

Lateral Lumbar Interbody Fusion, Indications and Complications—An Updated Review

Yun-lin Chen

Ningbo No.6 Hospital

Ou-jie Lai

Ningbo No.6 Hospital

Wei-hu Ma

Ningbo No.6 Hospital

Qi-xin Chen (✉ cylzju@zju.edu.cn)

Second affiliated hospital of Zhejiang University School of Medicine

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Abstract

Purpose

To perform an updated and comprehensive review of LLIF; we will also introduce a new modified LLIF named as crenel lateral interbody fusion (CLIF) to reduce the approach-related complications

Methods

A systematic and critical review of recent literature was conducted. The sources of the data were from PubMed, MEDLINE, Embase, and Cochrane. Key search terms were "transpsoas", "interbody fusion", "LLIF", "XLIF", and "DLIF"

Results

Stand-alone LLIF has the risk of cage subsidence and non-union rate. LLIF has less complication compared with other approaches because of its minimal invasive, but it still has some specific complications.

Conclusion

LLIF is a safe, effective and lower complication rate technique when compared to other interbody fusion methods.

1. Introduction

Degenerative lumbar diseases are a common condition in the elder, resulting in lower back pain, spinal instability, radiculopathy and claudication [1]. The prevalence of lower back pain among patients over than 65 years is about 56% [2]. The treatment of degenerative lumbar disease is controversial. Lumbar fusion has been the optimal option for a variety of spinal pathologies including lumbar degenerative diseases. Currently, the recommended surgical procedures used for fusion in the lumbar spine are divided into the following major approaches, anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), and lateral lumbar interbody fusion (LLIF).

Several studies have documented the complications of these approaches [3, 4]. Anterior approaches have the risk of abdominal organs damage (<1%), vascular injury (1.3%-15.6%), post-operative ileus (0.6%-5.6%), and sympathetic injury (1.7%-13.3%) [3, 5-7]. Posterior approaches may lead to nerve root injuries (9%–16%), postoperative radiculitis (6.7%–16.4%), and incidental durotomies (5.4%–10%) [3, 6, 8].

LLIF is a minimally invasive spine surgical procedure that uses a small incision and directly access to the intervertebral disc by the retroperitoneal area. LLIF was also called as transpsoas interbody fusion, extreme lateral interbody fusion (XLIF), and direct lateral interbody fusion (DLIF). Ozgur first described

LLIF in 2006 [9]. LLIF does not require direct entry into the spinal canal or neuroforamen or the retraction of nerve roots. It reduced risk of iatrogenic nerve root injury and post-operative durotomies when compared with posterior approaches. LLIF can use a substantially larger interbody cage when compared with TLIF or PLIF, which resulting in greater bone-cage contact area, superior initial stability and less of cage subsidence [10-11]. However, LLIF also has some disadvantages, such as the risk of neurological deficit, cage subsidence, and implant failure [7]. Moreover, L5/S1 level is inaccessible in this approach. Operator should pay more attention to the L4/5 level because of the increased risk of lumbar plexus injury.

The purpose of this study is to perform an updated and comprehensive review of LLIF; we will also introduce a new modified LLIF named as crenel lateral interbody fusion (CLIF) to reduce the approach-related complications [12].

2. Methods

A comprehensive search of several databases was performed. The database included Medline, OVID, Embase, and Cochrane. The key word was “transpsoas”, “lateral lumbar interbody fusion”, “direct lumbar interbody fusion”, “extremely lateral lumbar interbody fusion”. The articles were thoroughly checked and evaluated on the basis of study design, and outcomes. Clinical studies that reported about indications, complication, and outcomes of lateral lumbar interbody fusion were included. Manual search of reference lists was also performed to make sure related studies were not missed. Risk of bias assessment was conducted using the Newcastle-Ottawa scale.

3. Results

3.1 Surgical techniques

The modern lateral lumbar interbody fusion was first performed and described by Ozgur. For the procedure, patients were positioned in a standard lateral decubitus position; the table was bent with the apex to increase room between iliac crest and the rib. The hips and knees are flexed to relax the psoas muscle. The affected level was located by fluoroscopy. X rays image should demonstrate co-linear vertebral body end plates and pedicles.

A 2-3 cm longitudinal incision was made; the incision was continued with the external oblique muscle, followed by the internal oblique muscle. Then the transversus abdominis muscle and its underlying transversalis fascia were exposed. The lateral surface of the spine was reached through the retroperitoneal space. An expandable retractor was placed and visualization of the disc space obtained. Discectomy and preparation of the disc space were performed, followed with placement of cage and bone graft. A new modified LLIF named as crenel lateral interbody fusion (CLIF) reached the lateral space of the spine through anterior 1/3 of the psoas muscle. The modified technique included operation under direct visualization, the safe transpsoas approach and the adjustable microretractor. The psoas major

was split longitudinally along the muscle fiber according to the safe working window. It can reduce the approach related complications of traditional LLIF [12].

3.2 Indications and contraindications

Indications of LLIF are similar to other lumbar interbody fusion techniques. Because of the limitation of ilium, LLIF was generally considered contraindicated at the L5/S1 level. Siu reported three cases in which LLIF was successfully conducted at the lumbosacral junction (LSJ). They analysed the patients' spinopelvic parameters and psoas anatomy, concluded the low pelvic incidence (40-50°) appeared with low-lying iliac crests, which was suitable for LLIF in LSJ for all cases [13]. LLIF can be safely performed at the L5/S1 level in selected cases.

Most LLIF procedures were performed for degenerative lumbar diseases, such as lumbar canal stenosis, lumbar spondylolisthesis, degenerative scoliosis and discogenic lower back pain [14]. Contraindication of LLIF included severe osteoporosis, history of retroperitoneal infection or disease, previous retroperitoneal dissection or injury. LLIF used to treat spinal infection was still controversial. Patients suffering from retroperitoneal scarring and fibrosis may be at high risk for complications due to inadvertent injury. It is typical in patients with a history of diverticulitis, radiotherapy to the abdomen, or previous abdominal surgery (nephrectomy or total colectomy). Gan et al treated thoracic and lumbar invasive tuberculosis with DLIF, they make the conclusion of less injury and quick recovery after surgery [15]. LLIF may be not suitable for active infection, but it can be used for those chronic diseases.

3.3 Stand-alone LLIF

Stand-alone means LLIF without posterior fixation, which can be used for patients with good bone quality. It also can be used for adjacent segment disease (ASD). However, stand-alone has the risk of cage subsidence and non-union rate. Nitin reported the effect of LLIF in the older patients (median age was 74 years), they found a lower femoral neck t-score <-1.0 correlated with a higher incidence of graft subsidence [16]. Bocahut et al. reported 97% fusion rate, but incidence of subsidence was still as high as 32% [17]. Abdala et al. performed an extensive radiographic study of graft subsidence following stand-alone LLIF, and they proposed a grading scale to describe the degree of subsidence. Grade 0 (0%–24% of the graft height) and Grade I (25%–49% of the graft height) are low grade, and Grade II (50%–74% of the graft height) and Grade III (75%–100% of the graft height) are high grade [18]. Tempel et al. revealed a significantly higher incidence of revision surgery in patients with high-grade subsidence compared with those with low-grade subsidence. They concluded high-grade subsidence was a significant predictor of the need for revision surgery, whereas age, body mass index, T-score, and number of levels fused were not [19]. Aichmair et al. showed LLIF was an effective option for ASD with regard to both the clinical and radiographic outcomes, while stand-alone group has higher reoperation rate when compared to circumferential fusion group [20]. Watkins et al. reported stand-alone has non-union rate of 19% per level and 27% per patient [21].

Subsidence of the LLIF graft may be because of insufficient preparation of endplates during the operation or inadequate stabilization allowing micro-motion between the graft and endplates resulting in end-plate fracture or osteolysis (Fig.1). Wagner reported a case with displaced end plate fracture after LLIF, and then they managed the fracture with transforaminal endoscopic decompression [22]. For stand-alone LLIF, posterior instrumentation may be necessary to increase segmental stability to get solid fusion. This may be done using percutaneous or open surgery.

3.4 LLIF for adult spinal deformity

LLIF has been described as an excellent option for treatment of adult spinal deformity [23, 24, 25]. Castro et al. reported 62 patients diagnosed with adult degenerative scoliosis that underwent stand-alone LLIF, they achieved reasonable coronal and sagittal correction in the final follow-up, as well as the improvements in pain and function. However, the incidence of subsidence was about 29% [26]. Attenello et al. reported twenty-two patients underwent LLIF combined with open laminectomy and posterior pedicle instrumentation (13 patients) or percutaneous pedicle instrumentation without decompression (9 patients). Both open and percutaneous posterior techniques following LLIF significantly improved clinical outcomes. Coronal Cobb angle and regional lumbar lordosis were improved both in open and percutaneous groups. Open procedures resulted in significantly better radiographic improvements [27].

Approaching the curve from the concave or convex side was controversial. Most studies showed concave side permits easier access to the disc spaces with favorable axial rotation to the surgeon, while approaching the convex side might require more incision. Shin et al. evaluated the size of the psoas muscle as well as the relative position of the great vessels and ventral nerve roots along the convexity and concavity of the curve in magnetic resonance imaging-based study [28]. They concluded that approaching the convexity of the curve provides the surgeon with optimal disc space access through a larger safe zone compared to the concavity. Takata et al. concluded the interval distance between the lumbar segmental arteries is much shorter along the concave side, potentially increasing the risk of injury and hemorrhage when from the concave approach [29]. Kanter et al. reported 63 patients undergoing LLIF with convex (23 patients) or concave approaching (40 patients). There were no statistically significant clinical or operative complication rates, and clinical outcomes and coronal deformity were improved regardless of a concave or convex approach to the curve. However, in cases wherein L4-5 is in the primary curve, approaching the fractional curve at L4-5 from the concave approach (63.3%) may be associated with a higher complication rate compared to a convex approach (31.6%) [30].

Sembrano et al. compared four approaches (ALIF, LLIF, TLIF and posterior spinal fusion, PSF) to treat 147 patients with sagittal imbalance, they concluded LLIF had the ability to improve sagittal contour as well as other interbody approaches and was superior to PSF in disc height restoration. However, ALIF could provide greater segmental and lumbar lordosis correction [31]. Bae et al. compared PSF, ALIF combined with PSF, LLIF combined with PSF in 221 patients with sagittal imbalance, and they showed LLIF+PSF had lower rates of proximal junction kyphosis and mechanical failure at the upper instrumented vertebra and less back pain, less disability and better SRS-22 scores [32].

3.5 Complications

The most common complications following open surgery are approach-related (i.e., blood loss, wound infection), implant-related (i.e. implant break-down, failure, cage subsidence, infection (Fig.2)), radiographic (i.e., pseudoarthrosis, adjacent segment failure, inadequate correction, etc.), neurological, or medical (i.e., cardiac, pulmonary, etc.). LLIF has less complication compared with other approaches because of its minimal invasive, but it still has some specific complications. In this study, we introduce the neurological, visceral and vascular complications.

3.5.1 Neurological complications

Epstein showed minimal invasive surgeries (TLIF, PLIF, ALIF, LLIF) has a higher incidence of root injuries, radiculitis or plexopathy [33-35]. He recommended LLIF was not safe, and we should stop this procedure. It was related to its anatomy.

In the retroperitoneal space, the ilioinguinal, iliohypogastric, and lateral femoral cutaneous nerves freely downward to reach the anterior iliac crest. Once the retroperitoneal space is reached, the blunt dissection of this space requires special care to avoid injury these main nerves.

The anatomic structures at risk during LLIF are the nerves in the lumbar plexus dorsally and major vessels ventrally. Moving from cranial to caudal spinal levels (ie, L1-2 to L4-5), the psoas muscle and lumbar plexus course further ventrally and are at greater risk of injury [14]. Regev et al. used MRI for an anatomic study of the lumbar plexus and its relationship to the lumbar disc. Their data described a corridor that they termed the lateral access safe zone. This safe zone narrows from L1/2 to L4/5 (48% to 13%) [36]. Banagan et al. reported nerve root at L4/5 level were at greater risk for injury when compared to other levels from the cadaveric study [37]. To minimize the risk of intra-operative neurological injury, intra-operative electrophysiologic monitoring is a necessary tool to prevent nerve injury while traversing the psoas muscle and during placement of the retractor.

Thigh pain, paresthesias and weakness were the most commonly symptoms. Hijji et al. reviewed 6819 patients in 63 articles, transient neurologic was 36.07%, persistent neurologic was 3.98%. Transient complications included transient motor weakness (14.11%), transient hypoesthesia (17.13%), and transient thigh symptoms (26.51%) [38]. Gammal et al. reviewed 2913 patients in 24 articles, they showed the incidence of post-operative thigh symptom ranged as high as 60.7%, with 9.3% of patients complained a motor deficit related to direct nerve injury [39].

In recent studies, lumbar plexus injury was still the most common neurological complication [40-42]. Moro et al. proposed a method that divides the lateral aspect of the vertebral body into 4 zones, from anterior to posterior [43]. The lumbar plexus was located at the zone IV of the vertebral body. It passes obliquely outward, behind and through the psoas muscle. The genitofemoral nerve arises from the L2 and L3 nerve roots, and was response for narrowing the safe zone at the L2/3 level. Retractor usage in LLIF

has been associated with transient thigh pain, hip flexion weakness, and sensory changes due to injury to psoas muscle and irritation of related nerves [44, 45].

3.5.2 Visceral and vascular complications

The retroperitoneum is divided into three individual compartments: the anterior pararenal space (APS), posterior pararenal spaces (PPS), and the perirenal space (PRS) [46]. APS includes ascending or descending colon, duodenal loop, pancreas. PPS includes fat tissue, and PRS includes kidney, renal vessel, adrenal glands, renal pelvis and proximal ureter. Injury of the peritoneum or the fasciae when exposing the retroperitoneal space may result in injury to the ascending or descending colon in a LLIF approach. Suratwala et al. reported a case of acute renal infarction in a 72-year-old female following LLIF with percutaneous pedicle screw for correction of adult spinal deformity [47]. A lateral approach to the anterior lumbar spine may precipitate renal artery occlusion and renal infarction in patients with atherosclerosis. They recommended we should pay attention to patients with deformities around the origin of the renal arteries and great vessels, especially in patients with atherosclerosis. Several studies also reported renal or renal vessels injury during the LLIF approach [48-50]. In order to minimize injury to the kidney, Iwanaga et al. analysed the anatomy of kidney and interdiscal space, they concluded the closest distance on L1/2, L2/3 and L3/4 ranged from 13.2 mm to 32.9 mm, 20.0 mm to 27.7 mm, and 20.5 mm to 46.6 mm. The distance is large enough at L4/5 level [51].

Vasiliadis et al. reported two cases that developed acute liver and gastric necrosis due to an occlusion of celiac artery, after a spine deformity correction underwent LLIF [52]. The surgeon should be alert for an appearance of a medial arcuate ligament syndrome (MALS) if a large correction for ADS is planned. Safaee et al. report a case of an intra-operative aortic injury. Aortic injury happened during the discectomy. The patient underwent endovascular placement of an aortic cuff graft at the level of the injury followed by completion of the interbody fusion [53].

The rates of visceral and vascular injury were rare, always less than 1% [54, 55]. Direct injury to the adjacent vascular structures with surgical instruments is the most common reason of vascular injury in LLIF. Hu et al. found that the vena cava would be at risk of injury using the right-sided approach in 71% patients, while the aorta was at risk in 29% of patients accessed from the left side [56]. The risk of injury is obviously higher in patients with deformity.

Visceral and vascular complications can have devastating outcomes; therefore, knowledge of the patient's anatomy is essential during preoperative planning. Minimized working corridor makes it more difficult to control vascular or visceral injury. Chen et al. modified the approach; they split the psoas muscle anterior than LLIF, but posterior than OLIF, so they could undergo the operation under direct visualization. Their study showed the modified surgical technique reduces the approach related complications of traditional LLIF through the operation under the direct visualization, the safety transpsoas approach and the adjustable microretractor [12].

3.6 Outcomes

LLIF has the advantage of placing a large interbody cage to maximize contact with the cortical bone. The large cage allows for indirect decompression of the lumbar canal and foramen because of the restoration of disc height and stretches of the ligament. Kepler et al. reported average foraminal area increase of 35% and posterior intervertebral height increase of 70% after LLIF [57]. The large cage also improved initial stability and the ability to control spinal alignment to correct the deformity. Park et al. showed the cage position with the anterior 1/3 of disc space was better for achieving the restoration of the segmental angle without compromising the indirect decompression [58]. Kono et al. compared the mini-open TLIF and LLIF for treatment of degenerative lumbar spondylolisthesis, and concluded LLIF and mini-open TLIF had equally post-operative clinical results, while LLIF had less blood loss and great correction of disc height [59].

Though many studies have been addressed the significant improvements of both clinical and radiographic outcomes after LLIF, there are still some case that required myelogram (iCTM) to evaluate the effect of indirect neural decompression after LLIF [62]. They concluded iCTM evaluation might reduce the risk of unnecessary direct decompression procedure and reoperation.

There are some limitations in our study. Firstly, the quality of this study was not high. Secondly, heterogeneity remains to be an important factor. Thirdly, there are other outcomes can be evaluated, but these factors could not be analyzed because of insufficient data.

4. Conclusion

LLIF is a safe, effective and lower complication rate technique when compared to other interbody fusion methods. The lateral approach avoids the great vascular risk of the ALIF and extensive soft tissue dissection and neural manipulation of the PLIF and TLIF. LLIF can restore the disc height and indirect decompress the neural canal and lateral recess. Vascular and visceral complication of LLIF was rare; much more attention should be taken to the pre-operative patients' anatomy. However, approach-related neurological complications remain a major concern. Modified crenel lumbar interbody fusion could reduce the complications under direct visualization, safe psoas approach and adjustable microretractor.

Abbreviations

ALIF: anterior lumbar interbody fusion

APS: anterior pararenal space

ASD: adjacent segment disease

CLIF: crenel lateral interbody fusion

DLIF: direct lateral interbody fusion

iCTM: intraoperative computed tomography myelogram

LLIF: lateral lumbar interbody fusion

LSJ: lumbosacral junction

MALS: medial arcuate ligament syndrome

PLIF: posterior lumbar interbody fusion

PPS: posterior pararenal spaces

PRS: perirenal space

PSF: posterior spinal fusion

TLIF: transforaminal lumbar interbody fusion

XLIF: extreme lateral interbody fusion

Declarations

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Competing interests

Yun-lin Chen, Ou-jie Lai, Wei-hu Ma, and Qi-xin Chen declare that they have no conflict of interest.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient. A copy of the consent form is available for review by the Editor of this journal.

Availability of data and material

The datasets supporting the conclusion of this article are included within the article.

Authors' contributions

All authors participated in the management of manuscript. CYL drafted the manuscript. LOJ AND MWH wrote discussion and introduction. CQX supervised the writing of the manuscript. All authors read and approved the manuscript.

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Figures

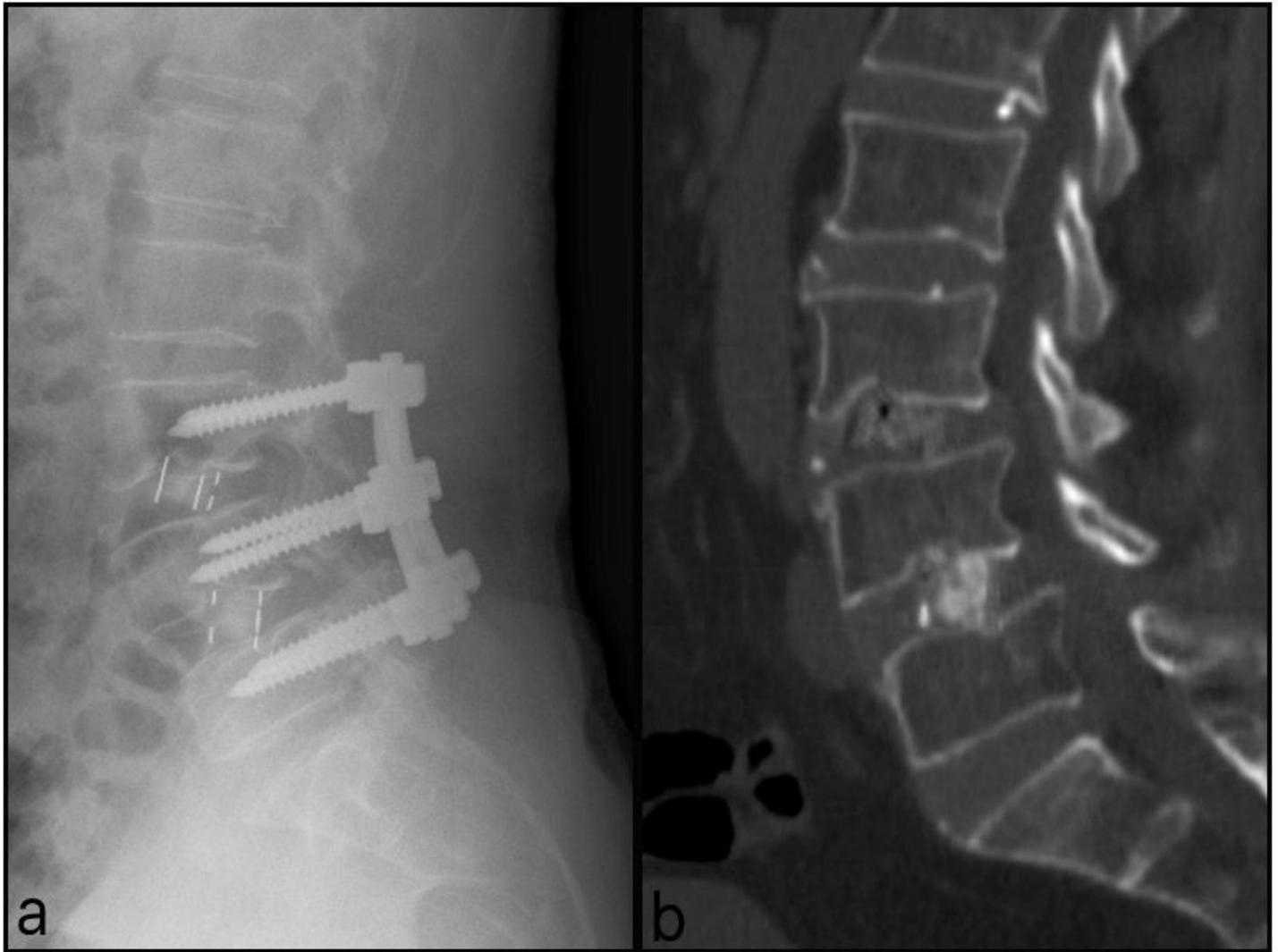


Figure 1

(a) lateral X ray and (b) sagittal CT scan show the fracture of L3 and L4 superior end plate after the LLIF procedure.

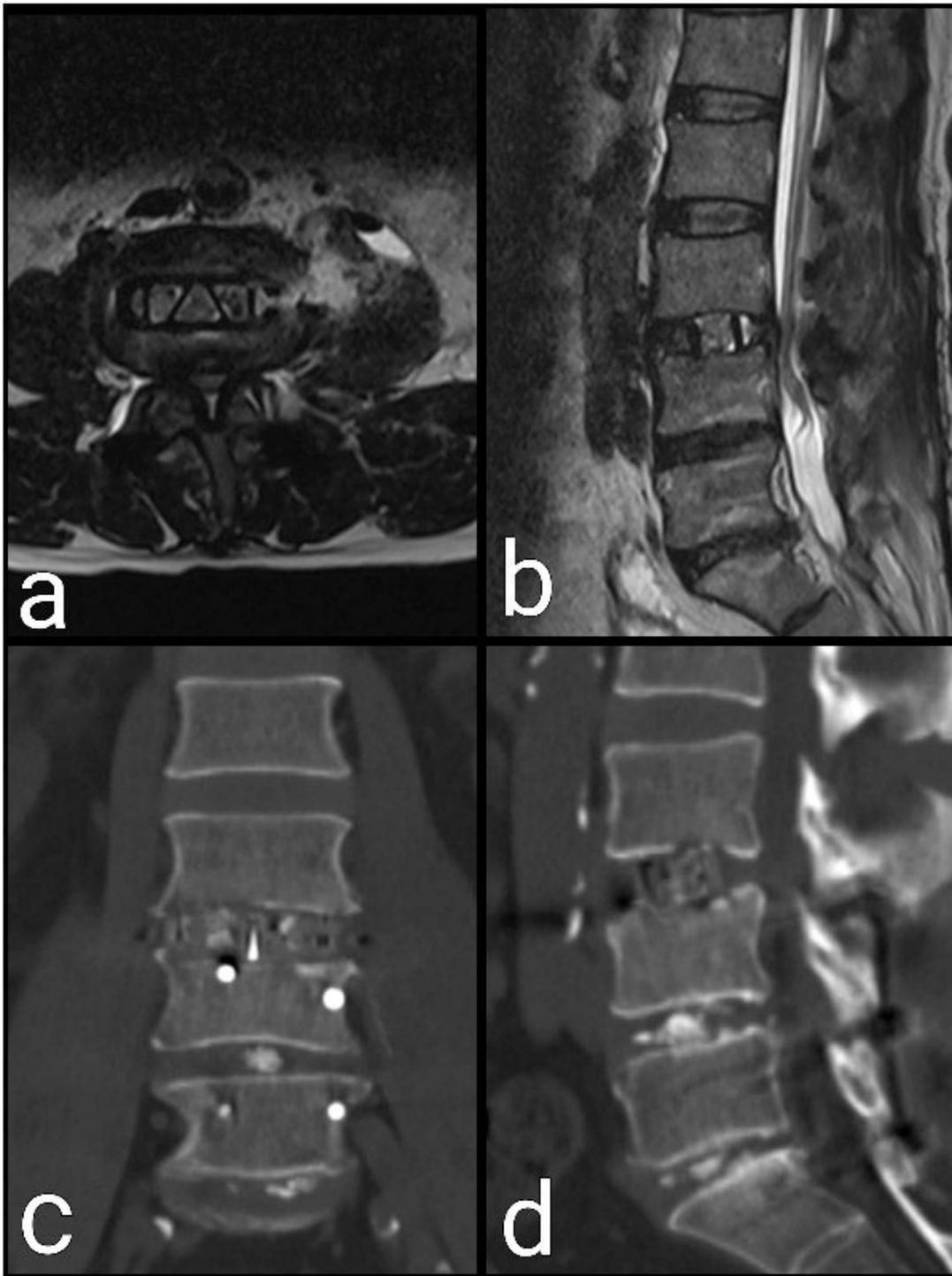


Figure 2

(a) axial MR image shows the abnormal signal around the cage, and edema of psoas muscle. (b) sagittal MR scan shows the fluid around the intervertebral cage. (c) coronal and (d) sagittal CT scan shows the erosion of end plate of L3. The post-operative pathological report confirms the intervertebral infection.

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