Perspective on the true incidence of bowel perforations occurring with extreme lateral lumbar interbody fusions. How should they be treated?

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INTRODUCTION

What is the true risk of bowel perforation (BP) following open or minimally invasive (MI) extreme lateral lumbar interbody fusion (XLIF)? What is the truth? Further, if peritoneal symptoms/signs arise following XLIF/MI XLIF, it is critical to obtain an emergent consultation with general surgery who can diagnose and treat a potential BP.

ABSTRACT

Background: What is the risk of bowel perforation (BP) with open or minimally invasive (MI) extreme lateral lumbar interbody fusion (XLIF)? What is the truth? Further, if peritoneal symptoms/signs arise following XLIF/MI XLIF, it is critical to obtain an emergent consultation with general surgery who can diagnose and treat a potential BP.

Literature Review: In multiple series, the frequency of BP ranged markedly from 0.03% (i.e. 1 of 2998 patients), to 0.08% (11/13,004), to 0.5%, to 8.3% (1 in 12 patients), up to 12.5% (1 in 8 patients). BPs attributed to different causes carry high mortality rates varying from 11.1% to 23%. For the 11 (0.08%) BP occurring out of 13,004 patients undergoing XLIF in one series, there was one (9.09%) death due to uncontrolled sepsis. In another series, where 31 BP were identified for multiple lumbar surgical procedures identified through PubMed (1960–2016), including 10 (32.2%) for lateral lumbar surgery including XLIF, the overall mortality rate was 12.9% (4/31).

Conclusion: The incidence of BPs occurring following XLIF/MI XLIF procedures ranged from 0.03% to 12.5% in various reports. What is the true incidence of these errors? Certainly, it is more critical that when spine surgeons’ patients develop acute peritoneal symptoms/signs following these procedures, they immediately consult general surgery to both diagnose, and treat potential BP in a timely fashion to avoid the high morbidity (87.1%) and mortality rates (12.9%) attributed to these perforations.

Keywords: Bowel, Extreme lateral lumbar interbody fusion, Perforation, Real frequency, Validation, XLIF, Minimally Invasive (MI) XLIF

INTRODUCTION

What is the true risk of bowel perforation (BP) following open or minimally invasive (MI) extreme lateral lumbar interbody fusion (XLIF) [Table 1]? Several studies identified vastly different frequencies of BP following XLIF/MI XLIF; the range varied from 0.03% (1/2988 patients), to 0.08% (11/13,004), to 0.5% (3/590), to 8.3% (1/12 patients), to 12.5% (1 of 8 patients) of cases. Whatever the true frequency of BP with XLIF/MI XLIF, it is most critical that spine surgeons recognize that new postoperative peritoneal symptoms/signs of BPS so that general surgery can be immediately consulted to both diagnose, and potentially treat this medical error in a timely fashion. Delays in diagnosing any type of BP are associated with high mortality...
| Author         | Journal/Date | Design                           | Population | Findings                              | Findings                              | Findings                            | Conclusion                              |
|---------------|--------------|----------------------------------|------------|---------------------------------------|---------------------------------------|--------------------------------------|-----------------------------------------|
| Bielecki et al.[3], Tech Coloproctol 2002 | LBP Morbidity MOR Peritonitis | 59 Pts Emergent OR | 16.9% MOR | 18 Primary Anastomosis | 11.1% MOR | 22.2% MOR | 36 Resection NO Anastomosis | 5 Non Resections | "Radical aggressive approach is recommended for most patients with LBP" |
| Biondo et al.[4], Am J Surg 2002 | 212 Pts Emergency OR Left Colon Perf 1992-2000 | Perforations: 133 (63%) Divertic 79 (37%) NonDivertic Divertic | 2007–2009 F/O 1.5 Mos 1/8 (12.5%) BP XLIF LBP | Most Common Cause LBP -Distal Colon Peritonitis | 2/8 (25%) Deficits XLIF/TLIF Motor | 307 (34%) Primary Resection + Anastomosis 16 Other | 18 (23%) MOR |
| Tormenti et al.[21], Neurosurg Focus 2010 | 8 AE MIS XLIF versus 4 Open TLIF Adult Scoli | 543,146 Lumbar OR 414 SE (0.8/1000) | Avg Age 61 66% F 37% Smokers 23% DM F/U 19 mos | Avg 1.2/Pt No Pseud No Instrument Failures | 197 Levels XLIF | 1 (0.6%) Major AE No BP 12% Minor 14% Sens 9% Iliop Motor | XLIIF Significant Improvement Outcomes Low AE |
| Marquez-Lara et al. [14], Spine 2014 | NIS Data 2002–2011 | 543,146 Lumbar OR 414 SE (0.8/1000) | BP 0.06/1000= 30/543, 146 Bowel Perf | Mortality BP 20X Greater with Sentinal Events Vascular Injury | 14.6 versus 0.7 per 1000 Cases | Highest Mortality for BP and Vascular Injuries | BP 1/8 (12.5%) MIS XLIF XLIF LBP Intraop Repair Thigh Pares |
| Balsano et al. [2], Eur Spine J 2015 | 1 Bowel Perf XLIF Case Report | Bowel Injury 70-year-old | L3-L4 And L4-L5 | Lateral Transposao Approach | XLIIIF Fusion 1 Bowel Perf |
| Uribé et al.[22], Eur Spine J 2015 | 13,004 MIS-LIF-25 Ortho 15 Neuro Pros XLIF Avoid Posterior Element Disruption | 11 (0.08%) Bowel Perf Literature BP: ALIF 1.7% TLIF 1.2% | Data 10 of 11 BP Avg Age 59 All Fusions 10 BP-Surgeon Experience 0-10 None 11-50 Cases (3 Surgeons) Over 50 cases (7 Surgeons) | Surgery 11 Patients 6 Laparotomies (Debride/Colecotony) 3 Colostomy 2-Insufficent Data When-BP Surgery 4 Intraoperatively 6 Early Postop (Days 2 (1 case), 3(2 cases), 5(1 case), 1 (no date)) | 100% Fused XLIF versus 96% Fused TLIF CT Bridging bone 100% Fused XLIF CT Bridging bone | Both Significant Neurological Improvement Outcomes 10 5 Full Recovery 1 Colostomy 1 Died Sepsis 1 Colon Repair 2 Lost F/O |
| Epstein et al.[5], SNI 2016 | 2 Year Outcomes MIS XLIF versus MIS TLIF DSpnd+ST 24 mos F/U | 1-2 Adjacent Levels L1-L5 Prospective Randomized Observational | 29 XLIF | 26 TLIF More Canal Area MIS TLIF 43.1 mm versus TLIF 4.1 mm | 3 MVI XLIF 1 Fatal | 3 LBP 45% Risk Cage Overhang |
| Epstein et al.[35], S656 | AE of XLIF Symp MVI Bowel Perf Sterile S Instr Fail | Deficit 4% Symp XLIF versus 15% ALIF 1 Sterile S | 3 MVI XLIF 1 Fatal 1 RH/Life Threatening 3 LP Injury/Sens | 3 Bowel Perf Literature Review (2 Cases) 1 Communication |

(Contd...)
| Author/Journal Date | Design | Population | Findings | Findings | Conclusion |
|---------------------|--------|------------|----------|----------|------------|
| **Segawa et al.**<sup>[18]</sup> J Spine Surg 2017 | MicroEnd XLIF 96 Pts One Surgeon | 84 1- Level 9-2 Level 3-3 Levels Avg 1.2 Levels/pt | Average Age 61 years Range 22-83 F/U 18 mos | 3 (3.1%) AE 2 End Plate Fractures 1 Deep SSI No Bowel Perf No MVI 61% Improved Cobb Angle 11% Correction Lordosis | MicroEnd XLIF “…one solution for severe visceral and vascular injuries related to XLIF” XLIF “…suited to treating complex … degenerative disease” |
| **Pereira et al.**<sup>[16]</sup> J Clin Neurosci 2017 | XLIF for ST DSpond 23 Pts 91% ST 35% Prior Surgery | Retrospective VAS ODI 48% Sens-LS 1 RH Treatment No Surgery Retrospective Survey 2013–2015 Response Rate 86.1% | XLIF Pros Restore Disc Height Improved Radiculopathy No BP | 540 AE 474 (84.8%) Analyzed AE 18% 5.15 Sens 4.3% Motor | MicroEnd XLIF “…one solution for severe visceral and vascular injuries related to XLIF” XLIF “…suited to treating complex … degenerative disease” |
| **Fujibayashi et al.**<sup>[7]</sup> Spine 2017 | 2 Years Japan 2988 Cases XLIF 1995 OLIF 1003 71 Sites | Retrospective Survey | Time to Diagnosis Lumbar Disc 18/31 (58.1%) Symptoms-Signs-Sepsis 12–2 Days-5–9 Days Abdominal Pain, Vomiting, Hypotension Peritonitis Cobb-Angle 1 of 2 Average 1.6 F/U 20 mos | 12 F Avg age 64.5 | 0.03% Vascular Injury 0.03% Lower Bowel Perf LBP 0.7% SSI 2.2% Reop | More BP/Peritoneal Laceration OLIF |
| **Paterakis et al.**<sup>[13]</sup> J Spine Surg 2018 | 12 XLIF Deg. Scoli w/wo Instr. Fusion | Retrospective. VAS, ODI Cobb-Angle 18/31 (58.1%) Lumbar Disc/Signs-Sepsis Abdominal Pain, Vomiting, Hypotension Peritonitis Correction Vertebra Slab 56.3% Time to Diagnosis VAS Improved form 7.1 to 2.2 | All 12 F Avg age 64.5 Timely Treatment | 0.03% Vascular Injury 0.03% Lower Bowel Perf LBP 0.7% SSI 2.2% Reop | 1 (8.3%) of 12 LBP- Bowel Perf Primary Anastomosis |
| **Siasos et al.**<sup>[19]</sup> J Spine Surg 2018 | 31 BP Lumbar OR 1960-2016 10/31-32.3% XLIF, ALIF TLIF 15-L5S1 16-L4S | Retrospective Survey | 3 Intraop 12<2 Days-5-2-7 Days 4–1 Week-1 yr | Abdominal Pelvic CT- Fluid in Abdomen, PneumoP, Abscess Instruments Close to Bowel | MicroEnd XLIF “…one solution for severe visceral and vascular injuries related to XLIF” XLIF “…suited to treating complex … degenerative disease” |
| **Tamburrelli et al.**<sup>[20]</sup> Eur Spine J 2018 | MIS XLIF Lysis/ Spond XLIF+PLF (Percutaneous PS Fusion) | Correction Vertebra Slab 56.3% Time to Diagnosis VAS Improved form 7.1 to 2.2 | Orderly Improved ODI Improved 36.8% to 24.1% SF 36 Physical Health 83.2% 1 yr | CT 1 yr-No Loosening “XLIF”… good correction of the listhesis… | MicroEnd XLIF “…one solution for severe visceral and vascular injuries related to XLIF” XLIF “…suited to treating complex … degenerative disease” |
| **Li et al.**<sup>[13]</sup> World Neurosurg 2019 | Learning Curve for 1st 30 Cases (2014) OLIF versus XLIF | Lumbar OR Disc, Stenosis, DS, Infection, Trauma, Tumor | Avg Age XLIF 58.4 Lumbar OR 56.1 XLI5 XLI5 24 1-Level, 4 at 2 Levels, 2 at 3 levels XLI5 Levels 5 L23, 9 L34 24 L45 | AE OLIF 33.3% (9 Cases) 3 Vascular 0 BP Other 1 Cage in canal, 2 Root injuries, 1 Sympathetic Chain Injury, 1 cage Displacement, 1 End Plate Injury | Lower AE XLIF 10% 3 Cases (1 Infection, 1 End Plate Injury; 1 sensory) 0 Vascular 0 BP |
| **Epstein**<sup>[6]</sup> SNI 2019 | Review AE XLIF-20 Studies 1080 XLIF | Deficits 30–40% Nerve Injury: 12.3% Lumbar PL, Ilioinguinal Iliohypogastric Genitofemoral LFC, SUBC, Symp | Deficits 0.04% Vascular Other: BP, Ileus, Sterile S 7.5% Pseud SUBS, Reop | MicroEnd XLIF “…one solution for severe visceral and vascular injuries related to XLIF” XLIF “…suited to treating complex … degenerative disease” | “Most XLIF studies are limited by study design, sample size, and potential conflicts of interest” |
rates ranging from 11.1–23%.\textsuperscript{\textacuted{13,14}} Notably, specific mortality rates for BP occurring in patients undergoing XLIF/MI XLIF ranged from 9.09% (1/11 BP in 13,004 XLIF patients) to 12.9% (4/31 BP occurring in a series of 18 patients following diskectomies/microdiskectomies, and 10 lateral procedures including XLIF).\textsuperscript{\textacuted{19,22}}

**FREQUENCY OF SPONDYLOYSIS WITH ISTHMIC SPONDYLOLISTHESIS**

In 2020, Aoki et al. reviewed 580 cases of lumbar spondylosis; 37 (6.4%) patients had spondylolisthesis, with 19 of 37 additionally demonstrating spondylolisthesis (51.4%) \textsuperscript{[1]}.

### Table 1: (Continued).

| Author | Journal Date | Design | Population | Findings | Findings | Conclusion |
|--------|---------------|--------|------------|----------|----------|------------|
| Rustagi et al.\textsuperscript{[17]} | Global Spine J 2019 | 590 XLIF 3 BP No BP for: 171 ALIF; 14 OAIF Avg Time to Diagnosis 4.7 Days (Range 3–7) | 3 BP Due to XLIF-3 F; Avg age 74.3 Symptoms Abdominal Pain Distention Fever Nausea/ Vomiting Sepsis | Abdominal/ Pelvic CT- Extraluminal Trapped Air Loss Bowel Continuity Increased Bowel Wall Thickness | Levels/Surgery L45-1 L2-4 XLIF/L2-S1 PF-1 L2-L5 XLIF-1 3 BP Operations Ileocecectomy/Side/ Side Anastomosis (1) Colectomy/ Ileostomy (1) Colectomy/End/End Anastomosis (1) | Outcomes 3 Good Quoted Literature Visceral Injuries with Anterior Procedures 0–5% |
| Aoki et al.\textsuperscript{[1]} | Sci Rep 2020 | Prevalence Lumbar Lysis and Spond with Deg ST | Lumbar Lysis Mostly Occurs in Adolescent Athletes | 580 Pts 37 (6.4%) Lysis 19 (51.4%) of 37 Spond EBL Less XLIF 85.4 ml versus TLIF 258 ml; Same Outcomes APCT Found 5 (5.5%) No BP but +PneumoP Symptomatic Abdominal Pain/ Fever Peritoneal Signs XLIF Preserved Facet Joints, Lamina, Parasp Musc Risk Factors-BP LLIF >3 Fusion Levels Surgery L23/L34 levels CT 48 h: PneumoP May Lead to Peritonitis | Majority Lysis/Spond 60/> Often Seen Higher Rate Improvement of LBP for XLIF versus TLIF Recommend Routine 48 hr Postop APCT Rule Out BP versus PneumoP |
| Hiyama et al.\textsuperscript{[8]} | Sci Rep 2020 | Study 90 LLIF APCT 48 h Postop | F/U 12.6 mos XLIF Shorter OR 109 min versus 153 min TLIF 2 BP Cases: 75 yo L23, L45, LS1-Colostomy 78 yo L45 LLIF Infection-2nd L34/ L45 LLIF-5 Days BP- Colostomy | F/U 12.6 mos XLIF Shorter OR 109 min versus XLIF 2 BP Cases: 75 yo L23, L45, LS1-Colostomy 78 yo L45 LLIF Infection-2nd L34/ L45 LLIF-5 Days BP- Sepsis | Outcomes APCT Found 5 (5.5%) No BP but +PneumoP Symptomatic Abdominal Pain/ Fever Peritoneal Signs XLIF Preserved Facet Joints, Lamina, Parasp Musc Risk Factors-BP LLIF >3 Fusion Levels Surgery L23/L34 levels CT 48 h: PneumoP May Lead to Peritonitis | Majority Lysis/Spond 60/> Often Seen Higher Rate Improvement of LBP for XLIF versus TLIF Recommend Routine 48 hr Postop APCT Rule Out BP versus PneumoP |
| Hwang et al.\textsuperscript{[8]} | Asian Spine J 2021 | Preop versus Postop 62 MIS TLIF versus 44 MIS TLIF for DSpond+ST Review BP versus PneumoP LLIF 2/140 Cases of BP (2016–2018) Study 90 LLIF APCT 48 h Postop | Lumbar Lysis Mostly Occurs in Adolescent Athletes | Lumbar Lysis Mostly Occurs in Adolescent Athletes | 580 Pts 37 (6.4%) Lysis 19 (51.4%) of 37 Spond EBL Less XLIF 85.4 ml versus TLIF 258 ml; Same Outcomes APCT Found 5 (5.5%) No BP but +PneumoP Symptomatic Abdominal Pain/ Fever Peritoneal Signs XLIF Preserved Facet Joints, Lamina, Parasp Musc Risk Factors-BP LLIF >3 Fusion Levels Surgery L23/L34 levels CT 48 h: PneumoP May Lead to Peritonitis | Majority Lysis/Spond 60/> Often Seen Higher Rate Improvement of LBP for XLIF versus TLIF Recommend Routine 48 hr Postop APCT Rule Out BP versus PneumoP |

Deg. Scoli: Degenerative Scoliosis, Instr.: Instrumented, F: Female, XLIF: Extreme Lateral Lumbar Interbody Fusion, Retrospect: Retrospective, VAS: Visual Analogue Scale, ODI: Oswestry Disability Scale, w/wo: with/without, mos: Months, AE: Adverse Events, MP: Meralgia Paresthetic, BP: Bowel Perforation, Ana: Anastomosis, Neuro: Neurological, Symp: Sympathectomy, MVI: Major Vascular Injuries S: Seroma, Instr.: Instrumentation failures, RH: Retroperitoneal Hematoma, IP: Iatrogenic Pseudoaneurysm, DCom: Direct Communication, Inj: Injuries, PF: Plexus, LFC: Lateral Femoral Cutaneous, SUBC: Subcostals Postop: Postoperative, Pseud: Pseudarthrosis, SUBS: Subsidence, Reop: Reoperations, Sens: Sensory, UT: Up to, LP: Lumbar Plexus, Ant: Anterior, PS: Pedicle Screw, MI/MIS: Minimally Invasive, TLIF: Transformaminal Lumbar interbody Fusion, LAP: Lapatotomy, BR: Bowel Resection, Pares: Paresthesias, LIS: Lateral Interbody Fusion, SS: Surgical Site Infection, OLIF: Oblique Lateral Interbody Fusion, SS: Spinal Disease, Lysis: Spondylosis, Spond: Spondylolisthesis, Deg: Degenerative, Pts Patient, DSpond: Degenerative Spondylolisthesis, MI/MIS: Minimally Invasive, EBL: Estimated Blood Loss, Paras: Paraspinal, Musc: Muscles, ST: Stenosis. F/O: Followed, DDD: Degenerative Disc Disease, ASD: Adjacent Segment Disease, Post Lam: Post Laminectomy Syndrome, DM: Diabetes, Avg: Average, Micro End: Microendoscopic. LBP: Large Bowel Perforation, Divertic: Diverticulitis, MOR: Mortality, MIS-LIF: Minimally Invasive Lateral Interbody Fusions, ALIF: Anterior Lumbar Interbody Fusion, GI: Gastrointestinal System, OAIF: Oblique Anterior Lumbar interbody Fusion, NIS: Nationwide Inpatient Sample, PneumoP: Pneumoperitoneum, LLIF Lateral Lumbar Interbody Fusion, APCT: Abdominal Pelvic CT, Neuro: Neurological., PF: Posterior Fusion, SE: Sentinel Events, OR: Operation/ Surgery, Perf: Perforation, Ortho: Orthopedic, Neuro: Neurosurgery, yo: Year Old

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emphasized that spondyloysis/spondylolisthesis defects were most typically reported in adolescent male athletes. Notably, these are the patients who may be specifically targeted for canal distraction/decompression with XLIF/MI XLIF supplemented with posterolateral fusions (PLF) performed utilizing pedicle screw instrumentation as these combined procedures offer preservation of the posterior elements.

**XLIF SUPPLEMENTED WITH POSTERIOR LATERAL FUSION (PLF) WITH PEDICLE SCREW INSTRUMENTATION FOR SPONDYLOLYSIS/SPONDYLolisthesis**

In select patients with isthmic spondyloysis/spondylolisthesis, XLIF/MI XLIF may be combined with posterolateral instrumented pedicle screw fusions to provide simultaneous anterior indirect canal decompression with posterior stabilization/fusion (PLF). This combination of procedures avoids disruption of the posterior elements (i.e. facet joints, laminae, spinous processes) [Table 1].

In Tamburrelli et al. (2018), MI XLIF were performed to address isthmic spondyloysis with spondylolisthesis, and were effectively supplemented with percutaneous pedicle screw fusions (PLF). This provided; “a reliable and safe option to the most common open procedures,” that usually included TLIF, while allowing for “good correction of the listhesis.”

**DIFFERENT FREQUENCIES OF BOWEL PERFORATIONS REPORTS FOR XLIF/MI XLIF**

For multiple series, the incidence of BPs attributed to XLIF/MI XLIF ranged between 0.03% to 12.5%; this left us questioning the true incidence of this surgical error [Table 1]. Specifically, BPs occurred in one case report, and with higher numbers of cases reported in other clinical series [Table 1]. In 2015, Balsano et al. described a 70-year-old male who, following a L3-L4/L4-L5 XLIF, developed a BP. Tormenti et al. (2010) found 1 (12.5%) BP occurring after performing just 8 MI XLIF (2007–9). Uribe et al. (2015) noted that out of 13,004 MI XLIF, there were 11 BPs. Surgeons in this study were experienced with XLIF/MI XLIF as they had performed between 11 to 50 cases or over 50 cases. When Fujibayashi et al. (2017) looked at 1995 patients undergoing XLIF with another 1003 having oblique lateral lumbar interbody fusions (OLIF), there was just one case (0.03% of 2988 patients) of a BP. Paterakis et al. (2018) later found that 1 of 12 patients (8.3%) undergoing XLIF for degenerative scoliosis sustained a BP (i.e. treated with a primary resection/anastomosis).

In 2018, Siasos et al. documented 31 BPs; 10 occurred after MI lumbar operations; (i.e. XLIF), anterior, lumbar interbody fusion [ALIF], and transforaminal lumbar interbody fusion [TLIF]), while 18 followed lumbar discectomies/microdiscectomies. In 2019, Rustagi et al. found 3 (0.5%) of 590 XLIF resulted in BP. Finally, Hwang et al. (2021) determined that 2 of 140 LLIF resulted in BP.

**STUDIES NOT SPECIFICALLY REPORTING THE INCIDENCE OF BOWEL PERFORATIONS**

Four clinical series, involving between 23 and 96 patients per study, did not discuss BP as occurring following XLIF/MI XLIF [Table 1]. In a prospective, multicenter combined randomized/observational series, Isaacs et al. (2016) looked at the 2 year outcomes for 1–2 adjacent-level L1-L5 MI XLIF (29 patients) versus MI TLIF (26 patients). These were performed to address degenerative spondyloysis and stenosis; no bowel perforations were observed. When Segawa et al. (2017) assessed the safety/efficacy of microendoscopic 1–3 level XLIF performed in 96 patients, they reported no BPs or vascular injuries. They attributed this to the introduction of the microendoscopy technique. When Pereira et al. (2017) evaluated 23 XLIF, they too encountered no BPs. Additionally, no BPs were cited in the Hiyama et al. series that compared the complications of 62 MI XLIF versus 44 MI TLIF. Of interest, they also found that XLIF operations were nearly 1/3 shorter than TLIF; the average blood loss of MI XLIF was reduced by 2/3, while the XLIF/MI XLIF procedures offered the benefit of preserving the posterior elements.

**SIGNIFICANT INCIDENCE OF NEUROLOGICAL, VASCULAR, AND OTHER INJURIES WITH XLIF/MI XLIF**

Many XLIF/MI XLIF studies cited high frequencies of new sensory (i.e. 5.15–75% including thigh paresthesias), new motor (5.15–40% - typically iliopsoas), and vascular (0.03–0.04%) injuries [Table 1]. Other postoperative complications included; 0.7% plus incidence of surgical site infections, end plate injuries/fractures, retroperitoneal hematomas, sterile seromas, postoperative ileus, pseudarthrosis, and the need for additional surgery.

**LEARNING CURVE FOR XLIF VERSUS OLIF**

In Li et al. (2019), the learning curve for the first 30 cases of XLIF versus OLIF were studied in patients undergoing lumbar surgery for disc disease, stenosis, degenerative spondyloysis, infection, trauma, or tumor. There was a 10% incidence of adverse events (AE) occurring within the early learning curve for 1-3 level XLIF versus 33.3% for OLIF. Patients were on average in their late fifties, and although none developed BP in either group in this series, 3 undergoing OLIF had major vascular injuries, while 3 patients having XLIF sustained minor
complications (i.e. 1 infection 1 end plate injury, and 1 new sensory deficit).

**FREQUENCY OF BOWEL PERFORATIONS WITH XLIF/MI XLIF**

Vastly different frequencies of BPs occurred in patients undergoing XLIF/MI XLIF, ranging from 0.03% to 12.5% [Table 1].\(^{7,9,15,19,21,22}\) Most critically, when patients develop new postoperative peritoneal symptoms/signs (i.e. abdominal pain, hyperemesis, hypotension, peritonitis, and sepsis), spinal surgeons should immediately consult general surgeons to both diagnose and surgically manage BPs if diagnosed and warranted. In Siasos et al., 3 cases of BP were diagnosed intraoperatively, while the remainder were diagnosed/operated on between 2 days and 1 week/1 year postoperatively.\(^{19}\) For 3 of the 590 patients in Rustagi et al. series, the diagnosis of BPs led to surgery performed an average of 4.7 days (range 3–7) postoperatively.\(^{17}\)

**DIAGNOSTIC FINDINGS FOR BOWEL PERFORATIONS ON ABDOMINAL/PELVIC CT SCANS**

Multiple studies also confirmed common findings on Abdominal/Pelvic CT scans (APCT) consistent with/diagnostic of BPs following XLIF/MI XLIF.\(^{17,19}\) These findings included; fluid in the abdomen, pneumoperitoneum, instrumentation close to the bowel, extraluminal trapped air, loss of bowel continuity, and increased bowel wall thickness.\(^{17,19}\) Of interest, Rustagi et al. (2019) noted: “The isolated presence of air/fluid in the retroperitoneal space is easily confounded by the presence of expected postoperative findings following TPIF (i.e. XLIF).”\(^{17}\) Alternatively, after observing 2 instances of BP out of 140 patients undergoing LLIF, Hwang et al. (2021) prospectively performed APCT within 48 postoperative hours.\(^9\) Out of 90 LLIF, they found that APCT studies performed in 5 patients (5.5%) with peritoneal symptoms had pneumoperitoneum; despite this, there were no documented BPs.\(^9\) They further correlated an increased risk of BP with LLIF fusion of more than 3 levels, and surgery performed at the L2-L3, and/or L3-L4 levels.

**TREATMENT OF BPS OF ALL ETIOLOGIES**

High mortality rates are reported for BPs occurring due to many different factors (i.e. especially diverticular disease, and non-diverticular disease exclusive of spinal surgery) [Table 1].\(^{3,4,14,17,19,22}\) One series cited an 11.1% mortality rate where primary resections/anastomoses were possible, but a 22.2% mortality if these were not feasible.\(^3\) The second study found an overall 23% mortality rate for BP, that included consideration of diverticular (133 patients) and non-diverticular-related (79%) perforations.\(^4\)

**HIGH MORTALITY RATE FOR BOWEL PERFORATIONS FOLLOWING XLIF/MI XLIF**

High mortality rates (i.e. up to 12.9%) are reported for BPs occurring due to XLIF/MI XLIF.\(^{14,17,19,22}\) This, therefore, warrants that patients presenting with new peritoneal signs following XLIF/MI XLIF should immediately undergo evaluation by general surgery to diagnose and potentially treat BPs. In Marzuez-Lara et al. (2014) National Inpatient Database involving 543,146 patients undergoing lumbar surgery, 30 patients had BPs/peritoneal injuries; they had a 20 fold greater mortality rate when compared to those without such intraoperative errors (i.e. 14.6 vs. 0.7/1000 cases).\(^{14}\) In Uribe et al. (2015), 11 (0.08%) out of 13,004 patients following MI XLIF had BPs.\(^{22}\) Repairs were performed intraoperatively (4 cases), or between postoperative days 2–5; the result was 1 death from sepsis, 5 full recoveries, one permanent colostomy, while 3 were lost to follow-up.\(^{12}\) For the 31 BPs identified in Siasos et al. review (2018), including 10 due to XLIF, ALIF, and TLIF, surgery to address BPs were performed intraoperatively (3 cases), and up to 1 week/1 year postoperatively.\(^{19}\) Further, when Rustagi et al. operated on 3 (0.5%) BPs out of a series of 590 patients undergoing XLIF, they were diagnosed and operated on an average of 4.7 days postoperatively, resulting in no deaths, but one permanent ileostomy.\(^{17}\)

**CONCLUSION**

The incidence of BPs reported following XLIF/MI XLIF procedures ranged from 0.03% up to 12.5% in multiple studies.\(^{7,9,15,17,19,21,22}\) Hence, it is apparent that the true incidence of BPs following these procedures is still not well defined [Table 1].\(^{7,9,15,17,19,21,22}\) What is clear, however, is that patients who acutely develop peritoneal symptoms/signs following XLIF/MI XLIF should immediately undergo evaluation by general surgery to diagnose and potentially surgically treat BPs if warranted [Table 1].\(^{3,4,14,17,19,22}\)

**Declaration of patient consent**

Patient’s consent not required as there are no patients in this study.

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**Conflicts of interest**

There are no conflicts of interest.
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Commentary

Bowel injury in spinal surgery is an uncommon event but well documented for traumatic SCI with associated thoracolumbar fracture/dislocations, interbody spacer migration, and prominent anterior instrumentation. As more lateral, anterior, and redo lateral surgery is performed on an aging population and more spinal surgeons are doing their own approaches, bowel injury may increase. A low threshold for postoperative CT-abdomen/pelvis as a routine precautionary measure may be needed to minimize the potential missed bowel injury or to provide an earlier diagnosis of bowel perforation versus paralytic ileus. Early mobilization, minimization of postoperative narcotics, and optimization of intraoperative anesthesia during surgery can minimize the incidence of ileus in this patient group, but the quick diagnosis and management of bowel perforation is the key to minimizing morbidity and mortality. Early general surgery consultation should be sought in any spine surgery cases with a questionable abdominal exam or postoperative radiographic findings.

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