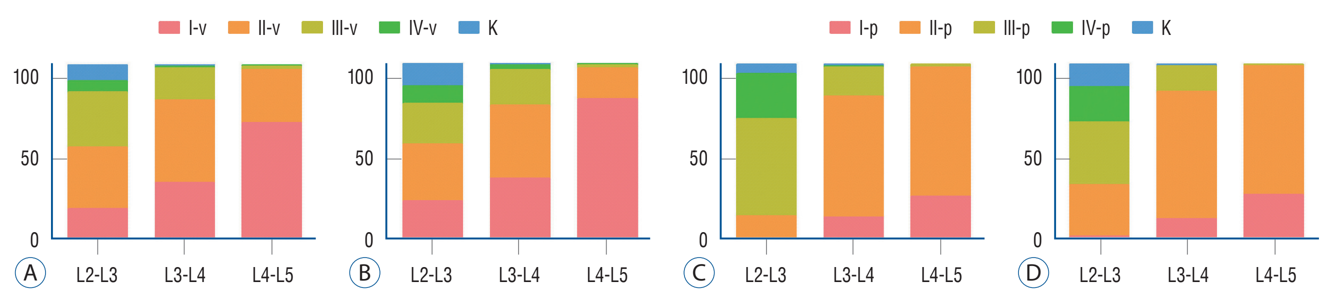

Fig. 2. Location of the ureter in the disc and psoas area. A : Location of the ureter on the left side according to the disc area classification. B : Location of the ureter on the right side according to the disc area classification. C : Location of the ureter on the left side according to the psoas area classification. D : Location of the ureter on the right side according to the psoas area classification. K : within kidney.

Table 1. Measurements of the anatomic parameters of the ureter and surrounding structures at each level

	Male (n=60)		Female (n=48)		Overall		*p*-value*
	Right	Left	Right	Left	Right	Left	
UVD							
L2-L3 (mm)	12.3±6.8	30.9±10.0	12.3±5.3	26.4±8.3	12.3±6.1	28.8±9.5	<0.01
L3-L4 (mm)	8.4±6.9	22.8±8.9	6.2±3.5	20.9±6.8	7.4±5.7	22.0±8.0	<0.01
L4-L5 (mm)	6.4±4.3	17.7±9.1	4.2±4.2	12.9±6.7	5.4±4.4	15.5±8.4	<0.01
UPD							
L2-L3 (mm)	9.8±6.5	10.7±9.1	5.4±4.3	5.4±5.1	7.7±5.9	8.2±8.0	0.593
L3-L4 (mm)	4.5±6.1	2.8±4.6	2.8±3.4	1.5±2.4	3.7±5.1	2.2±3.8	0.015
L4-L5 (mm)	3.9±3.9	1.3±3.8	6.3±4.2	2.0±3.6	5.0±4.2	1.6±3.7	<0.01
UDD							
L2-L3 (mm)	19.8±7.7	22.0±8.2	13.7±5.4	14.3±5.8	16.9±7.3	18.5±8.1	0.160
L3-L4 (mm)	15.6±6.2	14.3±7.0	10.8±3.8	9.4±4.6	13.5±5.8	12.1±6.5	0.108
L4-L5 (mm)	17.5±5.7	14.7±5.9	13.8±3.6	10.7±5.0	15.8±5.2	13.0±5.8	<0.01

*Comparison of overall parameters between left side and right side. UVD : ureter-vessel distance, UPD : ureter-psoas distance, UDD : ureter-disc distance

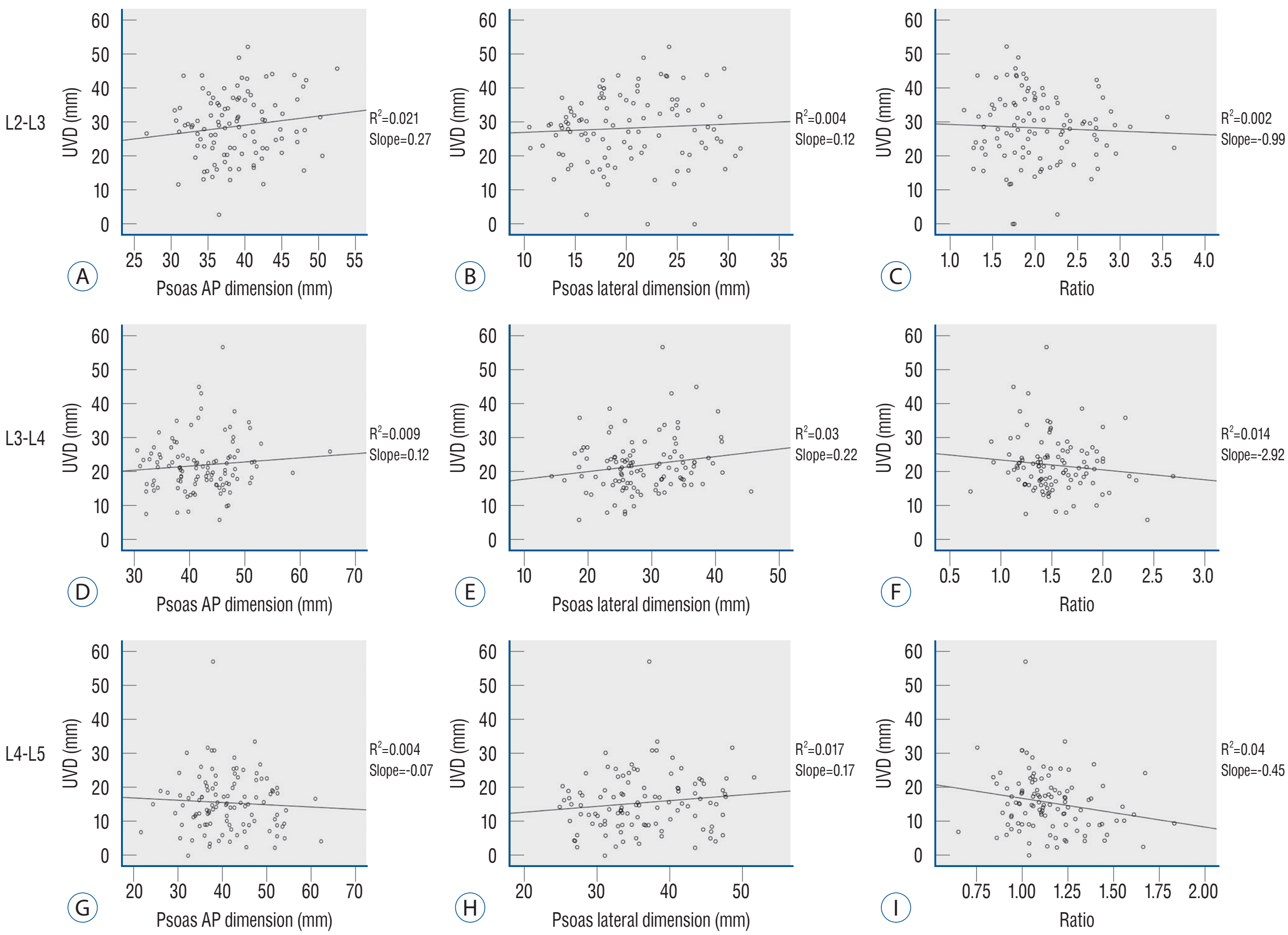

Fig. 3. The correlation between UVD and psoas dimensions on the left side. Disc levels of L2-L3 (A-C), L3-L4 (D-F), L4-5 (G-I). The lines were based on the linear regression with Pearson's correlation coefficient. UVD : ureter-vessel distance, AP : antero-posterior, ratio : psoas AP dimension : lateral dimension.

According to classification of the psoas zone, the position of the ureter was more lateral at L2/3. On the sides, the ureter located in zone I-p 0 subjects (0.0%), zone II-p 14 subjects (13.0%), zone III-p 60 subjects (55.6%), and zone IV-p 28 subjects (25.9%) at L2/3. As the ureter traveled, the ureter was positioned closer to the medial side. At L4/5, most of the ureters located in zone I-v (26 subjects, 24.1%) and zone II-v (80 subjects, 74.1%). Similar results were also found on the right side (Fig. 2C and D).

Relationship of the ureter to surrounding structures

The mean distance between the ureter-vessel distance (UVD) of the right side was 12.3±6.1 mm at L2-L3, 7.4±5.7 mm at L3-L4 and 5.4±4.4 mm at L4-L5, whereas on the left side, it was 28.8±9.5 mm at L3-L4, 22.0±8.0 mm at L3-L4 and 15.5±8.4 mm at L4-L5. Significant differences could be found between left side and right side at all levels (p<0.01). The mean distance between the ureter-psoas distance (UPD) on the right side was 7.7±5.9 mm at L2-L3, 3.7±5.1 mm at L3-L4 and 5.0±4.2 mm at L4-L5. On the left side, it was 8.2±8.0 mm at L2-L3, 2.2±3.8 mm at L3-L4 and 1.6±3.7 mm at L4-L5. UPD on the right and left sides were significantly different at both L3-L4 and L4-L5 levels. The mean distance between the UDD of the right side was 16.9±7.3 mm at L2-L3, 13.5±5.8 mm at L3-L4 and 15.8±5.2 mm at L4-L5. On the left side, it was 18.5±8.1 mm at L2-L3, 12.1±6.5 mm at L3-L4 and 13.0±5.8 mm at L4-L5 (Table 1).

Additionally, the relationship between UVD and psoas dimensions had been analyzed (Figs. 3 and 4). Unfortunately, we found correlations between UVD and psoas dimensions were weak on both sides from L2-L5.

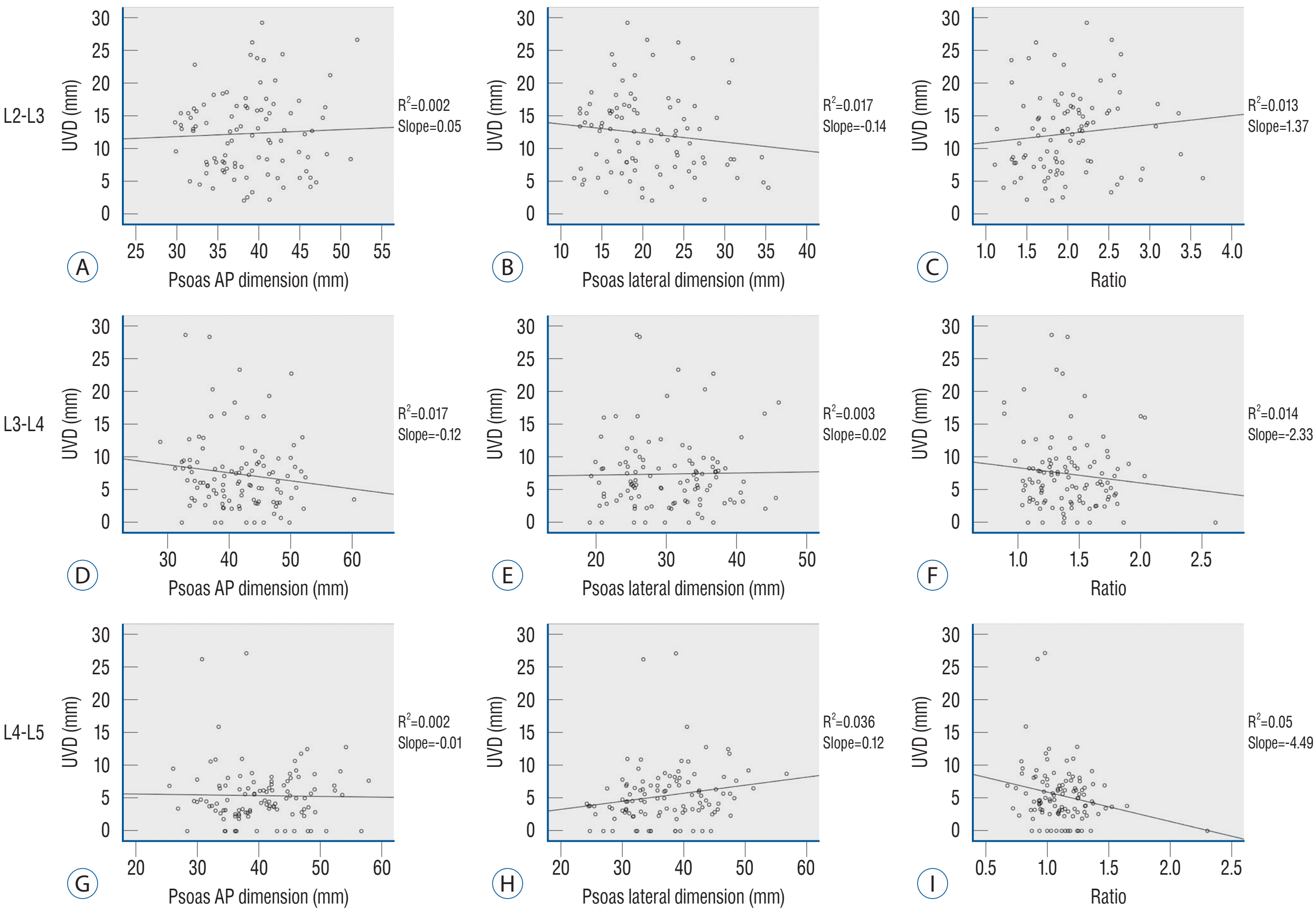

Fig. 4. The correlation between UVD and psoas dimensions on the right side. Disc levels of L2-L3 (A-C), L3-L4 (D-F), L4-5 (G-I). The lines were based on the linear regression with Pearson's correlation coefficient. UVD : ureter-vessel distance; AP : antero-posterior; ratio : psoas AP dimension : lateral dimension.

DISCUSSION

The LLIF surgical pathway is via the retroperitoneal space between the great vessels and the lumbar plexus, which is considered to be a safer surgical window to reach the intervertebral disc than posterior approach. Nevertheless, despite its theoretical benefits for minimally invasive spine surgery, this procedure is not without potential risk. The main challenge for LLIF is to access the disc without causing injury to adjacent structures around the surgical corridor. Of them, ureteral injury is rare, but the hazards of this complication can be underestimated. Anand and Baron[1] reported three cases of urological complications secondary to lateral lumbar spine surgery, including one of renal injury and two of ureteral injury. The renal injury led to brisk venous bleeding and blood pressure drop after the removal of the retractor, while hematuria and abdominal pain caused by ureteral injury were relieved after ureter stent placement. In addition, the detection of ureteral injury may be delayed because of nonspecific symptoms and inadvertent injury to it. Yoon et al.[14] reported a case of delayed ureteral stricture and ipsilateral kidney atrophy. The length of time until diagnosis can be as long as 3 months after surgery.

Key to preventing this complication is an understanding of ureteral anatomic relationships. In this study, we examined the location of the ureter by using contrast-enhanced CT scans in 108 healthy participants. Our results revealed that the ureter ran anteriorly and medially as it went down to the bladder. With reference to the intervertebral disc, over 30% of the ureters were located in III-v and IV-v at L2-L3 level. Therefore, the ureter may be in close proximity to the working corridor of XLIF with its direct lateral approach. At L3-L4 and

L4-L5 level, the majority of the ureters were located in I-v and II-v. This indicated that during the OLIF procedure, the ureter is likely to be close to the working corridor. With reference to the psoas, most of the ureters were located in III-p and IV-p at L2-L3 level, and the ureter is far from the working corridor of the OLIF, theoretically. But at L4-L5, over 90% of the ureters were located in I-p and II-p, which indicated the locations of ureter were close to surgical corridor of OLIF at L4-L5 disc level.

We also analyzed the location of the ureter in relation to retroperitoneal great vessels. The measurements showed that UVD was significantly larger at L2-L3 (12.3 mm on the right, 28.8 mm on the left) than that at L4-L5 (5.4 mm on the right, 15.5 mm on the left). Because the surgical corridor is narrowed at L4-L5[15], there is an increasing need of using retraction to keep adjacent structures out of the working space, which will pose great risk to the ureters. Furthermore, we investigated the potential relationship between UVD and psoas dimensions, as ureter was intimate with it. However, we found correlations between UVD and psoas dimensions were weak on both sides from L2-L5 with a low coefficient of determination (R^2<0.10). This indicated that the location of the ureter was variable because the ureter is covered by a fat tissue envelope and lacks fascial tissue to restrict its movement. Previous studies suggested that the ureteral injury might occur because of the limited exposure of the retroperitoneal space and blind maneuvering[2,7]. Therefore, to avoid unexpected damage to the ureter, it is imperative to directly visualize it and verify the ureter is not in the surgical pathway during LLIF.

There were a few limitations to the present study. First, the contrast-enhanced CT was performed on the supine position, while the lateral approach used the lateral decubitus position, which may affect the correlation of the ureter to vessels and psoas muscle[3,11,16]. The study presented by Ouchida et al.[11] demonstrated that the ureter would move anteriorly in the lateral decubitus position. Another limitation of this study was that the patients were all healthy participants. Spinal deformity, especially the vertebral rotation, will cause a relative change in the position of nerves and vessels[9,12]. Similar changes may also be seen in the ureter.

CONCLUSION

Knowledge of the ureters in relation to the lateral spine as they descend into the pelvis is important for spine surgeons. Our findings indicate that the location of the ureter varies widely among individuals. To avoid unexpected damage to the ureter, it is imperative to directly visualize it and verify the ureter is not in the surgical pathway during LLIF.

AUTHORS' DECLARATION

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Informed consent

This type of study does not require informed consent.

Author contributions

Conceptualization : CH, LZ; Data curation : CH; Formal analysis : ZB; Funding acquisition : CH; Methodology : CH, LZ; Project administration : CH; Visualization : ZB; Writing - original draft : CH; Writing - review & editing : LZ

Data sharing

None

Preprint

None

ORCID

Chunneng Huang	https://orcid.org/0000-0003-2433-8068
Zhenyu Bian	https://orcid.org/0000-0003-1338-9636
Liulong Zhu	https://orcid.org/0000-0002-1750-0314

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References

1. Anand N, Baron EM : Urological injury as a complication of the transpsoas approach for discectomy and interbody fusion. **J Neurosurg Spine 18 :** 18-23, 2013
2. Bjurlin MA, Rousseau LA, Vidal PP, Hollowell CM : Iatrogenic ureteral injury secondary to a thoracolumbar lateral revision instrumentation and fusion. **Spine J 9 :** e13-e15, 2009
3. Deukmedjian AR, Le TV, Dakwar E, Martinez CR, Uribe JS : Movement of abdominal structures on magnetic resonance imaging during positioning changes related to lateral lumbar spine surgery: a morphometric study: clinical article. **J Neurosurg Spine 16 :** 615-623, 2012
4. Fujibayashi S, Kawakami N, Asazuma T, Ito M, Mizutani J, Nagashima H, et al. : Complications associated with lateral interbody fusion: nationwide survey of 2998 cases during the first 2 years of its use in Japan. **Spine (Phila Pa 1976) 42 :** 1478-1484, 2017
5. Hijji FY, Narain AS, Bohl DD, Ahn J, Long WW, DiBattista JV, et al. : Lateral lumbar interbody fusion: a systematic review of complication rates. **Spine J 17 :** 1412-1419, 2017
6. Krieg SM, Bobinski L, Albers L, Meyer B : Lateral lumbar interbody fusion without intraoperative neuromonitoring: a single-center consecutive series of 157 surgeries. **J Neurosurg Spine 30 :** 1-7, 2019
7. Kubota G, Orita S, Umimura T, Takahashi K, Ohtori S : Insidious intraoperative ureteral injury as a complication in oblique lumbar interbody fusion surgery: a case report. **BMC Res Notes 10 :** 193, 2017
8. Lee HJ, Kim JS, Ryu KS, Park CK : Ureter injury as a complication of oblique lumbar interbody fusion. **World Neurosurg 102 :** e7-e14, 2017
9. Makanji HS, Le H, Wood KB, Jenis LG, Cha TD : Morphometric analysis of the retroperitoneal vessels with respect to lateral access surgery in adult scoliosis. **Clin Spine Surg 30 :** E1010-E1014, 2017
10. Mehren C, Mayer HM, Zandanell C, Siepe CJ, Korge A : The oblique anterolateral approach to the lumbar spine provides access to the lumbar spine with few early complications. **Clin Orthop Relat Res 474 :** 2020-2027, 2016
11. Ouchida J, Kanemura T, Satake K, Nakashima H, Segi N : Anatomic evaluation of retroperitoneal organs for lateral approach surgery: a prospective imaging study using computed tomography in the lateral decubitus position. **Eur Spine J 28 :** 835-841, 2019
12. Regev GJ, Chen L, Dhawan M, Lee YP, Garfin SR, Kim CW : Morphometric analysis of the ventral nerve roots and retroperitoneal vessels with respect to the minimally invasive lateral approach in normal and deformed spines. **Spine (Phila Pa 1976) 34 :** 1330-1335, 2009
13. Xu DS, Walker CT, Godzik J, Turner JD, Smith W, Uribe JS : Minimally invasive anterior, lateral, and oblique lumbar interbody fusion: a literature review. **Ann Transl Med 6 :** 104, 2018
14. Yoon SG, Kim MS, Kwon SC, Lyo IU, Sim HB : Delayed ureter stricture and kidney atrophy after oblique lumbar interbody fusion. **World Neurosurg 134 :** 137-140, 2020
15. Yusof MI, Nadarajan E, Abdullah MS : The morphometric study of l3-L4 and L4-L5 lumbar spine in Asian population using magnetic resonance imaging: feasibility analysis for transpsoas lumbar interbody fusion. **Spine (Phila Pa 1976) 39 :** E811-E816, 2014
16. Zhang F, Xu H, Yin B, Tao H, Yang S, Sun C, et al. : Does right lateral decubitus position change retroperitoneal oblique corridor? A radiographic evaluation from L1 to L5. **Eur Spine J 26 :** 646-650, 2017