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Standardizing MI-TLIF, a Proposal for a Reproducible Technique

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Abstract

Background: Minimally invasive transforaminal lumbar interbody fusion (MI TLIF) is a widely known and performed technique, however its versatility among different physicians continues to hinder its replication and results. Therefore, this study aimed to provide a step-by-step surgical guide to perform a safe MI-TLIF, based on the results obtained in patients operated on by a single surgeon over a period of 12 years. **Patients and methods:** A retrospective, single center, longitudinal, and observational cohort study was conducted with 931 patients who underwent MI TLIF by a single surgeon between 2010 and 2022 using the technique described on this paper, each with a minimum follow-up of 12 months. Criteria included Schizas classification, listhesis according to Meyerding classification, number of levels treated, cage size, and complications (screw repositioning or cerebrospinal fluid leak). Patient clinical outcomes were assessed using the Oswestry Disability Index (ODI), Visual Analog Scale (VAS) for pre- and postoperative radicular pain. Thin slice CT scans were used to assess the progression of the fusion using the Bridwell classification. In the statistical analysis, percentages, median, and interquartile range (IQR) were calculated. **Results:** Nine hundred and thirty one patients underwent MI TLIF using the technique described, eight hundred and eighty (94.5%) had a single level treated and fifty one (5.5%) had a 2 level procedure (982 levels), an 8mm cage was placed on five hundred and seventeenlevels (52.7%), six hundred and sixty three levels(67.6%) achieved grade I fusion, two hundred and sixty six levels (27.1%) achieved grade II fusion, 52 levels (5.3) achieved grade III fusion and one level (0.1) achieved a grade IV fusion or non-union. Revision surgery was performed on 3 patients (0.3%) for screw repositioning, cerebrospinal fluid leak was present on 2 patients during surgery and treated before closure. VAS scores and ODI were improved at 12 months postop (VAS from 8.70 to 2.30 and ODI from 34.2 to 14.1, ($p = 0.001$). **Conclusions:** The MI TLIF technique described could be a

safe and easy to replicate way to achieved lumbar interbody fusion, providingclinical and radiological benefits.

Keywords

MITLIF, Lumbar Interbody Fusion, Technique, Pain Relief and Disability

1. Introduction

Lumbar interbody fusion involves the placement of an implant within the intervertebral space after discectomy and preparation of the endplates, one of the first detailed techniques was described by Cloward in 1952 under the thesis "once a ruptured disc, always a ruptured disc", thereby stating that recurrent symptomswere very likely if only disc decompression was performed without arthrodesisbetween the intervertebral bodies, since it's the zonethat bares most of the loading forces [1]. In 1982, Harms and Rollinger introduced thetransforaminal lumbar interbody fusion (TLIF) as an effective method for a 360-degree spinal arthrodesis [2]. Later in the 2000s, minimally invasive foraminotomies and laminectomies were introduced for stenosis, fusion through a posterior approach with placement of an interbody cage and percutaneous screws and finally MI TLIF was introduced, as a way to reduce intraoperative bleeding, hospital stay, time to start ambulation, postoperative use of narcotics, and time to return to work [3]-[13].

To this day, in addition to MI-TLIF, there are different approaches to obtain a lumbar interbody fusion; posterior lumbar interbody fusion (PLIF), oblique lumbar interbody fusion (OLIF), anterior lumbar interbody fusion (ALIF) and lateral lumbar interbody fusion (LLIF) each and every one with its advantages and disadvantages, however MI-TLIF remains part of the basic armamentarium for spine surgeons as it is suitable for treating levels from L1 to S1. Indications include a wide range of spinal disorders, including stenosis, spondylolisthesis, recurrent disc herniation, and nonunion. Contraindications include epidural scarring, arachnoiditis, active infection and fused nerve roots. Its main disadvantages are injury to the paraspinal muscles and, compared to previous approaches, less coronal balance or lordosis recovery [14].

Lener and Wipplinger found many variations among surgeons when performing this approach, including positioning, the retractor or optical method to be used,and even the extent of decompression (complete or partial facetectomy). Likewise, trying to define the MI TLIF technique, they propose to exclude the use of an expandable non-tubular retractor, midline incisions, and not using a microscope or endoscope [15].

Although there is a consensus regarding the general steps for a MI-TLIF and multiple techniques described such as that of Lee and Wong, were a total facetectomy and ligamentum flavum removal are described [16] [17], we believethis

could increase the risk of tearing the dural sac when performed by unexperienced surgeons, so we propose the next standardized method as an alternative to guide the training of spine surgeons.

2. Surgical Technique

2.1. Operating Room Setup

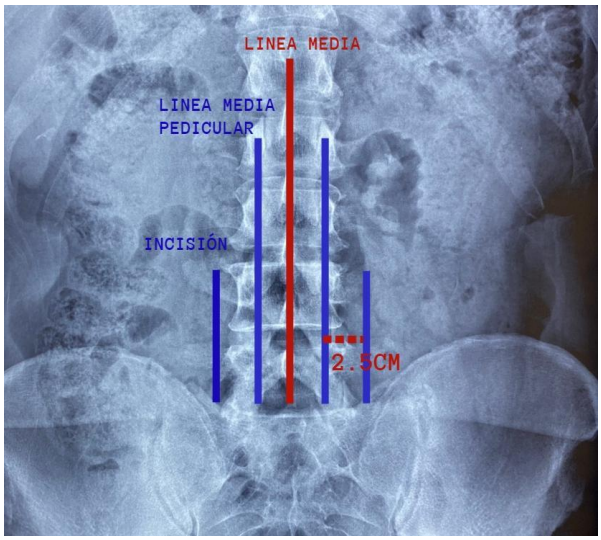
The use of total intravenous anesthesia (TIVA) and intraoperative neurophysiological monitoring (IOT) are highly recommended. The patient should be placed in a prone positionprotecting eyes, face and bony prominences exposed to pressure. We suggest using a radiolucent spine table (Jackson frame). If a conventional surgical table is used, caution should be taken with any radiopaque object interfering with X-rays. The surgeon (andmicroscope) must be positioned on the symptomatic side where decompression is intended. The attending surgeon and C-arm should stand in front of the surgeon, the anesthesiologist at the patient's head, so that the scrub nurse is at the patient's feet and can assist both surgeons. The image intensifier screen is usually at the feet of the patient, although if space allows, it is also possible at the head of the patient and to the side of the anesthesiologist to facilitate viewing the images (Figure 1). **Pearls and tips:** Moving the C-arm forward and backward across the table and changing the view from AP to lateral as easily and quickly as possible before surgery could decrease positioning errors during the procedure. The authors placed the rail adapter for the articulated arm caudally and ipsilateral to the approach.

Figure 1. OR setup. The surgeon and microscope are positioned on the symptomatic side where decompression would be performed. The assistant surgeon and C-arm should be positioned in front of the surgeon and the anesthetist at the patient's head. The scrub nurse stands at the patient's feet and can assist both surgeons.

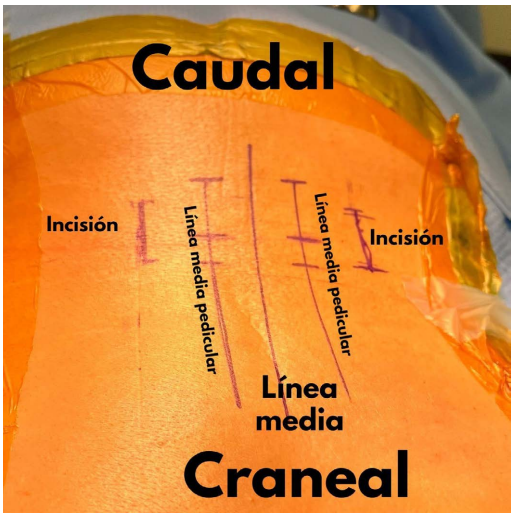
2.2. Incision Marking

An AP view should be taken to identify and mark the next references: mid spinal line, mid pedicle line and then measure 2.5 cm lateral from the mid pedicle line for the incision site. This distance allows the approach for decompression and placement of bilateral percutaneous screws.

A vertical line can be drawn on decompression side that will also help for screw access, on the contralateral side it is possible to make a vertical incision as well or to mark horizontal incisions for screw access, but if two or more levels must be done, a vertical incision is recommended (Figure 2). **Pearls and tips:** Getting a true AP and lateral view on the intensifier for each level allows for more precise screw placement.



(a)



(b)

Figure 2. (a) Midline (red single line) and bilateral mid-pedicle line (blue long lines) are located and marked, and then we measure 2.5 cm lateral from the mid-pedicle line for the incision site (blue short line). (b) Skin marking.

2.3. Incisions and K-Wires Insertion

A longitudinal incision is made slightly larger than the diameter of the maximum tubular retractor to be used. We suggest the use of monopolar coagulation to open up to the muscle fascia. A Jamshidi needle should be positioned bilaterally (reducing X-ray exposure) above the muscle fascia and obtain an AP view to identify the pedicle before introducing it through the muscle, avoiding bleeding due to manipulation. Once identified, the needle is placed on the superior and external edge of each pedicle and an average of 2 cm of the tip is introduced, avoiding to reach the medial edge of each pedicle. We suggest confirming trajectory and congruence with AP and Lateral projections, then the Kirschner wires are inserted and the needles are removed. (Figure 3) **Pearls and tips:** The

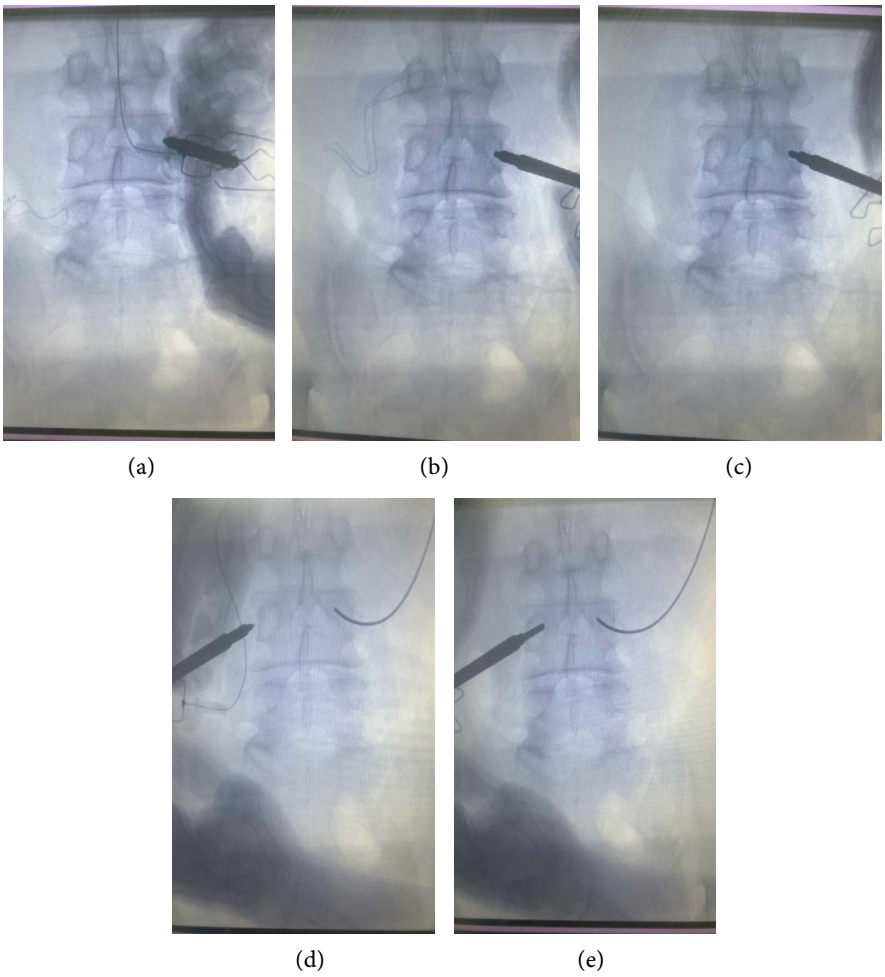


Figure 3. (a) Once the pedicle has been identified, the Jamshidi needle is placed on the outer edge of each pedicle. (b) It is progressively introduced in a superior and medial direction. (c) It is important to avoid going beyond the medial edge of the pedicle, once at this limit it is important to compare in the lateral projection that it is in the distal third of the pedicle, close to entering the vertebral body, at this point the Kirschner wire is inserted and Jamshidi needle is removed. (d) The position of the cable is verified and the contralateral needle is inserted, although it is possible to perform both sides simultaneously. (e) Needle trajectory without going beyond the medial edge of the pedicle.

first Jamshidi needle should be placed through the muscle but to insert the second a blunt digital dissection could be done following the path of the first Jamshidi reducing muscle trauma. The fascial opening should be larger than the skin incision to allow placement of the percutaneous rod in later steps. When using IOM, all needles should be tested before introducing the Kirschner wire and throughout the entire pedicle tract. The alignment and position of the needles should be considered from this point to facilitate rod placement.

2.4. Placement of Retractors

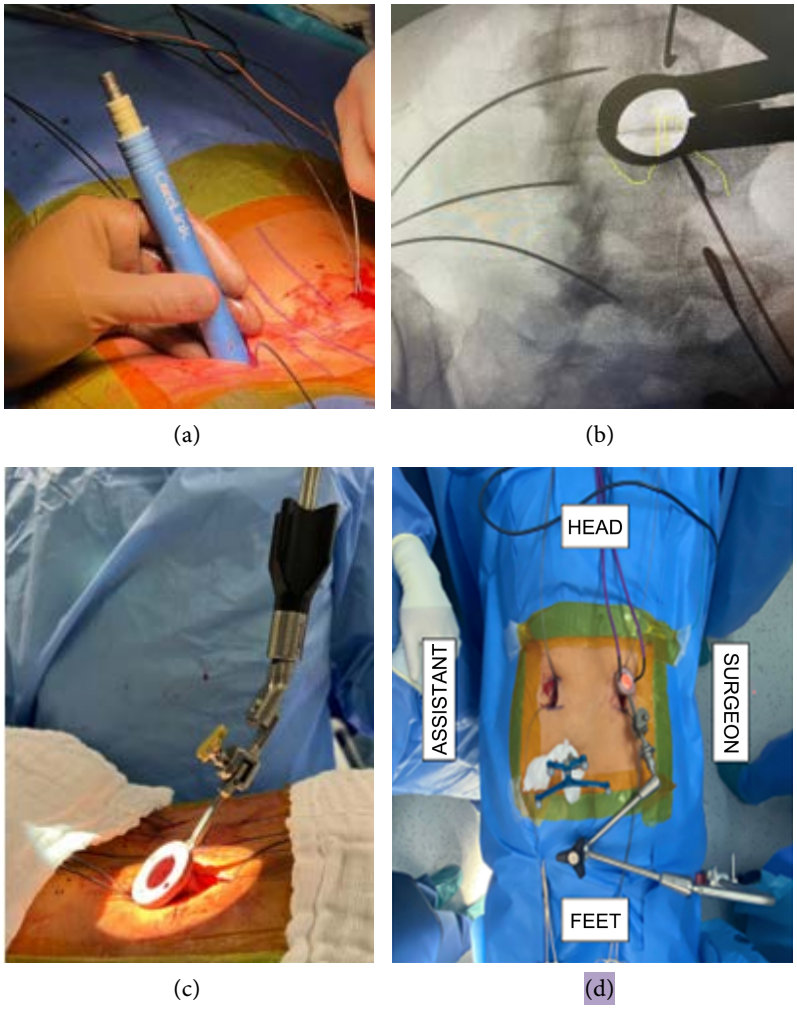
Using a trans muscular approach, the AP vision must guide the first tubular dilator, an oblique image could be obtained in the first cases to confirm its location (**Figure 4(b)**) until reaching the articular process which points to the intervertebral disc, once there, a gentle twist or circular dissection must be done before inserting the next dilator, followed by a slight tilt to allow blunt dissection, continuing with progressive placement of the tube diameter until the appropriate diameter is reached, a non-expandable tubular retractor of 18 mm diameter could be enough for a bullet shaped cage. An expandable tubular retractor is preferred when placing a banana-shaped cage. The retractor is fixed to an arm, confirming its position using fluoroscopy before removing the internal dilators.

Pearls and Tips: Before locking the arm, we must check that it does not interfere with instrumental manipulation near the tube channel when performing microscopic surgery or image acquisitions.

2.5. Decompression

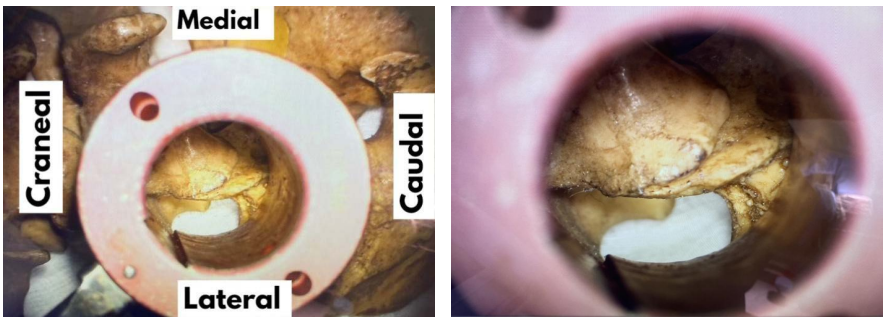
The remaining muscle tissue is initially coagulated from the periphery to the center with bipolar forceps to avoid bleeding and is removed with pituitary rongeur to locate the joint capsule. With a bayonet scalpel, the joint capsule is opened, identifying the articular facet. Laterally the superior articular process (SAP), medially the inferior articular process (IAP) and the facet joint between them (**Figure 5**).This last reference is used to follow its path with a high-speed drill medially throughout the joint until reaching the medial edge of the SAP, followed by epidural fat, obtaining a partial facetectomy, with no exposure of the dural sac or nerve roots but achieving direct decompression of the neural structures. Once exposed, the epidural fat coagulates along with the venous plexus until the intervertebral disc is exposed, knowing that it is a safe workplace. The main objective of this decompression is to avoid exposing roots to protect them.

When a central decompression is necessary, it is possible to extend the bone removal towards the ipsilateral lamina and subsequently the ligamentum flavum. Even if a bilateral decompression is sought, only angulation of the tubular retractor is required to extend the drilling to the base of the spinosa. For these procedures we suggest first having placed the interbody cage.

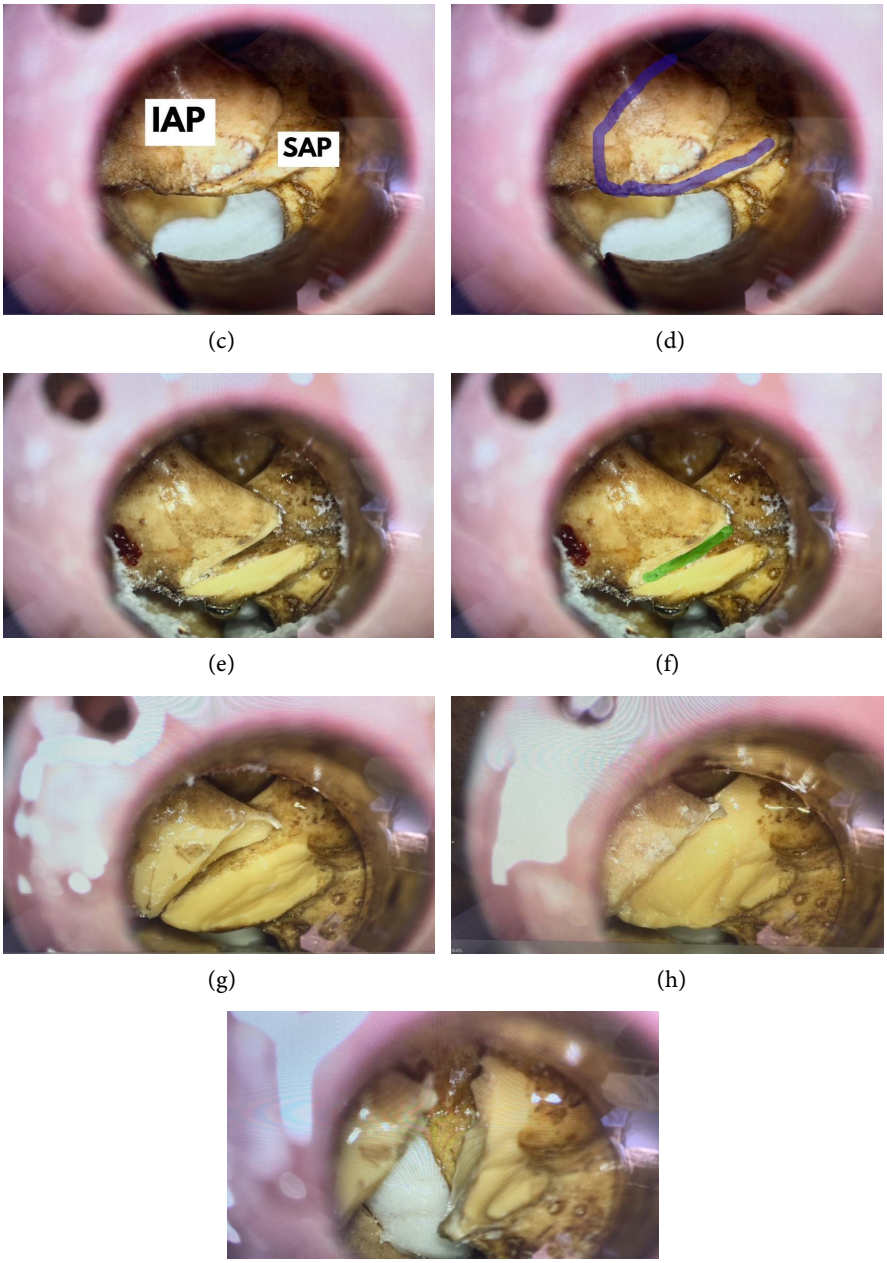


(a) (b) (c) (d)

Figure 4. (a) The dilator tubes of progressive size are inserted, the Kirschner wires can be used as a reference by introducing the first dilator in the middle of them to reduce radiation, always trying to palpate and identify bone structures. (b) Once the AP and Lateral projection are placed and confirmed, it is possible to take an oblique projection in the direction of our final tube, being able to identify the facet joint within the working path (articular facet outlined in yellow). (c) We recommend fixing the arm once the position has been verified, trying to ensure that when fixing it, is on a craniocaudal direction to reduce the possibility that it can be removed due to manipulation. (d) Suggested distribution of arm fixation to prevent it from getting in the way of x-ray images and allow maneuverability for the surgeon and assistant.



(a) (b)



(c) (d)

(e) (f)

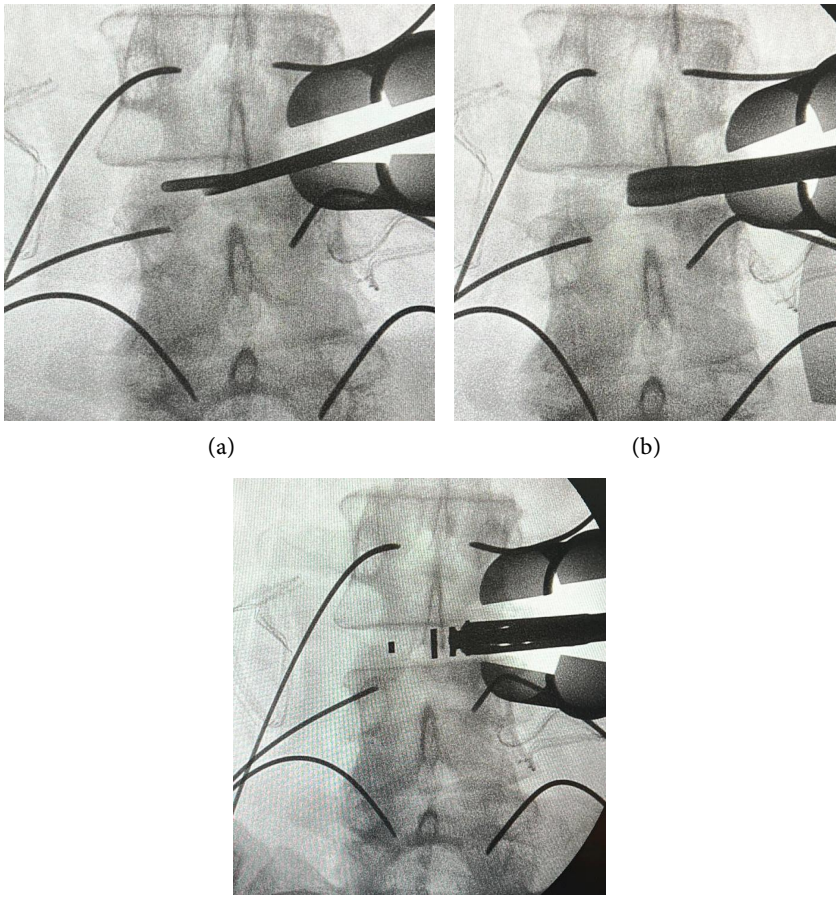
(g) (h)

(i)

Figure 5. (a) After removing the muscle tissue, the joint processes must be identified. (b) With the help of a microscope it is possible to distinguish each joint process. Laterally we find the superior articular process (SAP), medially the inferior articular process (IAP). (d) In blue outlined the edge of the SAP that is covered by the IAP. (e) Milling with a high-speed motor is started between both articular processes using their joint or facet as a reference, following it to expose the entire SAP. (f) In green the path of the facet to follow until the SAP is discovered. (g) Part of IAP removed with SAP exposure following articulation between both. (h) Much of the IAP removed respecting the isthmus and lamina, complete exposure of the SAP. (i) The SAP is removed, exposing the intervertebral disc and safety zone, achieving direct decompression of the protruding and descending root. Once exposed, the epidural fat coagulates along with the venous plexus until the intervertebral disc is exposed, knowing that it is a safe workplace. The main objective of this decompression is to avoid exposing roots to protect them.

2.6. Cage Placement

Once bone decompression is achieved, epidural fat coagulation is performed in the safety triangle obtained by exposing the annulus fibrosus, the annulus is opened with a bayonet scalpel, and intervertebral disc resection is initiated with pituitary clamp, in many cases The narrowness of the space does not allow an adequate discectomy, so the use of small shavers or dilators (Figure 6) and increasing them progressively allows the space to be expanded and facilitates disc resection in addition to preparing the platforms of the vertebral bodies. After removing as much of the disc as possible, the interbody cage is placed under direct vision and supported by X-ray. The most commonly used interbody cages are straight/bullet-shaped; if you decide to place a banana-shaped cage, greater bone resection is suggested (Figure 7).



(a) (b) (c)

Figure 6. (a) After opening the annulus fibrosus, the resection of the intervertebral disc begins, even managing to remove the disc beyond the midline. (b) In many cases, the narrowness of the space does not allow an adequate discectomy, so the use of small shavers or dilators and increasing them progressively allows the space to be expanded and facilitates disc resection in addition to preparing the platforms of the vertebral bodies. (c) After removing as much disc as possible, the interbody cage is placed under direct vision and supported by X-rays. With the aforementioned exposure, the retraction of neural structures should not be necessary.

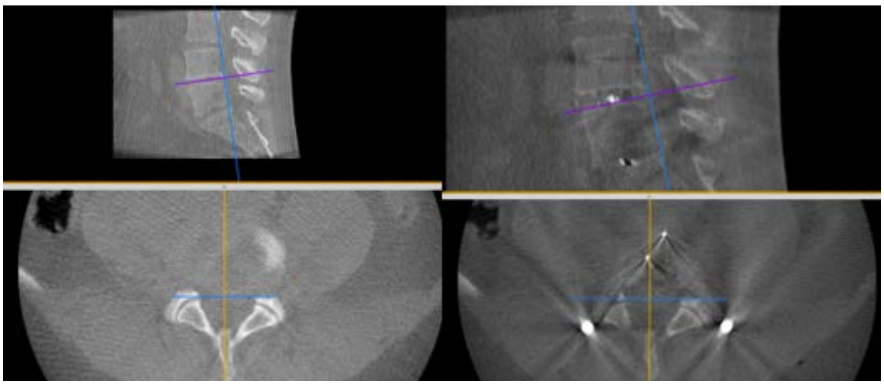


Figure 7. Preand postoperative CT scan study demonstrating the changes after the placement of the interbody cage and the resection of the articular processes respecting the lamina ipsilateral to the approach.

2.7. Placement of Screws and Rods

Once the cage position is confirmed, the size of the screw is chosen, using the Kirschner wire as a guide it is introduced until it reaches the bone surface, the trajectory is confirmed by fluoroscopy and gentle but firm pressure is applied to introduce the tip of the screw. Once this is achieved, it is not necessary to apply more pressure and the screw must be inserted simply by gently turning the screwdriver. Once the screws have been placed, the size of the rod is measured. The lordosis of the rod is confirmed and using the percutaneous screw tower it is introduced, first directing the rod almost vertically until it crosses the fascia and crosses the first tower, then it is placed horizontally confirming that it runs through all the towers by direct vision and an image of X-ray, after confirmation it is blocked and the rod holder is removed.

3. Material and Methods

After describing the surgical technique, a retrospective, longitudinal, observational cohort study was conducted, 1321 patients who underwent a MI TLIF surgery between 2010 and 2022 by the same surgeon (Dr. Perez Contreras) were considered, the indicationsused for surgery were grade I spondylolisthesis, degenerative disc with mechanical low back pain and or radicular symptoms with no response to 3 months of conservative management, one or two involved segments, inclusion criteria for this study also considered those patients who underwent the MI TLIF with the technique described above, with at least static and dynamic plain lumbar spine radiography and magnetic resonance imaging (MRI), postop CT scan at month 12, spinal stenosis with Schizas classification from A to C, and no prior surgery. Exclusion criteria included any modification to the technique described such as laminectomy or nerve roots exposure, three or more levels involved, Schizas D classification, grade II spondylolisthesis or higher, trauma involved, follow up less than 12 months. Only 931 patientsmet the criteria (982 levels). Schizas classification, grade oflisthesis according to Meyerding classification, operated levels, ODI and VAS scales for pre- and

postoperative pain were evaluated. Among variables used were cage size, fusion obtained according to Bridwell's scale, need of revision surgery or CSF leak among others.

In the statistical analysis, percentages, median, and IQR were calculated. There were no disclosures for this study, human data was collected in accordance with de the declaration of Helsinki, there was no financing since it was a study based on existing records of patients seen in the last 12 years.

4. Results

Nine hundred and thirty-one patients underwent MI TLIF using the technique described, eight hundred and eighty (94.5%) had a single level treated and fifty-one (5.5%) had a two-level procedure (982 levels), 704 patients (75.6%) were female, median age 56 years, IQR 8, with a predominance of 41 to 60 years (67%), 606 levels (61.8%) were a Schizas III classification and 151 (15.4%) levels hada grade Ilisthesis.

An 8 mm cage was placed on five hundred and seventeen levels (52.7%), six hundred and sixty-three levels (67.6%) achieved grade I fusion, two hundred and sixty-six levels (27.1%) achieved grade II fusion, 52 levels (5.3) achieved grade III fusion and one level (0.1) achieved a grade I fusion or non-union. Revision surgery was performed on 3 patients (0.3%) for screw repositioning, cerebrospinal fluid leak was present on 2 patients during surgery and solved before closure. VAS scores and ODI were improved at 12 months postop (VAS from 8.70 to 2.30 and ODI from 34.2 to 14.1 ($p = 0.001$).

5. Discussion

Even though there are multiple descriptions of techniques described to perform a MI TLIF and there is a consensus regarding the general steps, there are still lot of variations among surgeons, so we decided to guide us with Lener and Wipplinger [15] exclusion criteria for considering a procedure as minimal invasive, excluding thoseprocedureswere anexpandable non-tubular retractoror midline incisions were involved or if there was no a microscope or endoscope as optic assistance.

Some authors described the need of a complete facetectomy and ligamentum flavum removal, but we believe that such procedure shouldn't be done routinely but just when there's a sever central stenosis or a D schizas classification, since there's a higher risk of tearing the dural sac or injuring a nerve root, our technique describes just a partial facetectomy, and our results were similar to those of Lee *et al.* [16] whosuggests a total facetectomy, improving ODI from 30.32 to 15. 54, VAS from 7.80 to 2.20, $p = 0.001$). vs our results VAS from 8.70 to 2.30 and ODI from 34.2 to 14.1, ($p = 0.001$), but also as stated by them MI TLIF is challenging technique and requires a learning curve, and furthermore, surgical techniques are different in surgeons.

Furthermore, the percentage of patients with a need for surgical reinterven-

tion or the development of some complication is less than 3%, which supports what was established by Mooney [18] and Ramírez, [19] and translates into a benefit that directly impacts the reduction of healthcare costs by reducing hospital stay days, which is consistent with Chi Heon Kim. [5]

6. Conclusion

The MI TLIF technique described could be a safe and reproducible way to achieved lumbar interbody fusion, providingclinical and radiological benefits.

Abbreviations and Acronyms

MI TLIF: Minimal invasive transforaminal lumbar interbody fusion. SAP: Superior articular process. IAP Inferior articular process.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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