



# Anatomic evaluation of retroperitoneal organs for lateral approach surgery: a prospective imaging study using computed tomography in the lateral decubitus position

Jun Ouchida<sup>1</sup> · Tokumi Kanemura<sup>1</sup> · Kotaro Satake<sup>1</sup> · Hiroaki Nakashima<sup>1</sup> · Naoki Segi<sup>1</sup>

Received: 7 May 2018 / Accepted: 20 October 2018 / Published online: 30 October 2018  
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

## Abstract

**Purpose** The aim of this study is to investigate retroperitoneal organ distribution with the retroperitoneal approach in the lateral decubitus position.

**Methods** We enrolled 100 patients scheduled for lateral approach surgery, including LIF and lateral corpectomy. We performed computed tomography with lateral decubitus positioning (L-CT) to assess the position of the organs, including abdominal aorta, kidney, descending colon, ureter, and gonadal artery. Anteroposterior organ positions were divided into four zones: A, anterior to the anterior margin of the vertebral body; AL, anterior margin to the middle line of the vertebral body; PL, middle line to the posterior margin of the vertebral body; and P, posterior to the posterior margin of the vertebral body. We defined zone PL–P as the “approach zone.” Measurements obtained using L-CT were compared with those obtained in the conventional supine position (S-CT).

**Results** Retroperitoneal organs in the approach zone significantly decreased in lateral positioning. Eighty-three percent of kidney and 20% of descending colon remain in the approach zone in L-CT. Sixty-six percent of disk levels recorded for the descending colon in zone P in S-CT remained in the approach zone even in L-CT.

**Conclusions** We observed anterior migration in L-CT in all retroperitoneal organs. However, a considerable percentage of kidney and that of descending colon remain obstructed while performing LIF. We discuss that the preoperative imaging evaluation is beneficial, and gentle and meticulous surgical detachment is essential for safe and reliable lateral approach surgery, especially in the case that the descending colon extends outside zone P in S-CT.

**Graphical abstract** These slides can be retrieved under electronic supplementary material.

**Key points**

1. Lateral access surgery
2. Spinal fusion
3. Complication

		Lateral-CT			
zone		A	AL	PL	P
Supine-CT	A	96	4	0	0
	AL	96	0	4	0
	PL	60	27	13	0
	P	13	21	56	10

(%)

Safe zone	Approach zone

**Take Home Messages**

1. 83 % of kidney and 20 % of descending colon remain obstructed while performing LIF in lateral decubitus position.
2. Sixty-six percent of disk levels recorded for the descending colon in posterior margin of the vertebral body in CT in supine position remained in the LIF approach zone.
3. Gentle and meticulous surgical detachment is essential for safe and reliable lateral approach surgery especially in the case that the descending colon extends posterior to the posterior margin of the vertebral body in CT in supine position.

**Keywords** Lumbar spine 1 · Fusion 2 · Complication 3 · Lateral access surgery 4 · Visceral injury

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s00586-018-5803-x>) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

## Introduction

Lateral interbody fusion (LIF) is an established lateral approach surgical procedure for spinal fusion used to treat patients with instability, deformity, or lumbar canal stenosis [1–10]. It offers advantages including minimal invasion and lesser blood loss during surgery, greater surface for fusion, and higher preparation of the end plate for indirect decompression [2, 3, 5, 7, 9]. However, use of the retroperitoneal approach may result in critical intraoperative complications such as injury to the nerves, colon, ureter, great vessels, or other retroperitoneal organs [4–6, 8, 9, 11–18]. To prevent nerve injury, directional electromyography neuromonitoring devices have been used, and they are found to be clinically effective. Surgeons attempt to prevent organ injury by performing visual checks and palpating with fingers and protect the organs from surgical instruments and disk manipulation using retractors. Vascular and visceral injuries represent severe, life-threatening surgical complications and are sometimes difficult to diagnose intraoperatively [12, 15, 18].

Retroperitoneal organs show considerable anatomical variation [12, 19–24]. Therefore, evaluation of the position or malformation using preoperative computed tomography (CT) scans is useful to estimate intraoperative complications [20]. Although the surgical procedure is performed in the lateral decubitus position, few reports have conducted anatomical measurements of retroperitoneal organs in this position. This study aimed to investigate the distribution of retroperitoneal organs with the retroperitoneal approach in the lateral decubitus position.

## Materials and methods

### Subjects

A total of 100 consecutive patients scheduled to undergo lateral approach surgery, including LIF and lateral vertebral corpectomy, were enrolled from January 2015 to November 2016 at a single institution. We excluded patients who were unable to maintain a lateral decubitus position during the examination, had undergone surgeries affecting the retroperitoneal space (such as colorectal surgery and urologic surgery), or had degenerative scoliosis (Cobb's angle  $> 30^\circ$ ). Patients under the age of 55 were also excluded from this series due to concern over gonadal exposures. The following concomitant diagnoses were present: lumbar canal stenosis ( $n = 49$ ), spondylolisthesis ( $n = 38$ ), osteoporotic late collapse ( $n = 9$ ), and burst fracture of the vertebral body ( $n = 4$ ).

We performed a contrast-enhanced CT with supine positioning (S-CT) to detect vascular malformations and anatomical features of the major and minor vessels, ureter, and other organs for this surgical approach. A plane CT with left side up lateral decubitus positioning (L-CT) was also performed to assess the position of retroperitoneal organs with the retroperitoneal approach. CT settings were optimized to reduce the effective dose of radiation during the examination. These measurements, which were obtained using L-CT, were compared with those obtained using conventional S-CT (Fig. 1). The study was approved by our hospital's Institutional Review Board, and each participant signed a written consent form after admission.

### Methods for CT scan in lateral decubitus position

In L-CT, patients were placed in a position with  $30^\circ$  hip flexion and  $30^\circ$  knee flexion to ensure the posture could be easily maintained on the CT table. A pillow was placed

**Fig. 1** Anterior migration of retroperitoneal organs in computed tomography (CT) with lateral decubitus positioning (72-year-old female with lumbar canal stenosis). **a** CT in conventional supine position; **b** CT in lateral decubitus position. AA, abdominal aorta; DC, descending colon (posterior edge); U, ureter; and GA, gonadal artery. **b** Kidney position was obtained at the maximum anteroposterior diameter. K, kidney (posterior edge)



to support the patient's head, and they were instructed to place their forearm under their head to prevent artifacts. A 64-line multi-slice CT (Light Speed VCT; GE Healthcare Bio-Sciences, Piscataway, NJ, USA) was used for the CT examination in both S-CT and L-CT.

### Evaluation of retroperitoneal organs

Distribution of retroperitoneal organs was evaluated by both S-CT and L-CT in a reconstructed axial view at each disk level. The examination included the abdominal aorta, kidney, descending colon, ureter, and gonadal artery. Anteroposterior positions of these organs were divided into four zones with regard to the vertebral body: Zone A was anterior to the anterior margin of the vertebral body; zone AL extended from the anterior margin to the middle line of the vertebral body; zone PL extended from the middle line to the posterior margin of the vertebral body; and zone P was posterior to the posterior margin of the vertebral body (Fig. 2). Except for the kidney, organ positions were evaluated at each disk level (L1/2–L4/5). Kidney position was obtained at the maximum anteroposterior diameter. Measurement points were set at posterior margin of the abdominal aorta, kidney, and descending colon and at the center of the ureter and gonadal artery. We defined zone A–AL in L-CT, in which these organs are normally extracted from the surgical field using the retractor, as the “safety zone” and zone PL–L in L-CT as the “approach zone.”

### Statistical analysis

StatMate software (ATMS Co., Ltd, Tokyo, Japan) was used for statistical analyses. All values are expressed as mean  $\pm$  standard deviation. The Chi-square test was used to determine any significant differences in the deviations of organs between S-CT and L-CT. Statistical significance was set at  $P < 0.05$ .

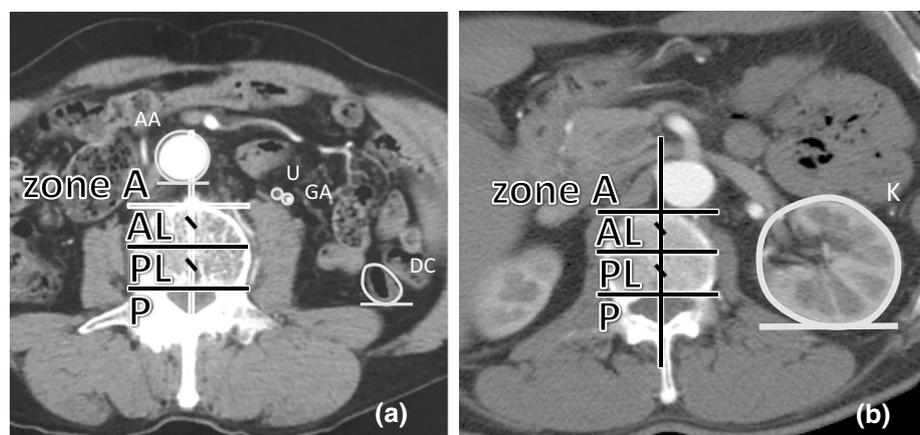
### Results

Patients consisted of 42 males and 58 females, with an average age of 71.8 years (55–85 years) at the time of surgery. Mean body mass index (BMI) was  $23.8 \pm 3.4$  kg/m<sup>2</sup>. We observed anterior migration of retroperitoneal organs in L-CT (Table 1). In all measurements in both S-CT and L-CT, the abdominal aorta was located in zone A. The descending colon showed individual variation in S-CT. While the frequency of occurrence of the descending colon in zone A increased, 20% of all measurements remained in the approach zone even in L-CT. For the ureter and gonadal artery, deviations measured in the approach zone in L-CT were quite low. The occurrence of almost all retroperitoneal organs which are the descending colon, the ureter, the gonadal artery, and the kidney in the approach zone was significantly lower in L-CT than in S-CT (Table 2). However, the frequency of the descending colon and kidney in the approach zone in L-CT was 20% and 82%, respectively. In terms of the migration of the descending colon in each zone, 66% of the descending colon recorded in zone P in S-CT remained in the approach zone, even in L-CT (Table 3).

### Discussion

LIF is an established surgical procedure for spinal fusion to treat patients with trauma, degenerative, or deformity diseases. Additionally, using a specially designed retractor, LIF offers advantages, including less tissue trauma and lesser blood loss during the surgery [2–5, 7, 9, 10]. Complications associated with lateral approach surgery on the lumbar spine have been previously reported [4–6, 8, 9, 11–18]. These include vascular, colonic, and ureter injuries, which occur relatively infrequently, but are sometimes life threatening and negatively influence a patient's quality of life. If these complications occur, they require additional

**Fig. 2** Measurement of retroperitoneal organs. **a** Anteroposterior organ positions were divided into four zones (A, AL, P, and PL) with regard to the vertebral body. AA, abdominal aorta; DC, descending colon (posterior edge); U, ureter; and GA, gonadal artery. **b** Kidney position was obtained at the maximum anteroposterior diameter. K, kidney (posterior edge)



**Table 1** Results

	S-CT				L-CT				
	A (%)	AL (%)	PL (%)	P (%)	A (%)	AL (%)	PL (%)	P (%)	
<i>Abdominal aorta</i>									
L1/2	44	56	0	0	L1/2	60	40	0	0
L2/3	66	44	0	0	L2/3	70	30	0	0
L3/4	88	12	0	0	L3/4	92	8	0	0
L4/5	87	13	0	0	L4/5	92	8	0	0
Total	67	33	0	0	Total	77	23	0	0
<i>Descending colon</i>									
L1/2	42	23	26	10	L1/2	73	12	8	8
L2/3	33	21	24	21	L2/3	71	16	10	3
L3/4	12	41	21	26	L3/4	66	13	22	0
L4/5	6	29	38	26	L4/5	53	18	26	3
Total	23	29	21	27	Total	65	15	16	4
<i>Ureter</i>									
L1/2	23	54	15	8	L1/2	70	20	10	0
L2/3	20	67	13	0	L2/3	90	10	0	0
L3/4	35	62	3	0	L3/4	82	18	0	0
L4/5	59	41	0	0	L4/5	82	18	0	0
Total	37	56	6	1	Total	83	16	1	0
<i>Gonadal artery</i>									
L1/2	100	0	0	0	L1/2	100	0	0	0
L2/3	76	6	3	15	L2/3	97	3	0	0
L3/4	59	41	0	0	L3/4	91	9	0	0
L4/5	56	41	3	0	L4/5	94	6	0	0
Total	66	28	2	5	Total	94	6	0	0
<i>Kidney</i>									
	0	3	6	91		3	15	26	56

**Table 2** Frequency of retroperitoneal organs in the approach zone (%) in supine and lateral positioning

Organs	S-CT (%)	L-CT (%)	P
Abdominal aorta	0	0	NS
Descending colon	48	20	<0.001
Ureter	7	1	0.07
Gonadal artery	7	0	0.02
Kidney	97	82	<0.01

Statistical analysis was performed by Chi-square test. Lateral, lateral positioning; NS, nonsignificant; and supine, supine positioning

treatment by a general surgeon, urologic surgeon, or other professional surgical team and lead to prolonged hospitalization and increased cost [7, 12–15, 17, 18]. Moreover, due to smaller incisions and a narrow surgical field, these injuries are often caused by blinded manipulation and are sometimes escape the surgeon's notice. Although the surgical procedure is performed in the lateral decubitus position, few studies have conducted anatomical measurements of retroperitoneal organs in this position. To the best of our knowledge, this is

the first study to investigate the distribution of retroperitoneal organs with the retroperitoneal approach in the lateral decubitus position.

We found anterior migration in L-CT of all retroperitoneal organs. The ureter and gonadal artery moved to the safety zone in most cases in the lateral decubitus position. These organs run along the psoas major muscle, and it is possible that movement of the psoas major muscle accompanied by hip joint flexion shifts the organs forward during LIF in the lateral decubitus position. As such, using the transpsoas approach in the lateral decubitus position is expected to reduce the risk of injury to the ureter and gonadal artery.

A certain percentage of the kidney and descending colon remained in the approach zone in L-CT. Two-third of the disk levels recorded for the descending colon in zone P in S-CT remained posterior to the anterior margin of the vertebral body (zones AL, PL, or P) even in L-CT. In comparison with previous studies, Hopper et al. reported that the frequency of occurrence of the bowel found posterior to the kidneys (retrorenal colon) according to a CT scan was 4.7% in the prone position [22]. They showed that the retrorenal colon was exclusively found at the level of the

**Table 3** Migration of the descending colon in the lateral decubitus position by zone (A, AL, PL, P)

Zone		L-CT			
		A	AL	PL	P
S-CT	A	96	4	0	0
	AL	96	0	4	0
	PL	60	27	13	0
	P	13	21	56	10

(%)

Safe zone	Approach zone
-----------	---------------

The descending colon in zone P in S-CT remained in the approach zone even in L-CT with high frequency. L-CT, computed tomography in lateral decubitus position; S-CT, computed tomography in conventional supine position

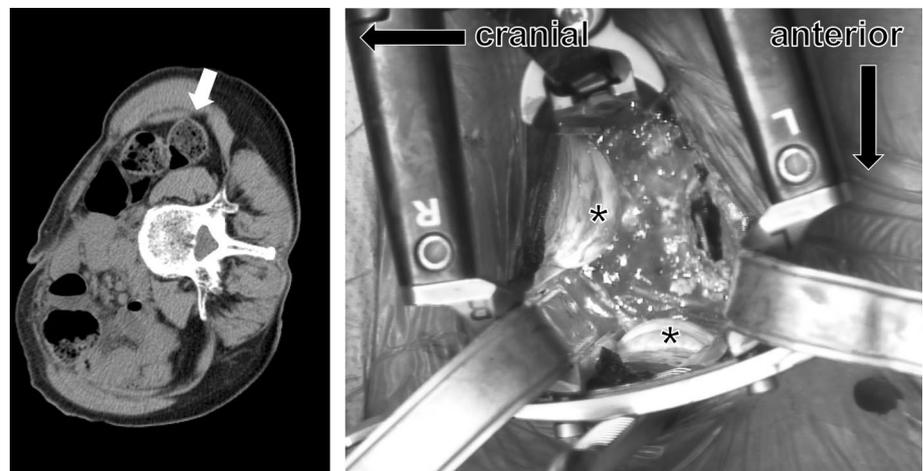
lower renal poles. Prassopoulos et al. reported the results of 1203 consecutive CT examinations [23]. They found that the frequency of occurrence of the descending colon between the kidney and the psoas muscle was 0.7%, with a higher frequency in females, young adults, and individuals with less intra-abdominal fat. In the current study, a total of five patients (5%) showed the colon posterior to the margin of the kidneys, which is only 16% of cases that the descending colon showed low anterior migration and remained in the approach zone in the lateral decubitus position. Definitely determining which factors implicate the remaining parts of the colon in the approach zone in L-CT is beyond the scope of this study. Further research is needed to determine the risk factors predicting the colon’s existence in the approach zone in the lateral decubitus position.

Some spine surgeons may have a misunderstanding that the peritoneum and its content or retroperitoneal content should be automatically mobilized anteriorly by the lateral decubitus position and could create enough retroperitoneal

space to allow subsequent lateral access. However, the results of this study show that in two-third of cases, the descending colon remained in the approach zone of LIF even in the lateral decubitus position.

While performing LIF, these organs are evacuated from surgical instruments using the retractor and/or palpation by the fingers to avoid injury. In Fig. 3, we present an illustrative case of a 70-year-old female with lumbar canal stenosis. This case showed that the descending colon remained in the approach zone even in L-CT, and intraoperative findings indicated that the parietal peritoneum containing the descending colon protruded between the retractor arms into the surgical line of view. Due to its fluidity, we believe that there is a considerable risk of colonic injury due to scratching by sharp instruments such as curettes and scalpels or punches to the protruding part of the colon by the retractor. Being surrounded by fatty tissue, the colon can be difficult to notice, and surgeons must therefore pay close attention in cases where retroperitoneal organs exist in the approach

**Fig. 3** An illustrative case (70-year-old female with lumbar canal stenosis). **a** Computed tomography in lateral decubitus position (L-CT); **b** intraoperative finding. **a** The descending colon remains in the approach zone even in L-CT (arrow). **b** Membrane (\*) containing the descending colon protrudes between the retractor arms into surgical line of view



zone. There is a potential risk of colonic injury in cases where the descending colon exists in the approach zone during LIF. In these cases, the decision to use an alternative method of spinal fusion (e.g., posterior lumbar fusion) is a possible solution to prevent colonic injuries. Although colonic injuries occur infrequently, they can be critical and life threatening [7, 12–15, 17, 18].

To avoid these fetal visceral complications during surgery, individual anatomic assessment and identification of the pathway for exposure to the posterior pararenal space in preoperative images is beneficial, and gentle and meticulous surgical detachment is essential for safe and reliable lateral approach surgery [24].

There were a few limitations to the present study. First, we could not discuss the influence of lateral bending. Lateral bending postures are mainly induced during LIF using the surgical bed, which can bend. It is possible that retroperitoneal organs may behave differently when lateral bending is induced simultaneously in the lateral decubitus position. It is difficult to investigate imaging under lateral bending using a non-portable CT system.

Another limitation of this study was that all patients were Japanese. Mean BMI of the sample was relatively low; thus, it is unclear whether study results can be generalized to other populations with thicker fatty tissue in the peritoneal space. Study results can be more suitably applied to Asian populations.

In conclusion, we observed anterior migration in L-CT of all retroperitoneal organs. Placing patients in the lateral decubitus position during LIF reduces the risk of injury to the retroperitoneal organs to some extent. However, a considerable percentage of the kidney and that of descending colon remain obstructed while performing LIF. We emphasize the importance of preoperative imaging evaluation and meticulous attention with securing visible surgical field during surgery, especially in cases where the descending colon extends outside zone P in S-CT.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interests.

## References

- Moller DJ, Slimack NP, Acosta FL Jr, Koski TR, Fessler RG, Liu JC (2011) Minimally invasive lateral lumbar interbody fusion and transpoas approach-related morbidity. *Neurosurg Focus* 31:E4. <https://doi.org/10.3171/2011.7.focus11137>
- Malham GM, Parker RM, Goss B, Blecher CM (2015) Clinical results and limitations of indirect decompression in spinal stenosis with laterally implanted interbody cages: results from a prospective cohort study. *Eur Spine J* 24(Suppl 3):339–345. <https://doi.org/10.1007/s00586-015-3807-3>
- Oliveira L, Marchi L, Coutinho E, Pimenta L (2010) A radiographic assessment of the ability of the extreme lateral interbody fusion procedure to indirectly decompress the neural elements. *Spine (Phila Pa 1976)* 35:S331–S337. <https://doi.org/10.1097/brs.0b013e3182022db0>
- Berjano P, Balsano M, Buric J, Petrucci M, Lamartina C (2012) Direct lateral access lumbar and thoracolumbar fusion: preliminary results. *Eur Spine J* 21(Suppl 1):S37–S42. <https://doi.org/10.1007/s00586-012-2217-z>
- Rodgers WB, Gerber EJ, Patterson J (2011) Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases. *Spine (Phila Pa 1976)* 36:26–32. <https://doi.org/10.1097/brs.0b013e3181e1040a>
- Sofianos DA, Briseno MR, Abrams J, Patel AA (2012) Complications of the lateral transpoas approach for lumbar interbody arthrodesis: a case series and literature review. *Clin Orthop Relat Res* 470:1621–1632. <https://doi.org/10.1007/s11999-011-2088-3>
- Tormenti MJ, Maserati MB, Bonfield CM, Okonkwo DO, Kanter AS (2010) Complications and radiographic correction in adult scoliosis following combined transpoas extreme lateral interbody fusion and posterior pedicle screw instrumentation. *Neurosurg Focus* 28:E7. <https://doi.org/10.3171/2010.1.focus09263>
- Uribe JS, Deukmedjian AR (2015) Visceral, vascular, and wound complications following over 13,000 lateral interbody fusions: a survey study and literature review. *Eur Spine J* 24:386–396
- Youssef JA, McAfee PC, Patty CA, Raley E, DeBauche S, Shucosky E, Chotikul L (2010) Minimally invasive surgery: lateral approach interbody fusion: results and review. *Spine (Phila Pa 1976)* 35:S302–S311. <https://doi.org/10.1097/brs.0b013e3182023438>
- Ozgun BM, Aryan HE, Pimenta L, Taylor WR (2006) Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J* 6:435–443. <https://doi.org/10.1016/j.spinee.2005.08.012>
- Knight RQ, Schwaegler P, Hanscom D, Roh J (2009) Direct lateral lumbar interbody fusion for degenerative conditions: early complication profile. *J Spinal Disord Tech* 22:34–37. <https://doi.org/10.1097/bsd.0b013e3181679b8a>
- Anand N, Baron EM (2013) Urological injury as a complication of the transpoas approach for discectomy and interbody fusion. *J Neurosurg Spine* 18:18–23. <https://doi.org/10.3171/2012.9.spine12659>
- Aichmair A, Fantini GA, Garvin S, Beckman J, Girardi FP (2015) Aortic perforation during lateral lumbar interbody fusion. *J Spinal Disord Tech* 28:71–75. <https://doi.org/10.1097/bsd.00000000000000067>
- Assina R, Majmundar NJ, Herschman Y, Heary RF (2014) First report of major vascular injury due to lateral transpoas approach leading to fatality. *J Neurosurg Spine* 21:794–798. <https://doi.org/10.3171/2014.7.spine131146>
- Flouzat-Lachaniette CH, Delblond W, Poignard A, Allain J (2013) Analysis of intraoperative difficulties and management of operative complications in revision anterior exposure of the lumbar spine: a report of 25 consecutive cases. *Eur Spine J* 22:766–774. <https://doi.org/10.1007/s00586-012-2524-4>
- Moro T, Kikuchi S, Konno S, Yaginuma H (2003) An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery. *Spine (Phila Pa 1976)* 28:423–428; discussion 427–428. <https://doi.org/10.1097/01.brs.0000049226.87064.3b>
- Fujibayashi S, Kawakami N, Asazuma T, Ito M, Mizutani J, Nagashima H, Nakamura M, Sairyu K, Takemasa R, Iwasaki M (2017) Complications associated with lateral interbody fusion: nationwide survey of 2998 cases during the first two years of its use in Japan. *Spine (Phila Pa 1976)*. <https://doi.org/10.1097/brs.00000000000002139>

18. Balsano M, Carlucci S, Ose M, Boriani L (2015) A case report of a rare complication of bowel perforation in extreme lateral interbody fusion. *Eur Spine J* 24(Suppl 3):405–408. <https://doi.org/10.1007/s00586-015-3881-6>
19. Guerin P, Obeid I, Gille O, Bourghli A, Luc S, Pointillart V, Cursolle JC, Vital JM (2011) Safe working zones using the minimally invasive lateral retroperitoneal transpsoas approach: a morphometric study. *Surg Radiol Anat* 33:665–671. <https://doi.org/10.1007/s00276-011-0798-6>
20. Sakai T, Tezuka F, Wada K, Abe M, Yamashita K, Takata Y, Higashino K, Sairyo K (2016) Risk management for avoidance of major vascular injury due to lateral transpsoas approach. *Spine (Phila Pa 1976)* 41:450–453. <https://doi.org/10.1097/brs.0000000000001234>
21. Prassopoulos P, Gourtsoyiannis N, Cavouras D, Pantelidis N (1990) A study of the variation of colonic positioning in the pararenal space as shown by computed tomography. *Eur J Radiol* 10:44–47
22. Hopper KD, Sherman JL, Luethke JM, Ghaed N (1987) The retrorenal colon in the supine and prone patient. *Radiology* 162:443–446
23. Prassopoulos P, Gourtsoyiannis N, Cavouras D, Pantelidis N (1994) Interposition of the colon between the kidney and the psoas muscle: a normal anatomic variation studied by CT. *Abdom Imaging* 19:446–448
24. Kanemura T, Satake K, Nakashima H, Segi N, Ouchida J, Yamaguchi H, Imagama S (2017) Understanding retroperitoneal anatomy for lateral approach spine surgery. *Spine Surgery and Related Research* 1:107–120

## Affiliations

Jun Ouchida<sup>1</sup> · Tokumi Kanemura<sup>1</sup> · Kotaro Satake<sup>1</sup> · Hiroaki Nakashima<sup>1</sup> · Naoki Segi<sup>1</sup>

✉ Jun Ouchida  
orthochida@gmail.com

<sup>1</sup> Department of Orthopedic Surgery, Konan Kosei Hospital, Japan Agricultural Cooperatives Aichi, 137 Omatsubara, Takaya-cho, Konan, Aichi 483-8704, Japan