Venous anatomy of the lumbar region applied to anterior lumbar interbody fusion (ALIF): Proposal of a new classification

Alejandro Vargas-Moreno*, Roberto Diaz-Orduz, Miguel Berbeo-Calderón

Neurosurgery Department, Hospital Universitario San Ignacio. Pontificia Universidad Javeriana, Bogotá, Colombia

A R T I C L E   I N F O

A B S T R A C T

Background: Anterior lumbar interbody fusion (ALIF) is a good alternative for the surgical treatment of lumbar degenerative disc disease. The primary vascular complications regarding this intervention involve the common iliac vein bifurcation complex (CIVC). Currently, no classification system allows defining which patients are more prone to these complications. We aimed to perform a retrospective study evaluating the anatomy of the common iliac CIVC at the L5-S1 disc proposing a novel classification system as it relates to the ALIF difficulty.

Methods: 91 consecutive patients who underwent ALIF at the L5-S1 level were included. We categorize the CIVC at the L5-S1 disc space into four types according to the veins position along the disc space. The patient records were reviewed for demographic information, surgical characteristics, and complications. The surgical difficulty was rated at the end of the procedure.

Results: 54% of the patients were women. The mean age was 52.5 ± 14.8 years. Mean surgical bleeding was 152 ml (range 20ml -3000 ml), and mean surgical time was 79 ± 13.3 minutes. Berbeo-Diaz-Vargas (BDV) classification type 4 was found in 43.9% of the patients. The surgical complexity was associated with the bleeding magnitude and surgical time spent ($p<0.01$), not being related to the corporal mass index or sacral slope. Bleeding magnitude, surgical time, and surgical complexity were significantly related to the BDV classification system ($p<0.01$). Weighted Cohen´s kappa index for the BDV scale was 0.89 (95% IC 0.822 – 0.974).

Conclusions: BDV scale is a reliable and reproducible tool for the classification of CIVC significantly related to a higher incidence of bleeding, prolonged operating time, and increased perceived difficulty by the surgeon.

Introduction

Lumbar degenerative disc disease (LDDD) prevalence is estimated at 3.6% worldwide. 20% of patients with this condition report that the symptoms are severe enough to prevent them from returning to work [1,2]. LDDD can lead to a narrow lumbar canal, which is expected to affect more than 64 million of patients over the age of 60 by 2025 [3–5].

Within the surgical options for the treatment of LDDD, anterior lumbar interbody fusion (ALIF) plays a crucial role given its ability to improve segmental and global lordosis of the intervened region, also generating adequate foraminal and spinal canal decompression with a low complication profile [6–9]. The most frequently ALIF intervened level is L5-S1 [10,11].

A significant difficulty for this approach lies in the iliac vascular anatomy, which are the main anatomical structures associated with surgical complications in this location and whose injury is reported in between 1.9% and 24% of patients [12–14], most often venous and on the left side.

Currently, no imaging classification allows defining, in a preoperative way, the possible difficulty associated with the intervention considering the iliac vein vascular anatomy at the L5-S1 level, thus being able, if a more significant difficulty is expected, to consider an alternative approach that can ensure a similar clinical outcome by minimizing the perioperative risks of the patient. We analyze the local vascular anatomy of the lumbar region in several patients taken to this intervention to define and propose a classification that allow us to answer this question.

Materials and methods

The completion of this work was approved by the research office and ethics committee of the Hospital Universitario San Ignacio.

Data extraction

This is a retrospective analysis of a prospectively collected cohort that evaluated the different baseline, radiological, and surgical characteristics of patients over the age of 18 who were electively treated via

* Corresponding author at: Neurosurgery Department, Hospital Universitario San Ignacio,Cra.7 #40- 62, Bogotá, Colombia.
E-mail address: Vargas-alejandro@javeriana.edu.co (A. Vargas-Moreno).

ALIF. In some patients, a minimally invasive lateral interbody fusion of an adjacent segment or transpedicular posterior screw fixation was performed in the same procedure. Patient enrollment occurred between July 2018 and May 2020.

Two neurosurgeons specializing in spine surgery (MB, RD) performed the procedure using an extraperitoneal technique [8], inserting an artificial disc in the created space. The collection of the different essential data was carried out by searching our institution medical history registration system, and a radiographic analysis with measurement of coronal and sagittal alignment parameters was also performed [15].

The results were compiled and reviewed by three researchers. Patients who had been lost in follow up or did not have complete data in the medical history were excluded.

Variables of interest

The information collected included preoperative characteristics: demographics, previous surgery in the lumbar spine, clinical examination findings, imaging findings in lumbar nuclear magnetic resonance imaging (MRI) at the level to be intervened, measurement of the value of the sacral slope in a panoramic x-ray study as well as factors associated with surgery (levels intervened via ALIF during surgery, surgical intervention associated with ALIF (lateral or posterior), use of intraoperative neurophysiological monitoring, operative bleeding, surgical time for ALIF and complications).

Intraoperative bleeding was divided into mild (<100 ml), moderate (100-200 ml), and severe (>200 ml), as well as surgical time, was classified into five groups (10 minutes each), starting in less than 70 minutes, up to more than 100 minutes (considering the incision time until skin closure).

Once the intervention was complete, treating neurosurgeons classified the difficulty of surgery into five degrees (Very Easy, Easy, Moderate, Difficult, Very Difficult), taking into account the difficulty for disc exposure and subsequent procedure, as well as the need for vascular dissection. In any of the procedures, a general (access) surgeon was required for the intervention. In addition, the patient's venous iliac vascular anatomy was preoperatively classified concerning the upper edge of the L5-S1 disc before initiating the intervention in a lumbar nuclear magnetic resonance T2 axial cut.

Classification of venous vascular anatomy (Berbeo– Diaz – Vargas classification)

The iliac vascular complex is intimately related to the anterior part of the lumbar spine, mainly to the L4, L5, and S1 vertebral bodies [16–19]. In ALIF, the manipulation and displacement of vascular structures is key to the adequate exposure of the intervertebral disc and makes it vital to preoperative identify, mainly at the venous level, the structures whose injury can completely change the course of the surgery.

Being the L5-S1 level the most frequently intervened, it is imperative to adequately describe and preoperative classify the vascular anatomy at this segment. We have noticed that the division of the vertebral body and disc space into three equal areas facilitates the analysis of the relationship between the right and left iliac veins (Fig. 1).

The primary determinant of difficulty during the ALIF intervention is the common left iliac vein location, which can compromise this entire zone given its trajectory to the iliocava junction. Sometimes small venous afferents belonging to the iliolumbar vein (ILV) or ascending lumbar vein (ALV) can be evident in relation to the medial edge of the right iliac vein [18,19]. These can be safely ligated, although giving a greater difficulty to the intervention. We propose the following classification based on the observations of our group over time: **(For a detailed explanation, refer to Fig. 1).**

TYPE 1

1a: Left iliac vein(s) (LIV) in contact with zone I

Right iliac vein(s) (RIV) in contact with zone 1, less than a zone away from the LIV

1b: LIV in contact with zone 1

RIV without contact with zone 1, but less than a zone away from the LIV

1c: LIV in contact with zone 1

RIV without contact with zone 1 and more than one zone away from the LIV

1d: LIV in contact with zone 1

RIV without contact with zone 1 and more than one zone away from the LIV, however, with an associated venous medial branch of lower caliber (ILV or ALV) that is less than a zone away from the LIV.

TYPE 2

No vessels contacting zone 1

Both vessels (LIV and RIV) in contact with zone 2

Less than two areas away between the vessels (LIV and RIV)

TYPE 3

No vessels contacting zone 1

Only one of the vessels (LIV or RIV) is in zone 3 (More than 50% of its area)

There are less than three zones away between the vessels (LIV and RIV)

TYPE 4

More than 50% of both vessels (LIV and RIV) are in zone 3

Statistical analysis

Descriptive statistics are presented as mean, standard deviation, and range for continuous variables and frequency and percentage for categorical variables. Shapiro Wilk test was applied to ensure normal distribution of the data. The Chi-square test, together with Fisher's exact test, was used to compare categorical variables to find a relationship between them using a 95% degree of significance.

To assess the agreement in assessing the proposed classification, we compared the observed values in the radiological classification reported by two of the work authors and a certified radiologist, quantifying it with the weighted Cohen Kappa coefficient. Statistical analysis was performed using IBM SPSS Statistics version 26.0 software.

Results

Population characteristics

Between July 2018 and May 2020, 91 patients were intervened via ALIF to manage degenerative lumbar disease. 54% of the patients were women. The age at the time of surgery (Average $\pm$ ED) was 52.5 ± 14.81 years, with patients having a mean BMI of 27.8 ± 4.09. 13% of patients had a previous surgical intervention (3 posterior transpedicular fusions, two isolated laminectomies, two interbody fusions, four discectomies, and one patient intervened with a posterior column stimulator).

No patient had a history of previous spine surgery through an anterior approach. Unilateral radicular pain was the most common clinical presentation affecting 34% of patients, followed by 20 cases where this symptom was associated with lumbar axial pain.

Radiographic assessment

All patients had findings compatible with degenerative disc disease in the lumbar MRI, with 39 patients having changes compatible with grade IV and V disc degeneration on the Pfirrmann scale. 25% of the population had some grade of spondylolisthesis. One of the patients had a TLIF cage at level L5-S1, which was removed by an ALIF approach
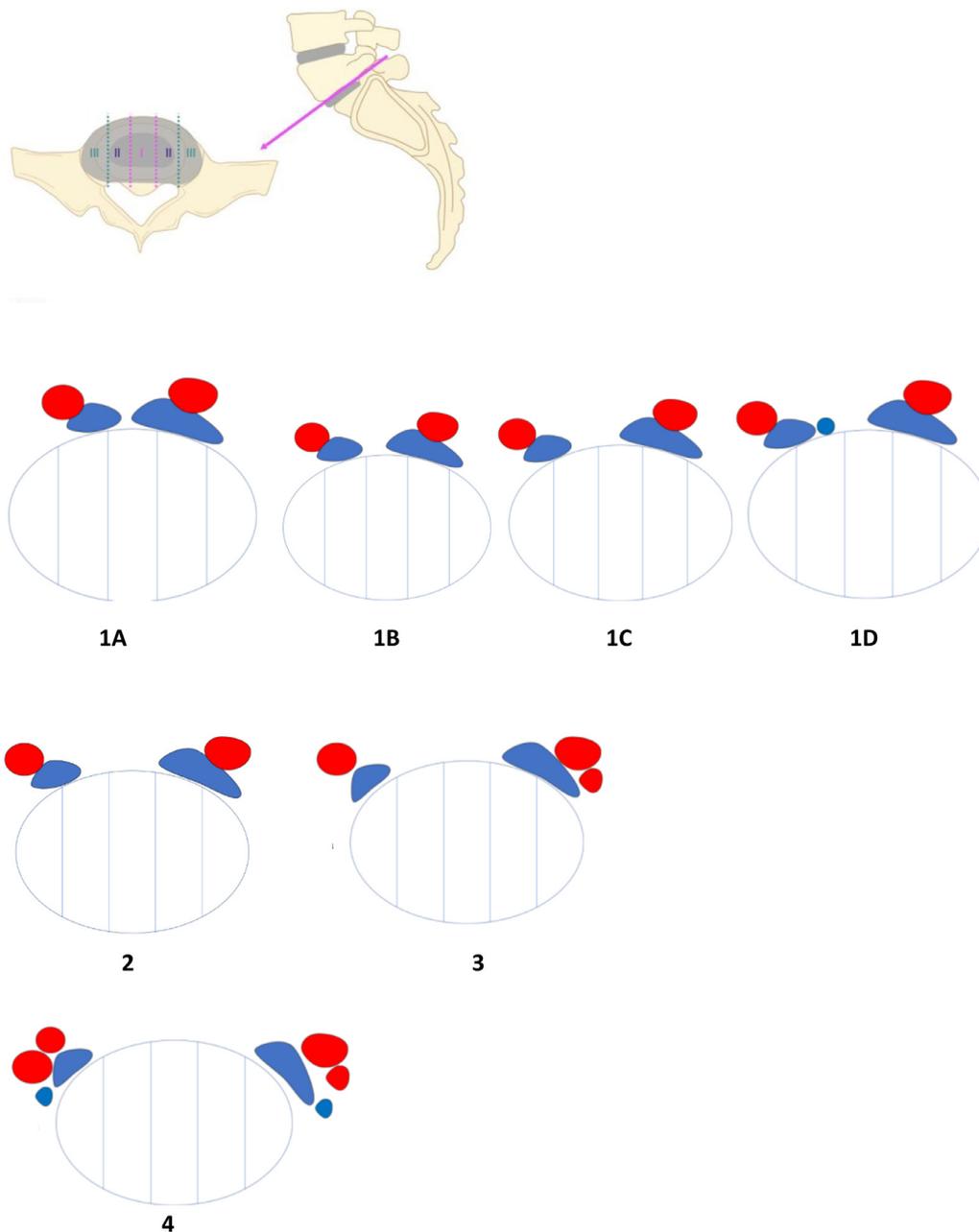
Fig. 1. Berbeo – Diaz – Vargas (BVD) classification: The superior border of the L5-S1 disc space, identified in and axial T2 MRI, is divided in a central and two lateral equal zones. The location of the left and right iliac veins (LIV)(RIV) is identified (Depicted in blue) in relation to the five zones of the disc.

repositioning a new one on this level. The mean sacral slope (SS) was 34.6 ±8.07˚, finding patients in all groups of Roussouly's lumbar lordosis classification [20].

Surgical features

22.8% of patients were intervened, in addition to ALIF, by LLIF, in 1, 2, and 3 levels in 19%,33.3%, and 47.6% of cases, respectively. Intraoperative neurophysiological monitoring was used in 44.5% of surgeries. Transpedicular instrumentation was performed in conjunction with ALIF in the same operation in 9 patients, with stand-alone ALIF L5-S1 being performed in 51 patients. The most common combination of multiple levels intervened via ALIF was L4-L5-S1, happening in 15 patients.

The average surgical bleeding was 152 cc (Minimum 20cc and Maximum 3000 cc). Four complications were identified, all involving vascular structures (Rupture of the left iliac vein or an afferent vein). They were handled intraoperatively by the leading surgical group (No vascular surgeon required) and completing the surgery in all cases in which the presence of them was documented. Surgical time for ALIF L5-S1 was 79 ± 13.3 minutes (Table 1).

Perceived surgical difficulty and Berbeo Scale - Diaz – Vargas

The Berbeo – Diaz – Vargas (BDV) classification found that the most common type was 4 (43.9% of the total), followed by type 3 (31.8%) and type 1 (18.6%). No patient was classified within subtype 1a. The Kappa weighted coefficient agreement among the evaluators evaluating the images for classification was 0.89 (95% CI 0.822 – 0.974). Given the absence of patients in group 1a, and in order to optimize statistical analysis, we grouped patients in the type 1 classification (Table 2).

Table 1

Demographic and surgical characteristics.

	Total patients - n= 91 (100%)			
Sex	42 men (46.1)			
	49 women (53.8)			
	Mean	**Min.**	**Max.**	**ED**
Age	52.5	18	92	14.8
BMI	27.8	17.6	36	4
MRI imaging findings				
Degenerative disc disease (DDD)			63 (69.2)	
DDD and spondylolisthesis			14 (15.3)	
High grade spondylolisthesis			12 (13.1)	
TLIF cage in L5-S1 disc space			1 (1.)	
Sacral slope	**Mean**	**Min.**	**Max.**	**ED**
	34.6	10	62	8
Rousseoly Class				
1 y 2		48 (52.7)		
2		38 (41.7)		
3		5 (5.4)		
Clinical findings				
Axial back pain (BP)			18 (19.7)	
BP and unilateral radicular leg pain			20 (21.9)	
BP and bilateral leg radicular pain			8 (8.7)	
Unilateral radicular leg pain			32 (35.1)	
Bilateral radicular leg pain			13 (14.2)	
Surgical characteristics				
LLIF levels				
			YES	21 (23)
			L3-L4	1 (1)
No		70 (76.9)	L3-L4-L5	5 (5.4)
			L2-L3-L4-L5	10 (10.9)
			L2-L3-L4	2 (2.1)
			L4-L5	3 (3.2)
Intraoperative electrophysiological monitoring				
No	49 (53.8)		Yes	42 (46.1)
ALIF Levels				
L3-L4-L5-S1			1 (1)	
L4-L5-S1			14 (15.3)	
L5-S1			52 (57.1)	
L4-L5-S1 with posterior fusion			3 (3.2)	
L5-S1 with posterior fusion			21 (23)	
	Mean	**Min.**	**Max.**	**ED**
Time for ALIF L5-S1	79	60	120	13.3
	Mean	**Min.**	**Max.**	**ED**
Bleeding ALIF L5-S1	130	20	3000	369.3

BMI: Body mass index.

Table 2

Vascular radiological classification and surgery difficulty perceived.

Vascular radiological classification n=91 (100%)	
1a	0 (0)
1b	5 (5.4)
1c	10 (10.9)
1d	2 (2.1)
2	5 (5.4)
3	29 (31.8)
4	40 (43.9)
Surgery difficulty perceived	
Very easy	16 (17.5)
Easy	28 (30.7)
Moderate	23 (25.2)
Difficult	19 (20.8)
Very Difficult	5 (5.4)

Table 3

Classification and confounding variables.

BDV classification Type					
Sex	1	2	3	**4**	**p**
Men	8	3	14	17	**p=**
Women	9	2	15	23	**0.88**
BMI<24.9	7	3	11	12	
25-29.9	9	1	12	20	**p=0.26**
>30	1	1	6	8	
SS <35	13	4	12	19	
36-45	4	1	14	19	**p=0.232**
>45	0	0	3	2	
Bleeding Mild	5	3	26	38	
Moderate	11	2	2	2	**p<0.001**
Severe	1	0	1	0	
Time <70	0	0	0	39	
71-80	0	0	24	1	
81-90	3	2	5	0	**p<0.001**
91-100	6	2	0	0	
>100	8	1	0	0	
Difficulty Very easy	0	0	1	15	
Easy	3	0	14	11	
Moderate	2	2	7	12	**p<0.001**
Hard	9	3	5	2	
Very hard	3	0	2	0	

BMI: Body mass index.
SS: Sacral Slope.

When looking for differences between imaging classification groups in order to identify whether variables could influence their presentation, it was found that there was no relationship between sex, BMI, or SS by performing Fisher's exact test (p-0.88, p-0.26, and p-0.232, respectively) and the classification into four groups (1 to 4) of the venous anatomy (Table 3).

Table 4
Surgery perceived difficulty and confounding variables.

Surgery perceived difficulty		Very Easy	Easy	Moderate	Hard	Very Hard	p
SS	<35	5	15	13	11	4	
	36-45	10	12	7	8	1	**p=0.367**
	>45	1	1	3	0	0	
BMI	<24.9	8	13	5	5	2	
	25-29.9	5	12	14	8	3	**p=0.33**
	>30	3	3	4	6	0	
Bleeding	Mild	14	23	21	12	2	
	Moderate	2	5	1	7	1	**p=0.006**
	Severe	0	0	1	0	2	
Time	< 70	15	10	17	2	0	
	71-80	0	10	2	5	0	
	81-90	0	3	1	4	2	**p<0.01**
	91-100	0	3	1	7	0	
	>100	0	2	2	1	3	

BMI: Body mass index.
SS: Sacral Slope.

A significant relationship was found between the magnitude of the intraoperative bleeding (p<0.01) and the degree of classification on the BDV scale, finding decreasing intraoperative bleeding rates in ascending types of classification (3-4), indicating a more favorable venous configuration. Likewise, when assessing intraoperative time and its possible link to classification, it was found that patients with lower classification values were prone to present a prolonged surgical time (p<0.01).

Overall, 30% of ALIF procedures were perceived as easy by surgeons at the end of the surgery, with 24% of cases perceived as difficult and very difficult. The difficulty stratification of surgery, perceived by the surgeon at the end of the surgery, was significantly influenced by the intraoperative bleeding presented, as well as with the duration of the intervention (p=0.006 and p<0.01), being greater (Time and bleeding) in the highest perceived degree of difficulty, without being related to BMI or SS (p-0.33 and p-0.367) of the patient (Table 4).

In analyzing the relationship between the proposed classification and the perception of surgical difficulty, a connection was found between the two, showing greater perceived difficulty by the surgeon with the initial types of the BDV classification (p<0.001).

Discussion

We propose the BDV classification as a simple method for evaluating iliac vein vascular anatomy at the L5-S1 disc level, defining which group of patients might have prolonged surgical times, major intraoperative bleeding, and increased surgical difficulty. The BDV classification was significantly correlated with a higher incidence of bleeding, a prolonged intraoperative time, and a greater difficulty perceived by the surgeon in all the groups evaluated, additionally presenting an outstanding level of agreement according to its assessment among evaluated observers.

The perceived surgical difficulty was significantly correlated with the duration of the intervention and with the intraoperative bleeding presented, without an association with BMI. This parameter can negatively impair the performance of a correct ALIF surgical approach, but did not influence our group results. We did not find an association between the angle of the sacral slope and the surgical complexity.

Although previously operated patients where included in our cohort, none of them had a previous procedure through an anterior approach, which made them suitable for the analysis. The main determinant of difficulty measurement was the iliac vein complex vascular anatomy dissection and none of these patients had any factors that could (pre operatively) alter these anatomic structures nor add more difficulty on their dissection.

Although there is still controversy about whether the above techniques are better than posterior fixation techniques at the lumbar level,

it is clear that ALIF is an efficient, safe technique with reproducible results [7,10,11]. Jiang et al. reported in their systematic review that clinical outcomes and failed fusion rates are similar between the two techniques (posterior and anterior), with radiological parameters (including disc height restoration, segmental and global lordosis) that are superior in the ALIF, nevertheless having a higher cost, bleeding and surgical time when compared to transforaminal interbody fusion [21]. Other authors have reported that ALIF results in minor bleeding and reduced surgical times than posterior approach interventions [22], findings that correlate with our results (and additional reports) [23] with an average bleeding of 152 ml, with certain cases in our series, where major bleeding (up to 3000 ml) was present. Likewise, the average intraoperative time of our interventions was 79 minutes, which is similar to those reported in other studies [22–25] and can be equally prolonged if disc exposure is complicated.

The efficiency and safety of the ALIF allow its association in the same operation or in a subsequent time, with other techniques to optimize the outcomes of patients, a phenomenon that we show in a significant percentage of our population, and that increases the versatility of this technique as part of the arsenal of the spine surgeon. The association with additional anterior fusion techniques (LLIF) implies the mandatory use of neurophysiological monitoring [8], reserving this tool in patients only intervened by ALIF with or without circumferential fusion by our group, to those with high-grade spondylolisthesis, documented neurological deficit, or prior surgical intervention.

Factors such as the learning curve of the ALIF, as well as possible difficulty in the exposure of the vertebral body for an adequate implementation of the technique, restrict its use and can be associated with a higher level of complications and poorly satisfactory outcomes [7,9,23], reinforcing the usefulness of a scale that allows predicting this type of outcomes within patients as we currently propose.

The low incidence of complications in our group does not assess an adequate association between the proposed classification and the incidence of this type of incidents, a phenomenon that could be correlated if a larger sample is evaluated.

A significant limitation of our work is its retrospective and single-institution nature, with a lack of longitudinal follow-up to define the long-term impact on patients, recognizing that a multicenter study could provide robust, more generalized data when considering additional surgeons. The absence of patients with classification in group 1a does not imply that this type is not possible, given the significant anatomical variability within patients, and although it is not present in the current series, it has been found in our practice. We also believe that the subdivision of the type 1 is necessary. Although not statistically significant in our analysis (Because of the scarce population of patients in the Type

1 group), in future studies, investigators would want to evaluate the impact of this sub-types on patients' outcomes.

Additionally, the absence of a more significant number of patients with BMI > 35 in our cohort limits our conclusions in this population.

Moreover, spine surgery, and its minimally invasive form of implementation, have increased its frequency as a substantial treatment alternative over the past decade [10,11,15]. The decrease in the number of complications for the patient, the shorter hospital stay and surgical time, the relevant results, and the economic impact of this type of techniques, has allowed their use for the management of different spine pathologies [1,7,8,10], still needing tools that allow improving the optimal selection of the patients in order to improve their outcomes. We consider our classification to be a step forward in this direction towards precision medicine, and we will continue its study to define additional findings in further studies.

Conclusion

To our knowledge, ours is the first vascular imaging classification in patients taken to surgery using ALIF. Our imaging classification Berbeo – Diaz – Vargas is a reliable and reproducible tool for the classification of iliac vascular venous anatomy in lumbar nuclear magnetic resonance imaging, before intervention by ALIF L5-S1, significantly related to a higher incidence of bleeding, prolonged operating time, and increased perceived difficulty by the surgeon. We propose that patients who present a higher degree of difficulty in classification, unless they are in the hands of an experienced surgeon, be considered for further intervention, however, considering the retrospective feature of our series that only provides level III evidence.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Summary sentence

We aimed to evaluate the anatomy of the common iliac vein bifurcation complex (CIVC) at the L5-S1 disc proposing a novel grading system applied to the ALIF procedure, the BDV scale.

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