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Comparison of segmental lordosis gain of prone transpsoas (PTP) vs. lateral lumbar interbody fusion

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Abstract

Introduction Lumbar interbody fusion is a standard method to treat certain degenerative conditions that are refractory to conservative treatments. LLIF reduces posterior muscle damage, can relieve neurological symptoms through indirect decompression, provides increased stability with its wider cages, and promotes more significant segmental lordosis than standard posterior techniques. However, the technique possesses its issues, such as unusual positioning, possible plexus-related symptoms, and median segmental lordosis correction. Trying to ease those issues, the idea of a prone transpsoas technique occurred.

Methods Retrospective, single-centric, comparative, and non-randomized study. The authors paired patients receiving lateral lumbar interbody fusion (LLIF) or prone transpsoas (PTP) to evaluate the technique's impact on the segmental lordosis correction. A correlation test selected the covariates for the matching. *p*-Values inferior to 0.05 were deemed significant.

Results Seventy-one patients were included in the analysis, 53 in the LLIF group and 18 in the PTP group. The significant covariates to the segmental lordosis correction were technique, preoperative segmental lordosis, cage position, and preoperative pelvic tilt. After the paring model, PTP showed significant segmental lordosis correction potential regarding the LLIF.

Conclusion The prone transpsoas approach can significantly enhance the correction of segmental lordosis proportionated to the traditional LLIF approach.

Keywords Lateral lumbar interbody fusion · Segmental lordosis · Prone transpsoas · Propensity-score matching · Lumbar spine surgery

Introduction

Lumbar interbody fusion is a standard method to treat certain degenerative conditions that are refractory to conservative treatments. To improve surgery outcomes for this population, minimally invasive techniques have become popular, aiming to reduce the extent of surgery, amount of blood loss, length of hospitalization, and recovery time [1, 2].

Dr. Luiz Pimenta and collaborators initially described the lateral lumbar interbody fusion (LLIF) in 2006, a technique that proved to be a safe and effective procedure to treat a vast range of lumbar disorders [2–4]. LLIF reduces posterior muscle damage, can relieve neurological symptoms through indirect decompression [5–7], provides increased stability with its wider cages [8], and promotes more significant segmental lordosis than standard posterior techniques [9, 10]. The LLIF also has limitations, such as minor segmental lordosis improvements and postoperative neurological deficits transitory in 90% of cases and the necessity to reposition the patient to the instrument posteriorly to perform direct decompression when needed [11, 12].

Trying to overcome issues traditional LLIF issues, in 2020, Dr. Pimenta and Dr. Taylor published the description of a novel approach to the LLIF, with the patient in a prone position [13]. The theoretical concept of this approach is that positioning the patient in a ventral fashion allows a single-position surgery, with optimal position to perform posterior maneuvers when needed [13, 14] while enhancing the patient's lordosis with only table positioning [14, 15].

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Therefore, this article aims to compare the correction of the segmental lordosis promoted by the traditional LLIF and the prone transpsoas technique (PTP).

Methods

This is a retrospective, single-centric, comparative, and non-randomized study. An IRB board approved the study, and all patients that had their data analyzed had prior fulfilled a free consent form.

Patient population and inclusion and exclusion criteria

The inclusion criteria are patients undergoing single-level prone transpsoas interbody fusion or lateral lumbar interbody fusion surgery, with lateral profile X-ray at baseline and 6 months to 1-year follow-up, and with baseline computerized tomography, patients receiving surgery from one of the two senior surgeons of the clinic, and patients receiving cages with lordosis between 10 and 12°, with width between 22 and 26 mm.

The exclusion criteria were patients with low-quality X-rays that do not allow adequate measurements, and patients with subsidence > 25% at the follow-up (5 patients which composed 5% of the initially screened cohort), and patients with non-degenerative pathologies (Fig. 1).

Techniques

The prone transpsoas technique was performed according to the Pimenta et al., 2020 article [1]. The selected patients did not receive any osteotomy or anterior longitudinal ligament. All the patients received posterior instrumentation with percutaneous pedicle screws.

The lateral lumbar interbody fusion was performed according to the described in Ozgur et al., 2006 and Pimenta et al., 2018, articles [2, 3]. The selected patients did not receive any osteotomy or anterior longitudinal ligament. All the patients received posterior instrumentation with percutaneous pedicle screws.

The two senior surgeons of the institution performed both the LLIF and PTP cases.

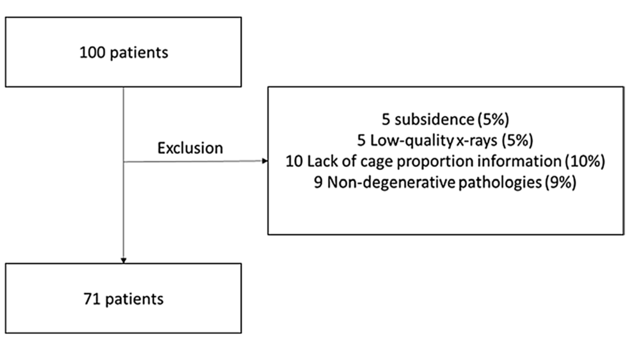

Fig. 1 Flowchart of the patient inclusion

Measured parameters and outcomes

Index level segmental lordosis (SL), both preoperative and postoperative, pelvic incidence (PI), pelvic version (PT), sacral slope (SS), lumbar lordosis (LL), the delta segmental lordosis (postop SL–preop SL), and the cage position over the vertebral body (see definition below).

The cage position was defined by the location of the center of the cage concerning the vertebral body. To perform the measurement, the size of the vertebral body was measured in millimeters, then the distance from the posterior margin of the vertebral to the posterior margin of the cage (posterior distance) and added to the half of the cage size to obtain the position of the center of the cage. Cage Position = Position of the Center of Cage/Vertebral Body Size (Fig. 2).

All parameters, except the cage position component variables (measured at computerized tomography), were measured in the lateral standing neutral orthostatic position profile X-ray. All postoperative x-rays were collected from the 6 to 12 months follow-up.

Propensity-score matching (PSM)

The authors divided the patients into two groups, PTP and LLIF. Then, a propensity-matched score analysis was used to match the patients according to specific covariates.

Correlation to derivate critical covariates

Variables with significant correlation with delta segmental lordosis composed the PSM model.

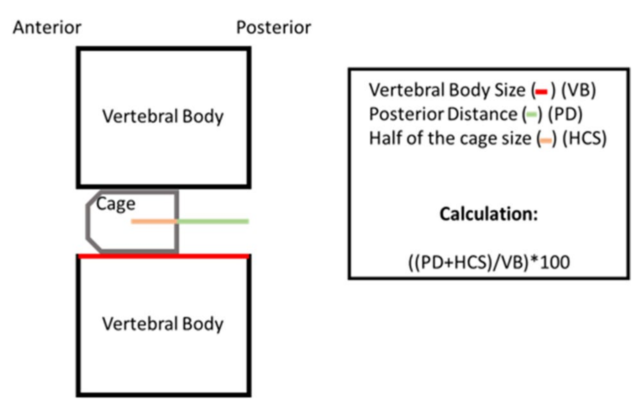

Fig. 2 Image exemplifying the cage position measure

The matching model

The chosen methodology was the nearest neighbor method, where the pairing occurs with the closest neighbor of the other group [16, 17]. The PSM model used a 1:1 pairing ratio (PSM ratio 1:1). The standardized mean (SMD) and the Adjusted Variance (VR) values of the included covariates were used to assess the pairing efficacy. Covariates with SMD values above 0.10 or inferior to −0.10 or VR values higher than 0.2 or smaller than −0.2 are considered unbalanced [18, 19].

Treatment effects after the matching

The treatment effects will be assessed using variance tests to assess the difference in segmental lordosis among the groups.

Statistical analysis

The software R (CRAN, Vienna, Austria) [20] analyzed and described the data. The authors used the tidyverse package to tidy, organize and describe the data [21], and the FastDummies [22] package to perform the dummiezation of categorical variables included in the models. To evaluate the normality of the sample, the authors used the Shapiro–Wilk test and performed the test for variances among the groups, the Wilcox test. The authors used the MatchIt package [23] and the cobalt package [24] to realize the balance analysis to perform the propensity score match. *p*-Values equal or inferior to 0.05 were deemed as statistically significant.

Results

Seventy-one patient were included in the analysis, 53 in the LLIF group and 18 in the PTP group. The demographic data of the patients are given in Table 1.

Prior matching

The mean preoperative segmental lordosis (SL) in the LLIF group was 5.6° (±4.2°), while in the PTP group, 6.8° (±6°), $p=0.6$. As for the cage position in both groups, of the majority, the patients had the cage positioned at the center of the vertebral body (57.7% vs. 57.4%, $p=0.8$). Finally, the mean delta segmental lordosis of the LLIF group was 2.6° (4.5°) and 6.6° (6.5°) for the PTP group ($p=0.03$) (Table 2). The effect of the PTP regarding the segmental lordosis correction was Large ($r=0.34$, 95% confidence interval [0.04, 0.58]).

Table 1 Demographic data of the patients

Label	Variable	Técnica		Total	Test
		LLIF	PTP		
Gender	F	22 (66.67%)	11 (33.33%)	33 (56.90%)	*p* Value: 0.6637 (Pearson's Chi-squared test)
	M	18 (72.00%)	7 (28.00%)	25 (43.10%)	
	NA	13	0	13	
	Total	53 (74.65%)	18 (25.35%)	71 (100.00%)	
Age	Min/max	27.0/79.0	32.0/79.0	27.0/79.0	*p* Value: 0.6698 (two sample *t*-test)
	Med [IQR]	58.5 [52.0; 65.2]	55.0 [49.0; 67.0]	58.0 [49.0; 66.8]	
	Mean (SD)	57.6 (11.0)	56.2 (13.3)	57.2 (11.6)	
	N (NA)	44 (9)	18 (0)	62 (9)	
Cage angulation (º)	10	52 (75.36%)	17 (24.64%)	69 (97.18%)	*p* Value: 0.4455 (Fisher's exact test for count data)
	12	1 (50.00%)	1 (50.00%)	2 (2.82%)	
	Total	53 (74.65%)	18 (25.35%)	71 (100.00%)	
Operated level	L1L2	1 (100.00%)	0 (0%)	1 (1.41%)	*p* Value: 0.5785 (Fisher's exact test for count data)
	L2L3	3 (60.00%)	2 (40.00%)	5 (7.04%)	
	L3L4	5 (62.50%)	3 (37.50%)	8 (11.27%)	
	L4L5	44 (77.19%)	13 (22.81%)	57 (80.28%)	
	Total	53 (74.65%)	18 (25.35%)	71 (100.00%)	
Pathology	Disc degeneration	19 (76.00%)	6 (24.00%)	25 (35.21%)	*p* Value: 0.0123 (Fisher's exact test for count data)
	Adjacent level disease	4 (80.00%)	1 (20.00%)	5 (7.04%)	
	Spondylolisthesis	29 (82.86%)	6 (17.14%)	35 (49.30%)	
	Stenosis	1 (16.67%)	5 (83.33%)	6 (8.45%)	
	Total	53 (74.65%)	18 (25.35%)	71 (100.00%)	

Table 2 Results of the variance tests prior the pairing

Technique	*N*	Preoperative lordosis	PI (°)	SS (°)	PT (°)	LL (°)	Cage position (%)	Delta lordosis (°)
LLIF	53	5.6 (4.2)	56.2 (13)	35.3 (12.2)	20.4 (10.6)	51.6 (15.3)	57.7 (11.1)	2.6 (4.5)
PTP	18	6.8 (6)	52.1 (11.3)	33.9 (11.3)	18.2 (10)	48.8(11.9)	57.4 (13.4)	6.6 (6.5)
		0.61	0.39	0.47	0.98	0.60	0.77	0.03

( ) Standard deviation; *N* number of patients

Correlation analysis and matching

After the correlation analysis, four parameters showed significance regarding the segmental lordosis correction: technique, preoperative segmental lumbar lordosis, cage position, and preoperative pelvic tilt.

The pairing occurred using the following covariates: preoperative segmental lordosis cage position, and preoperative pelvic tilt, while the technique divided the groups. The matching model followed a 1:1 ratio. The model respected the thresholds for balance stipulated in the methodology section.

After the matching

After the propensity-score matching, 36 patients composed the model, 18 in the LLIF group and 18 in the PTP group. The preoperative segmental lordosis of the LLIF group increased to 6.1° (±5.1°), and as expected, the PTP group remained with the same value of 6.8° (±6°), $p=0.83$. Finally, after pairing, the segmental lordosis, correction of the LLIF group decreased to 1.9° (±4.7°) while the PTP remained at 6.6° (±5.5°) ($p=0.02$) (Table 3). The effect of the PTP regarding the segmental lordosis correction was very large ($r=0.44$, 95% confidence interval [0.06, 0.69]).

Discussion

Studies point out the need for manutention or the correction of the spinopelvic parameters, even in degenerative cases, to achieve successful surgery [25, 26]. Moreover, in cases of minor degeneration, studies show that segmental lordosis correction is paramount to avoiding pathologies such as adjacent level disease [27, 28]. The present study showed that the PTP allowed for significantly higher correction power for segmental lordosis correction when compared to the traditional lateral approach.

Parameters associated with segmental lordosis correction

Many factors play a significant role in restoring the segmental lordosis, with some researchers showing that cage geometry and position are critical factors in achieving good correction in segmental lordosis, such as cage angulation, cage position, and cage height [12, 29, 30]. Moreover, other studies show that one of the main drivers of segmental lordosis correction is preoperative segmental lordosis [31, 32]. Findings aligned with the present article findings that showed the cage position (cage position) and the preoperative segmental lordosis as significantly correlated to the segmental lordosis correction.

Segmental lordosis correction with LLIF and PTP

Studies showed the positive impacts of the LLIF technique in correcting segmental lordosis. Sembrano et al. reported on 35 patients who underwent LLIF at 54 levels. The authors reported that LLIF resulted in statistically significant increases in SL of 3.2°. Similarly, Walkins et al. reported sixty patients who underwent LLIF at 86 levels, showing that the LLIF increased SL by 2.2°. Furthermore, when comparing the gain of lordosis of the LLIF technique with other procedures, only the ALIF technique enables higher gains of segmental lordosis than the LLIF. Despite those

Table 3 Results of the variance tests after the pairing

Technique	*N*	Preoperative lordosis	PI (°)	SS (°)	PT (°)	LL (°)	Cage position (%)	Delta lordosis (°)
LLIF	18	6.1 (5.1)	55.6 (13.3)	37 (13.1)	17.3 (10)	56.5 (15.8)	58.8 (10.3)	1.9 (4.7)
PTP	18	6.8 (6)	52.1 (11.3)	33.9 (11.3)	18.2 (10)	48.8 (11.9)	57.4 (13.4)	6.6 (6.5)
		0.89	0.40	0.79	0.80	0.12	0.92	0.03

( ) Standard deviation; *N* number of patients excellent results, recent literature reviews showed that the LLIF segmental lordosis correction presents higher variability with gains of around 2° [33]. Like those found with the LLIF cohort of this study with a mean correction of 2.7° in segmental lordosis.

As for the PTP, one of the proposed advantages of the prone position is to allow a lordotic-friendly frame. A positive sign of these affirmations comes from a study published by Polina et al., 2021, showing that patients had a significant increase in segmental and lumbar lordosis when positioned in a prone frame compared to patients in lateral decubitus [14]. Moreover, Amaral et al. 2021 [15], in an MRI study, showed that patients positioned in prone decubitus had an increase in lumbar lordosis compared to themselves in lateral or dorsal decubitus. Finally, Pimenta et al., 2020 showed a mean increase of 6.1° segmental lordosis correction after performing the PTP technique [34].

Limitations

The main limitation of the work is the small sample size that does not allow a more robust pairing and limits the predictive power of the regression. The authors chose the variables that they considered more correlated to the segmental lordosis correction phenomenon to tackle this limitation. Another limitation was that the surgeries occurred at different periods. The authors performed the sample pairing based on significant predictors of the segmental lordosis correction to tackle this issue. Also, the surgeons for both the LLIF and PTP cases were the same.

Conclusion

The prone transpsoas approach can significantly enhance the correction of segmental lordosis proportioned to the traditional LLIF approach. This might help reduce even more the occurrence of pathologies such as adjacent level disease, which are commonly associated with insufficient lumbar lordosis correction.

Author contributions GH, RA, RM, FM and LP were involved in the conceptualization of the study. GH, RM, JM were involved into the writing of the manuscript and dta curation. DA, RA, IB were involved in the investigation part of the study. GH were responsible for the formal analysis and data visualization. GH, DA, RM, FM and RA were involved in the methodology section of the study.

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Data availability There are no associated data with this manuscript.

Declarations

Conflict of interest Dr. Luiz Pimenta receives consultant fees from Alphatec; Dr. Rodrigo Amaral receives consultant fees from Alphatec, Nuvasive, and Astrolab. The other authors have no conflicts to disclose.

Ethical approval The ethics committee approved the research.

Informed consent All patients fulfilled a informed consent regarding have their data collected to the study.

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