Complications Associated With Oblique Lumbar Interbody Fusion at L5-S1: A Systematic Review of the Literature

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INTRODUCTION: Oblique lumbar interbody fusion (OLIF) at L5-S1, also known as a lateral decubitus anterior lumbar interbody fusion (ALIF) or anterior-to-psoas (ATP) approach, is a technique that provides a minimally invasive corridor to a key segment in the spine for degenerative conditions and deformity correction. However, the evaluation of complications associated with this level has been difficult as prior reports include other levels that have different anatomic considerations.

OBJECTIVE: To present a systematic review of previously reported cases of OLIF, lateral ALIF, and an ATP approach at L5-S1 to discuss their associated complications.

METHODS: Following preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines, a PubMed search was performed up to January 2021 to identify literature describing OLIF, lateral ALIF, and ATP approaches involving the L5-S1 levels. A quality assessment with risk of bias analysis was performed using the methodological index for non-randomized studies (MINORS) assessment tool for each study. Data we then extracted to identify all complications.

RESULTS: The initial search yielded 532 publications. After screening, there were 18 studies with 553 total patients who underwent OLIF including L5-S1. Analysis of these studies demonstrated a vascular complication rate of 2.5%, bowel-associated complication rate of 0.5%, ureteral injury rate of 0%, neurological injury rate of 1.9%, pseudarthrosis rate of 7.3%, and reoperation rate of 2.2%.

CONCLUSION: The L5-S1 level remains an important target for sagittal alignment in both degenerative and deformity surgery. The OLIF surgical corridor to this level presents special anatomic and clinical considerations and is a safe approach to minimize morbidity with minimally invasive access.

KEY WORDS: ALIF, APLIF, antepsoas lumbar interbody fusion, anterior-to-psoas, L5-S1 interbody fusion, oblique lumbar interbody fusion, OLIF

Lumbar interbody fusion techniques are used to treat a variety of pathologies such as degenerative disc disease, spondylosis, and spinal instability. Different techniques are indicated depending on patient history and presenting symptoms. Minimally invasive surgery (MIS) techniques have recently emerged as alternatives to open procedures, but further evaluation is necessary because the prevalence of complications is yet to be quantified for each technique. MIS techniques have varying advantages and complications, which must be considered prior to operating on patients to minimize risks and provide good clinical outcomes.

The oblique lumbar interbody fusion (OLIF) approach to L5-S1, which is also described as a lateral anterior lumbar interbody fusion (ALIF) or anterior-to-psoas (ATP) approach, utilizes a minimally invasive oblique retroperitoneal corridor to access the anterior midline of the disc space. MIS techniques are advantageous over traditional large exposures because they reduce...
complications and postoperative pain while also improving recovery times.\textsuperscript{2} OLIF achieves favorable outcomes because it provides both a large intraoperative field of view and a large surface area for instrumentation.\textsuperscript{1} The OLIF technique has been used at the level L1-S1; however, the L5-S1 level in particular has a greater risk for complications because of potential injury to vascular, urological, and gastrointestinal structures.\textsuperscript{1,5}

Complications of these approaches must be thoroughly considered in patients who require spinal fusion. We present a systematic review of the current literature to discuss complications associated with the minimally invasive oblique approach to L5-S1.

\section*{METHODS}

\subsection*{Search Strategy}

Our systematic review was performed while following preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. A literature search was conducted on PubMed and was filtered by publications with only human subjects in English from the earliest records to January 21, 2021 using the following search equation: \textit{“L5-S1 AND (OLIF OR oblique OR antepsoas OR ‘minimally invasive’ OR ‘lateral AND ALIF’ OR ‘lateral anterior lumbar interbody fusion’ OR ‘anterior-to-psoas’).”} Another broader search was then performed for \textit{“OLIF OR antepsoas OR anterior-to-psoas OR lateral ALIF”} to find literature describing the entirety of lumbar interbody fusion using this technique, which was then further examined to capture descriptions of L5-S1 levels.

\subsection*{Inclusion Criteria}

A review was conducted by 2 independent reviewers (L.D.D.A. and M.H.P) and the following were removed based on exclusion criteria: duplicates; articles not published in a peer-reviewed journal or abstract-only; articles that are not case reports, case series, or clinical trials; articles that did not describe an oblique, ATP, or lateral ALIF approach to L5-S1; and articles of an L5-S1 approach but in supine position or via a transperitoneal corridor. After exclusion, the remaining articles were screened based on the following inclusion criteria: reports of OLIF, ATP, or lateral ALIF approach in the lateral position via a retroperitoneal corridor to the anterior L5-S1 disc space and reported complications or adverse events. Any disagreements in inclusion or exclusion of articles were settled by a third reviewer (O.H.). The steps for the review and article selection process are summarized in the Figure.

\subsection*{Data Extraction Process}

Articles that met search criteria were further examined and data were extracted from all articles for the following parameters by 2 independent reviewers (L.D.D.A. and M.H.P): number of patients, age, sex, diagnoses treated, follow-up time, operation time, hardware failures, and all reported complications or adverse events related to the minimally invasive oblique or antepsoas approach to L5-S1.

\subsection*{Quality Assessment and Risk of Bias}

The quality of the publications that fit inclusion/exclusion criteria and their risk of bias was assessed by 2 independent reviewers (L.D.D.A. and O.H.) using the methodological index for non-randomized studies (MINORS) assessment tool and disagreements were settled by a third reviewer (M.H.P).\textsuperscript{6} Each publication had its MINORS quality assessment graded with scores ranging from 0 to 1 for each individual criterion with the following defined score ratings: 0 (category not adequately reported) and 1 (category reported and adequate). Once every component of MINORS was assessed for a publication, the overall score was generated by summing the scores of each individual criterion. The ideal score is 6 (Table 1).

\section*{RESULTS}

The initial PubMed search resulted in 532 total papers, and after removing studies not published in English or not conducted on humans, 354 papers were retained. After implementation of the inclusion/exclusion criteria, 18 studies were identified that describe the use of OLIF, ATP, or a lateral ALIF approach to L5-S1 and their reports of complications were recorded (Table 2). All studies were retrospective in nature except 1 study by Miscusi et al.\textsuperscript{7} There were a total of 553 patients across studies, and because of mixed demographic populations, the reported gender distribution and age were not always reported specifically to the L5-S1 approach. When reported, follow-up times ranged from 3 to 35 mo.\textsuperscript{2,4,5,7-17} Publication dates ranged from 2002 to 2020. Diagnoses treated included all forms of lumbar degenerative disease, which included but were not limited to degenerative disc disease, discopathy, spinal stenosis, spondylolisthesis, degenerative scoliosis, disc herniation, and adjacent segment disease. Reported complication rates and adverse events included vascular, gastrointestinal, urological, and neurological injury. Also reported were rates of pseudarthrosis, implant failure, and reoperations for any reason.

\subsection*{Vascular Injury}

All 18 studies reviewed their vascular complication rates and altogether reported a rate of 14/553 patients (2.5\%) (Table 3).\textsuperscript{1,3,5,7-19} Thirteen studies reported no vascular injuries in their patient populations.\textsuperscript{4,5,7-10,13-19} Of the six studies reporting a total of 14 patients with vascular injury,\textsuperscript{1,3,11,12} all were associated with the common iliac vein or the iliolumbar vein. A total of 6 injuries were minor and treated with hemostatic compression,\textsuperscript{1,2} 5 injuries required direct intraoperative repair with clips or nonabsorbable suture,\textsuperscript{11,12} and 3 injuries had no treatment determined.\textsuperscript{3}

\subsection*{Gastrointestinal Injury}

There were 12 studies that reviewed bowel-associated complications associated with the approach to L5-S1 with a total complication rate of 2/433 patients (0.5\%) (Table 4).\textsuperscript{1,2,4,5,7,8,11,13,15,16,18,19} The only reported instances of bowel-associated complications involved 2 cases of superior mesenteric artery (SMA) syndrome.\textsuperscript{1,11} Tannoury et al\textsuperscript{11} reported 1 case of superior mesenteric ischemia diagnosed on postoperative day 4, which was treated with an uneventful partial colectomy. Woods et al\textsuperscript{11} also reported 1 case of SMA syndrome but did not
elaborate on its diagnosis or treatment. There were no instances of direct injury to the bowel itself, and 2 studies described inadvertent opening of the peritoneum, which was identified and then sutured primarily to reduce the onset of ileus.2,4

**Ureteral Injury**

Eleven studies specifically evaluated their patients to determine if there were any instances of ureteral injury (Table 5).1,2,7,8,10,11,13,15,16,18,19 There was a ureteral injury rate of 0/379 patients (0%) associated with this approach to L5-S1.

**Neurologic Complications**

A total of 12 studies evaluated patients who had postoperative neurological complications, including retrograde ejaculation or radiculopathy causing sensory or motor deficits resulting in an injury rate of 7/358 patients (1.9%) (Table 6).2,4,5,7,10-12,15-19 There was 1 patient who experienced retrograde ejaculation11 and 5 patients who experienced postoperative sensory deficits, out of which 4 resolved spontaneously, while the last was due to cage malpositioning and resolved after a reoperation.4,5,15 One study reported 1 patient with postoperative motor weakness, which resolved with posterior decompression surgery.15

**Other Adverse Events**

Nine studies examined fusion rates at the L5-S1 level and found pseudarthrosis in 28/385 patients (7.3%) (Table 7).2,7,9,11-16 Together, these studies included a heterogenous patient population that included both interbody fusion for degenerative disease as well as the inclusion of L5-S1 at the terminus of a long-segment deformity correction. Seven studies commented on
reoperations in 5/230 patients (2.2%).5,7,11-13,16,17 Rabbo et al13 reported reoperation in 1 patient with an infected hematoma, which required a return to the operating room (OR) for evacuation as well as another patient with cage malpositioning. Zairi et al5 had 1 patient with cage malpositioning causing intractable pain, which resolved after a reoperation to reposition the cage. Miscusi et al7 reported 1 patient who required a posterior direct decompression due to persistent radiculopathy from residual foraminal stenosis. Virk et al17 described 1 patient who developed bilateral sacral insufficiency fractures months after their surgery, which was treated with a revision procedure involving extension of posterior instrumentation to the ilium. Three studies specifically commented that no incisional hernias were observed in a total of 0/196 patients.1,4,11 Three other studies specifically commented on wound infections, in which there was 1 patient out of 192 (0.5%) who experienced a superficial wound infection treated conservatively with antibiotics.7,11,14

**DISCUSSION**

The unique anatomy at L5-S1 presents different challenges and considerations from L1-S5. Whereas a minimally invasive lateral approach at L1-S5 can be done transpsoas or antepsoas, L5-S1 is approached through the anterior disc space, which is positioned between the common iliac vessels. In this way, the OLIF, ATP approach and lateral ALIF at L5-S1 are more closely related to a supine ALIF except performed in a lateral position down a smaller minimally invasive retroperitoneal corridor. The potential complication profile then can differ significantly from lateral or antepsoas surgery at the proximal to mid-lumbar spine. Our systematic review found a vascular injury complication rate of 2.5%. Although left common iliac vein injuries were successfully repaired, care should be taken to identify them during retroperitoneal dissection to avoid injury, as well as appropriate patient selection where there is favorable positioning of the vein.3 The iliolumbar vein may also be injured, and in some cases, vessel ligation may be necessary to achieve safe anterior retraction of major vessels even without injury.1 The median sacral vein can be encountered and injured when approaching the L5-S1 disc space but can be safely divided with bipolar cautery or vascular clips.11

Mehren et al20 reported a large series comprising 812 patients who underwent OLIF approach, but their study does not include L5-S1 level. MIS approach to the L5-S1 level presents significant challenges to spine surgeons, especially the risks of neurovascular injury. A recent study by Woods et al11 on OLIF of

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**TABLE 1. MINORS Quality Assessment (Ideal Score = 6)**

| Authors and year | Total score |
|------------------|-------------|
| Wolfla et al, 2002 | 4           |
| Silvestre et al, 2012 | 4           |
| Kanno et al, 2014 | 4           |
| Fujibayashi et al, 2015 | 4           |
| Zairi et al, 2016 | 5           |
| Woods et al, 2017 | 5           |
| Woods et al, 2017 | 5           |
| Chung et al, 2017 | 3           |
| Chung et al, 2018 | 3           |
| Kim et al, 2018 | 3           |
| Anand et al, 2019 | 5           |
| Malham et al, 2019 | 4       |
| Mun et al, 2019 | 6           |
| Tannoury et al, 2019 | 4           |
| Miscusi et al, 2020 | 5           |
| Rabbo et al, 2020 | 3           |
| Virk et al, 2020 | 4           |
| Xi et al, 2020 | 4           |

**TABLE 2. Studies That Used a Minimally Invasive Oblique Antepsoas Approach for L5-S1 Lumbar Interbody Fusion**

| Authors and year | Number of patients | Mean follow-up (mo) |
|------------------|--------------------|---------------------|
| Wolfla et al, 2002 | 10 | 29                   |
| Silvestre et al, 2012 | 6 | 11.3                |
| Kanno et al, 2014 | 2 | NR                  |
| Fujibayashi et al, 2015 | 4 | 1                   |
| Zairi et al, 2016 | 6 | 12                   |
| Woods et al, 2017 | 94 | 6                   |
| Woods et al, 2017 | 6 | 24                   |
| Chung et al, 2017 | 26 | NR                 |
| Chung et al, 2018 | 6 | NR                  |
| Kim et al, 2018 | 32 | 26.1                |
| Anand et al, 2019 | 60 | 24                  |
| Malham et al, 2019 | 30 | 35                 |
| Mun et al, 2019 | 74 | 12.1                |
| Tannoury et al, 2019 | 70 | NR               |
| Miscusi et al, 2020 | 32 | 33.1               |
| Rabbo et al, 2020 | 17 | 28.3                |
| Virk et al, 2020 | 15 | NR                  |
| Xi et al, 2020 | 66 | 24.1               |

NR = not reported.
the lumbosacral spine reported a relatively acceptable vascular complications profile of 2.9% with access surgeon help and neuromonitoring use in cases requiring L5-S1 fusion.1

Bowel-associated complications were rare at a rate of 0.5% (n = 433) and direct bowel injury was avoided in all cases.1,2,4,11 A total of 2 studies described 3 patients where the peritoneum was inadvertently entered, in which case this was directly sutured closed to reduce the possible occurrence of ileus.2,4 In our review, the only bowel-associated complications were 2 occurrences of SMA syndrome, which can be devastating if unrecognized. Superior mesenteric ischemia may not appear until the postoperative period and may require colotomy or other medical management, so awareness of the vascular anatomy and avoidance of aggressive retraction is necessary.1,11 A high index of suspicion of severe abdominal pain in the early postoperative period is still advisable.

We found no reports of ureteral injury in previous cases of L5-S1 minimally invasive OLIF; however, injury is still possible because of the anatomic position of the ureters. Although previous reports found ureteral injury to most commonly occur at the level L2-L3 during OLIF,21,22 injury can also occur during L5-S1 because of the ureter’s location at the posterior portion of the peritoneum, which leaves it vulnerable to potential compression from tubular retractors.21 Therefore, complete retraction of the retroperitoneal fatty tissue to anteriorly mobilize the ureter and use a wide rostral to caudal development of the retroperitoneal plane during blunt dissection can help to avoid ureteric injury.21

Neurological complications can be avoided in L5-S1 OLIF with careful technique and sufficient anatomic knowledge. Although there are only reports of radiculopathy and retrograde ejaculation for the L5-S1 OLIF technique, other potential neurological complications should be considered. The iliohypogastric and ilioinguinal nerves may be encountered underneath the internal oblique muscle during blunt dissection through the abdominal wall so extensive skin and muscle incisions should be avoided.21,23 The genitofemoral nerve runs along anterior vertebral bodies below L1-L2 until it pierces the psoas around L4-L5 and runs anterior to it,23,24 so avoiding dissection of the anterior belly of the psoas beyond the median coronal plain and delicate retraction should be accomplished to prevent its injury and also that of the lumbar plexus and psoas muscle.21

### Table 3: Vascular Complications Associated With a Minimally Invasive Oblique Antepleos Approach at L5-S1

| Authors and year          | Total patients | Vascular injuries | % vascular injury rate |
|---------------------------|----------------|-------------------|------------------------|
| Wolf et al, 2002          | 10             | 0                 | 0                      |
| Silvestre et al, 2012     | 6              | 0                 | 0                      |
| Kanno et al, 2014         | 2              | 0                 | 0                      |
| Fujibayashi et al, 2015   | 1              | 0                 | 0                      |
| Zairi et al, 2016         | 6              | 0                 | 0                      |
| Woods et al, 2017         | 94             | 4                 | 3.6                    |
| Woods et al, 2017         | 6              | 1                 | 16.7                   |
| Chung et al, 2017         | 26             | 3                 | 11.5                   |
| Chung et al, 2018         | 6              | 0                 | 0                      |
| Kim et al, 2018           | 32             | 0                 | 0                      |
| Anand et al, 2019         | 60             | 0                 | 0                      |
| Malham et al, 2019        | 30             | 0                 | 0                      |
| Mun et al, 2019           | 74             | 3                 | 4.1                    |
| Tannoury et al, 2019      | 70             | 3                 | 4.3                    |
| Miscusi et al, 2020       | 32             | 0                 | 0                      |
| Rabbo et al, 2020         | 17             | 0                 | 0                      |
| Virk et al, 2020          | 15             | 0                 | 0                      |
| Xi et al, 2020            | 66             | 0                 | 0                      |
| **Total pooled**          | **553**        | **14**            | **2.5**                |
### TABLE 4. Bowel-Associated Complications Reported by Studies Associated With a Minimally Invasive Oblique Antepsoas Approach at L5–S1

| Authors and year | Total patients | Bowel injuries | SMA syndrome | % bowel injury rate |
|------------------|----------------|----------------|--------------|--------------------|
| Wolfla et al, 2002¹ | 10             | 0              | NR           | 0                  |
| Kanno et al, 2014² | 2              | 0              | NR           | 0                  |
| Zairi et al, 2016³ | 6              | 0              | NR           | 0                  |
| Woods et al, 2017⁴ | 94             | 0              | 1            | 1.1                |
| Chung et al, 2018⁵ | 6              | 0              | NR           | 0                  |
| Kim et al, 2018⁶   | 32             | 0              | NR           | 0                  |
| Anand et al, 2019⁷ | 60             | 0              | NR           | 0                  |
| Malham et al, 2019⁸ | 30             | 0              | NR           | 0                  |
| Mun et al, 2019⁹   | 74             | 0              | NR           | 0                  |
| Tannoury et al, 2019¹⁰ | 70         | 0              | 1            | 1.4                |
| Miscusi et al, 2020¹¹ | 32           | 0              | NR           | 0                  |
| Rabbo et al, 2020¹² | 17             | 0              | NR           | 0                  |
| **Total Pooled**   | **433**        | **0**          | **2**        | **0.5**            |

NR = not reported; SMA = superior mesenteric artery.

### TABLE 5. Ureter Injuries Reported by Studies Associated With a Minimally Invasive Oblique Antepsoas Approach at L5–S1.

| Authors and year | Total patients | Ureter injuries | % ureter injury rate |
|------------------|----------------|-----------------|---------------------|
| Wolfla et al, 2002¹ | 10             | 0               | 0                   |
| Kanno et al, 2014² | 2              | 0               | 0                   |
| Fujibayashi et al, 2015³ | 1             | 0               | 0                   |
| Woods et al, 2017⁴ | 94             | 0               | 0                   |
| Chung et al, 2018⁵ | 6              | 0               | 0                   |
| Anand et al, 2019⁷ | 60             | 0               | 0                   |
| Malham et al, 2019⁸ | 30             | 0               | 0                   |
| Mun et al, 2019⁹   | 74             | 0               | 0                   |
| Tannoury et al, 2019¹⁰ | 70         | 0               | 0                   |
| Miscusi et al, 2020¹¹ | 32           | 0               | 0                   |
| Rabbo et al, 2020¹² | 17             | 0               | 0                   |
| **Total pooled**   | **379**        | **0**           | **0**               |

The superior hypogastric plexus and sympathetic chain are often found anterior to the L5–S1 disc space during a surgical approach below the bifurcation of the aorta, so careful blunt dissection release of the adventitial layer, which contains the plexus, should be performed and use of a Bovie should be avoided to mitigate injury.¹¹,²⁵

Pseudarthrosis rates in our study were relatively high at 7.3%, which may be due to the fact that patient populations were exceptionally heterogenous and included multilevel fusions to the sacrum as well as long segment deformity corrections. However, there remains the possibility of some intrinsic disadvantage of fusion rate associated with this approach, especially when
TABLE 6. Neurological Injuries Reported by Studies Associated With a Minimally Invasive Oblique Antepsoas Approach at L5-S1

| Authors and year | Total patients | Retrograde ejaculation | Sensation disturbances | Motor weakness | % neuro-injury rate |
|------------------|----------------|-----------------------|-----------------------|---------------|--------------------|
| Kanno et al, 2014 | 2              | 0                     | 0                     | 0             | 0                  |
| Fujibayashi et al, 2015 | 1            | NR                    | 0                     | 0             | 0                  |
| Zairi et al, 2016 | 6              | 0                     | 1                     | 0             | 16.7               |
| Woods et al, 2017 | 94             | 1                     | 0                     | 0             | 1.1                |
| Woods et al, 2017 | 6              | NR                    | 0                     | 0             | 0                  |
| Chung et al, 2018 | 6              | 0                     | NR                    | NR            | 0                  |
| Kim et al, 2018  | 32             | NR                    | 2                     | 0             | 6.3                |
| Anand et al, 2019 | 60             | 0                     | 0                     | 0             | 0                  |
| Malham et al, 2019 | 30            | 0                     | 2                     | 1             | 10.0               |
| Mun et al, 2019  | 74             | 0                     | NR                    | NR            | 0                  |
| Miscusi et al, 2020 | 32           | 0                     | 0                     | 0             | 0                  |
| Virk et al, 2020  | 15             | 0                     | 0                     | 0             | 0                  |
| Total pooled     | 358            | 1                     | 5                     | 1             | 1.9                |

NR = not reported.

TABLE 7. Pseudarthrosis Associated With a Minimally Invasive Oblique Antepsoas Approach at L5-S1

| Authors and year | Total patients | Pseudarthrosis | % pseudarthrosis rate |
|------------------|----------------|----------------|-----------------------|
| Silvestre et al, 2012 | 6            | 1              | 16.7                  |
| Woods et al, 2017  | 94            | 5              | 5.3                   |
| Woods et al, 2017  | 6             | 0              | 0                     |
| Anand et al, 2019  | 60            | 0              | 0                     |
| Malham et al, 2019 | 30            | 0              | 0                     |
| Mun et al, 2019   | 74            | 12             | 16.2                  |
| Miscusi et al, 2020 | 32           | 0              | 0                     |
| Rabbo et al, 2020  | 17            | 2              | 11.8                  |
| Xi et al, 2020     | 66            | 8              | 11.2                  |
| Total pooled      | 385           | 28             | 7.3                   |

compared with historically lower reported rates of pseudarthrosis via a supine ALIF approach. It is also interesting to note that the pooled pseudarthrosis rate of 7.2% is higher than the reported reoperation rate of 2.2%, and we can only assume that some patients with pseudarthrosis were either asymptomatic or treated conservatively.

Limitations

This study being a systematic review of case reports and series has a number of limitations. All studies but 1 were retrospective, and therefore inherently contain bias. Reported follow-up times were variable and sometimes not indicated, but studies without these were not excluded because this current study focused on
conclusions of which the majority are intraoperative. There was variation in how studies reported complications, and because the studies in this review included both single-level L5-S1 procedures and multilevel fusions, it cannot be certain if the reported complications are specifically for L5-S1 or simply associated with the overall oblique approach. Nevertheless, the highest overall complication of vascular injury reported was almost always the left common iliac vein, which is typically only vulnerable during L5-S1 exposure.

CONCLUSION

To our knowledge, this is the first study to report complications associated with a minimally invasive oblique approach for fusion involving the L5-S1 level. We present this review to highlight the special anatomic and clinical considerations of this approach as the L5-S1 level remains an important target for sagittal alignment in both degenerative and corrective deformity surgery.

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