The Effect of Intraoperative Prone Position on Psoas Morphology and Great Vessel Anatomy: Consequences for Prone Lateral Approach to the Lumbar Spine

Mohammed Munim, Michael T Nolte[1], Alexander Butler, Vincent Federico[1], Noe C. Treviño, Athan George Zavras, Justin Walsh, Frank M Phillips[1], Matthew Wesley Colman[2]
[1]Rush University Medical Center, [2]Midwest Orthopaedics At Rush

INTRODUCTION:

Lateral lumbar interbody fusion (LLIF) was initially developed to be performed in the lateral decubitus position, facilitating indirect neural decompression and trans-apophyseal interbody cage insertion while obviating the need for paraspinal musculature dissection. Limitations of the traditional technique include difficulty establishing lordosis via positioning and – when posterior surgery is indicated – the requirement for procedure staging or the non-intuitive placement of pedicle screws in the lateral decubitus position. To address these drawbacks, attention has recently shifted towards the prone trans-psoas technique, which allows single position surgery, intuitive lordotic positioning, and if necessary, simultaneous access to the anterior and posterior columns. However, anatomical relationships between the vertebral column, psoas muscle and its contained lumbar plexus, and the retroperitoneal vasculature may be affected by prone positioning. This study sought to quantify radiographic differences in psoas morphology, great vessel anatomy, and lumbar alignment parameters between supine and prone positioning to optimize surgical planning and minimize the risk of neurovascular injury.

METHODS:

This study retrospectively analyzed a consecutive single-center cohort with lumbar degenerative pathologies. Any patient with intraoperative computed tomography (CT) imaging obtained using O-Arm spinal navigation while positioned extended-prone on an open Jackson table was included, regardless of procedure type. Patients were excluded if indicated for revision fusion, trauma, infection, or tumor. Measurements were made on supine preoperative magnetic resonance imaging (MRI) and prone intraoperative CT from L2 to L5 levels. These included the anteroposterior and mediolateral proximity of the psoas, aorta, inferior vena cava (IVC), and anterior iliac vessels to the vertebral body. Psoas transverse and longitudinal diameters, psoas cross-sectional area (CSA), total lumbar lordosis, and segmental lordosis were assessed. Supine and prone anatomies were compared via paired t test, while ANOVA and the Spearman correlation coefficient evaluated the relationship between lumbar level and the magnitude of translation.

RESULTS:

Fifty-one patients were included for analysis. Prone position produced significant psoas lateralization away from the vertebral body, especially at more caudal levels ($P < 0.001$). The psoas drifted slightly anteriorly when prone, which was non-significant, but the magnitude of anterior translation significantly decreased at more caudal segments ($P = 0.038$) and was lowest at L5 where in fact posterior retraction was observed ($P = 0.032$). When prone, the IVC (1.61 mm supine vs. 7.06 mm prone, $P < 0.001$) and right iliac vein (-2.72 mm supine vs. 1.44 mm prone, $P = 0.005$) migrated significantly anteriorly, however this effect was most prominent at cranial lumbar levels and decreased anterior displacement was seen at more caudal levels ($P < 0.001$). Additionally, the IVC drifted significantly laterally at L5 (16.01 mm supine vs. 20.61 mm prone, $P = 0.009$). In contrast, the proximal aorta experienced anterior translation with prone positioning (6.43 mm supine vs. 7.79 mm prone, $P = 0.028$) but remained relatively immobile distally. Mean segmental lordosis significantly increased when prone (11.46° supine vs. 14.56° prone, $P < 0.001$).

DISCUSSION AND CONCLUSION:

Prone anatomical references between the vertebral column, psoas muscle, and great vessels may differ intraoperatively from supine imaging. Relative to the vertebral body, the psoas demonstrated substantial lateral mobility when prone, and posterior retraction specifically at L5. IVC and right iliac vein experienced significant anterior mobility – particularly at more cephalad levels. Prone position enhanced segmental lordosis and may be helpful in optimizing sagittal restoration. Further clinical investigations are necessary to extend these radiographic findings in a clinical prone lateral cohort.

Figure 1. Anteroposterior (AP) and mediolateral (ML) reference lines drawn on both **(A)** sagittal and **(B)** axial plane images.

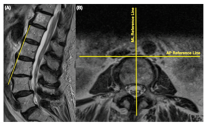

Figure 2. Schematic showing measured parameters. **(A)** Relative to the vertebral body, anteroposterior and mediolateral measurements included psoas position and iliac vasculature position. **(B)** Disc dimensions, psoas longitudinal diameter, transverse diameter, cross-sectional area, and proximity to the lateral aspect of the annulus fibrosus were measured at each level.

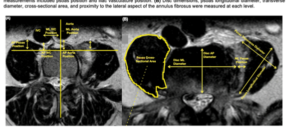

Table 2. Change in psoas parameters from supine to prone as compared via paired t-test. P-values represent results of paired tests at all levels by appropriate disc level.

	All Levels	L2-L3	L3-L4	L4-L5
Psoas Lateralization (mm)				
Right				
Supine	1.15 ± 2.61	0.71 ± 1.93	0.97 ± 2.52	1.64 ± 3.04
Prone	2.64 ± 3.93	0.68 ± 1.86	2.70 ± 4.09	3.87 ± 4.31
p-value	**< .001**	.851	**.005**	**< .001**
Left				
Supine	0.84 ± 2.15	1.15 ± 2.69	0.52 ± 1.89	0.94 ± 2.00
Prone	2.85 ± 4.28	2.12 ± 4.52	2.99 ± 4.30	3.19 ± 4.13
p-value	**< .001**	.208	**< .001**	**< .001**
Psoas Longitudinal Diameter (mm)				
Right				
Supine	41.64 ± 7.17	40.04 ± 7.35	42.53 ± 6.34	41.83 ± 7.79
Prone	40.87 ± 8.07	38.32 ± 6.60	41.27 ± 7.46	42.14 ± 9.29
p-value	.215	.669	.145	.860
Left				
Supine	41.08 ± 7.68	37.64 ± 8.48	42.33 ± 6.26	42.13 ± 7.87
Prone	42.04 ± 7.96	39.05 ± 7.33	42.82 ± 6.30	43.19 ± 9.43
p-value	.128	.136	.567	.531
Psoas Transverse Diameter (mm)				
Right				
Supine	29.04 ± 9.41	21.33 ± 7.87	28.98 ± 8.09	34.41 ± 7.93
Prone	29.27 ± 9.44	22.72 ± 7.95	28.83 ± 8.89	34.10 ± 8.21
p-value	.675	.150	.973	.668
Left				
Supine	29.79 ± 9.38	24.10 ± 10.80	29.01 ± 8.35	34.40 ± 6.80
Prone	28.78 ± 8.51	23.56 ± 9.17	28.26 ± 6.64	33.71 ± 7.94
p-value	.210	.638	.286	.272
Psoas CSA (mm^2)				
Right				
Supine	902.96 ± 325.20	685.93 ± 184.45	895.92 ± 249.90	1126.31 ± 286.60
Prone	893.86 ± 320.71	660.17 ± 238.03	869.81 ± 267.43	1074.85 ± 315.72
p-value	.347	.460	.292	.053
Left				
Supine	945.69 ± 379.75	641.56 ± 238.81	916.33 ± 285.23	1177.80 ± 389.92
Prone	929.10 ± 353.38	679.24 ± 219.45	897.97 ± 252.68	1123.65 ± 401.55
p-value	.119	.472	.462	.202
Segmental Angle				
Supine	11.46 ± 8.53	5.59 ± 4.98	9.48 ± 6.44	16.50 ± 9.00
Prone	14.56 ± 9.08	8.01 ± 3.60	12.11 ± 7.60	18.97 ± 9.53
p-value	**< .001**	**.012**	**< .001**	**< .001**

Bold p-value denotes statistical difference; CSA, Cross-Sectional Area

Table 1. Description of Radiographic Measurements.

Variables	Description	Units
AP psoas position	Distance between posterior border of the psoas muscle and anteroposterior reference line as determined by anterior vertebral body edge	mm
ML Psoas lateralization	Shortest distance between medial aspect of psoas the psoas muscle and lateral edge of annulus fibrosis on axial cut centered at the midpoint of the intervertebral disc space on the sagittal axis	mm
AP iliac vasculature position	Distance between posterior margin of the IVC, aorta, or common iliac arteries/veins and anteroposterior reference line as determined by anterior vertebral body edge	mm
Iliac vasculature lateralization	Distance between approximate midpoint of the IVC, aorta, or common iliac arteries/veins and midline reference line that bisects vertebral body and spinal canal	mm
Psoas longitudinal diameter	Longest diameter on an axial slice of the psoas muscle that approximately bisects it	mm
Psoas transverse diameter	Longest diameter of the psoas muscle accommodated on an axial slice of the psoas muscle that is orthogonal to the psoas longitudinal diameter	mm
Psoas CSA	Axial cross-sectional area of the psoas muscle	mm^2
Total lumbar lordosis	Cobb angle between superior plateau of L1 and inferior plateau of L5 in the sagittal plane	°
Segmental lordosis	Cobb angle between superior plateau of upper vertebral body and inferior plateau of lower vertebral body at L2-L3, L3-L4, and L4-L5 intervertebral disc spaces in the sagittal plane	°
Vertebral body size	Diameters between anteroposterior and lateral borders of vertebral body	mm

Abbreviations: AP, Anteroposterior; ML, Mediolateral; IVC, Inferior Vena Cava; CSA, Cross-sectional Area