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ORIGINAL ARTICLE

Clinical and radiological outcome of anterior–posterior fusion versus transforaminal lumbar interbody fusion for symptomatic disc degeneration: a retrospective comparative study of 133 patients

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Abstract Abundant data are available for direct anterior/posterior spine fusion (APF) and some for transforaminal lumbar interbody fusion (TLIF), but only few studies from one institution compares the two techniques. One-hundred and thirty-three patients were retrospectively analyzed, 68 having APF and 65 having TLIF. All patients had symptomatic disc degeneration of the lumbar spine. Only those with one or two-level surgeries were included. Clinical chart and radiologic reviews were done, fusion solidity assessed, and functional outcomes determined by pre- and postoperative SF-36 and postoperative Oswestry Disability Index (ODI), and a satisfaction questionnaire. The minimum follow-up was 24 months. The mean operating room time and hospital length of stay were less in the TLIF group. The blood loss was slightly less in the TLIF group (409 vs. 480 cc.). Intra-operative complications were higher in the APF group, mostly due to vein lacerations in the anterior retroperitoneal approach. Postoperative complications were higher in the TLIF group due to graft material extruding against the nerve root or wound drainage. The pseudarthrosis rate was statistically equal (APF 17.6% and TLIF 23.1%) and was higher than most published reports. Significant improvements were noted in both groups for the SF-36 questionnaires. The mean ODI scores at follow-up were 33.5 for the APF and 39.5 for the TLIF group. The patient satisfaction rate was equal for the two groups.

Keywords Symptomatic lumbar disc degeneration · Anterior–posterior fusion · Transforaminal lumbar interbody fusion

Introduction

The goal of a fusion of the lumbar spine is to obtain a primary solid arthrodesis so as to alleviate pain [10, 11, 14, 15, 19, 22, 31]. Different circumferential or "360°" fusion techniques have been described such as combined anterior–posterior fusion (APF), instrumented posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF).

TLIF has rapidly gained popularity in these last few years, since Harms reported his results in 1998 [17]. Because of its posterolateral extracanalar discectomy and fusion, it has been reported as a safe technique, without the potential complications described when using combined APF and PLIF techniques [17, 28]. Several authors have published retrospective studies comparing the TLIF technique to APF [16, 18, 35]. However, these studies included multiple diagnostic groups, and clinical as well as radiological outcomes were not always reported. Standard radiographs were used to assess fusion, which has been shown to underestimate pseudarthrosis rates [3, 5, 7].

This work is dedicated to the memory of Grace and Julia Hanson.

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Using recognized clinical and well-defined radiological outcome measures, we retrospectively compared two age and diagnosis matched populations who underwent either a TLIF or a combined APF for one or two level lumbar symptomatic disc degeneration (SDD).

Materials and methods

The prospective database of our Center was interrogated to extract data from patients that underwent a one or two level lumbar fusion and with a minimum follow-up of two years. Patients in both study groups had a primary diagnosis of SDD. Secondary associated diagnoses such as recurrent herniated nucleus pulposus (HNP) or other degenerative stenosis were accepted for inclusion. Subjects with attempted previous fusion (pseudarthrosis or persistent discogenic back pain after isolated solid posterolateral fusion) were also included, but the indication for the first surgery had to be a diagnosis of SDD. Patients with scoliosis, spondylolisthesis, infection, or tumor were excluded.

Pre-operative provocative discography with at least one control level was used to identify the level to treat based on reproduction of concordant pain in 79% of the patients. Pain was quantified using a ten points visual analog scale (VAS). The discographic indication for fusion was a score of at least 6/10 concordant pain and a negative control level. The technique for provocative discography was performed according to a well defined protocol that has been in use for several years by the radiologists involved in this study. For the 21% of patients who did not undergo pre-operative provocative discogram, the choice of fusion level was based on presence of obvious disc degeneration on plain radiographs such as traction osteophytes, severe disc space narrowing or endplate sclerosis. MRI criteria such as advanced desiccation, Modic type I change of the endplates, presence of high intensity zones (HIZ) [33] were also applied.

Surgical technique

The choice of the surgical technique (APF or TLIF) was based on surgeon's preference. Amongst the group of surgeons of this study, the technical aspects were very similar within both patient populations.

APF (anterior–posterior fusion) technique

The surgical sequence (anterior or posterior approach first) was by surgeon's preference. The lumbar spine was exposed through a retroperitoneal approach in all patients. Whenever deemed necessary, the ascending ilio-lumbar vein was ligated to avoid risk of tear at the L4–L5 level. A radical discectomy was performed. The posterior longitudinal ligament (PLL) was usually preserved. Endplate preparation was done by removing hyaline cartilage until punctuate bleeding of the subchondral bone. Care was taken not to weaken subchondral bone. Interbody structural allograft was then inserted. If the surgeon felt that the fitting of the anterior structural allograft was inadequate, an oblique anterior buttress screw was inserted. Interbody graft spacers were augmented with morcellised allograft.

The patient was then flipped and positioned prone for the posterior approach. This consisted in a classic midline incision with subperiosteal muscle detachment. If necessary, decompression was performed (laminotomy, complete or hemi-laminectomy, foraminotomy). Posterior instrumentation was then inserted: pedicle screws (PS) and rods, or less often translaminar facet screws (TLFS). If decompression was not wide laterally, laminae and facet joints were decorticated for fusion. If decompression was wide, dissection was carried on more laterally to the transverse processes which were then decorticated together with the facet joints and packed with a mix of locally harvested autograft and morcellised allograft.

TLIF technique

The technique used in this study was similar to that described by Harms [17]. The spine was approached through a classic posterior midline incision and subperiosteal muscular detachment. The side of facetectomy was chosen according to the subject's symptoms of leg pain if present. A 1 × 1 cm posterolateral annulotomy was made and subtotal discectomy was performed and the hyaline cartilage of endplates was removed. Once the surgeon was satisfied with endplate preparation, a boomerang shaped allograft spacer was inserted through the annulotomy and placed anteriorly, along the anterior apophyseal ring, so that its largest diameter was parallel to the coronal plane. A semilunar graft milled from a human femoral ring and provided by an independent manufacturer was mostly used, or less often a femoral ring that was split intraoperatively and was provided by a human bone bank. Additional autograft locally harvested from decompression was packed behind the allograft spacer in all cases. Laminae and the remaining contralateral facet joint were decorticated, and packed with bone graft (local autologous and allograft chips in all cases). Finally, the posterior fusion was instrumented with pedicle screws and rods.

Clinical charts were reviewed to gather follow-up information on post-operative short-term and long-term complications, additional surgical intervention done elsewhere, additional non-surgical treatments, etc. All operative reports were available in the clinical charts and were

reviewed for description of procedure and possible intra-operative complications.

Hospital charts containing operating room nurses' and anesthesiologists' reports as well as hospital stay summary were also reviewed to gather information regarding operating room time (OR time), estimated blood loss (EBL), immediate post-operative complications and length of hospital stay (LOS).

Clinical outcome was assessed at a minimum of 2 years follow-up and compared to a pre-operative baseline value using Short Form 36 (SF-36). Oswestry Disability Index questionnaires (ODI) were available only for the final outcome. A satisfaction questionnaire was added to allow patients to self-rate their result of surgical treatment.

Bony fusion was radiologically assessed at a minimum of 24 month follow-up. All the investigators met on several occasions to discuss the criteria for fusion status assessment. Fusion assessment was first done blindly and independently by all of the investigators. Doubtful cases were conjointly reviewed until a consensus was reached.

CT scans were used for fusion assessment. In both groups, all the subjects who did not have a CT scan during their follow-up to assess fusion were contacted to undergo a thin-cut CT scan. Two and half millimeter axial CT sections (GE LightSpeed systems) were obtained through the fusion mass as well as the adjacent segments with 1.25 mm reconstructions and both sagittal and curved coronal reformats.

The subjects who agreed to undergo these additional follow-up exams signed an informed consent explaining them the purpose of the study and the risks in relation to the use of radiation. Approval from our Institutional Review Board was obtained.

Qualitative criteria were used for CT scan fusion assessment as detailed in Tables 1 and 2. Approximately, 30% of endplate to endplate bridging bone surface was required to consider the interbody fusion to be radiologically fused [8]. For posterior and posterolateral fusion mass, a modification of Christensen's classification was used [7] (Table 2).

Both groups were further classified according to a final radiological outcome scale based on combined anterior and posterior fusion status information (Table 3):

Table 1 CT scan interbody fusion assessment scale

Grade	Criteria (CT scan)
P-1	Continuous intersegmental bridging bone (fused)
P-2	Doubtful intersegmental bridging bone (fragmented)
P-3	No intersegmental bridging bone (pseudo)

Table 2 CT scan posterior fusion mass assessment scale

Grade	Fusion status (interbody)	Criterias (axial cuts and coronal and longitudinal 2D reconstructions)
A-1	Fused	Bridging bone (BB) >30%
A-2	Probably fused	BB <30%
A-3	Indeterminate	No BB or indeterminate BB
A-4	Probably not fused	No BB + marginal lucencies
A-5	Pseudarthrosis	Cystic lucencies, graft fragmentation, marginal lucencies on screws

Table 3 Combined fusion assessment scale, per level, using CT scan 2D reconstructions

Anterior column	Posterior column
Solid fusion	
Fused (A-1)	Fused (P-1)
Fused (A-1)	Fragmented (P-2)
Fused (A-1)	Not fused (P-3)
Partial fusion	
Probably fused (A-2)	Fused (P-1)
Probably fused (A-2)	Fragmented (P-2)
Probably fused (A-2)	Not fused (P-3)
Inadequate fusion	
Probably not fused (A-4)	Fused (P-1)
Probably not fused (A-4)	Fragmented (P-2)
Probably not fused (A-4)	Not fused (P-3)
Not fused (A-5)	Fused (P-1)
Not fused (A-5)	Fragmented (P-2)
Not fused (A-5)	Not fused (P-3)
Indeterminate	
Indeterminate (A-3)	Fused (P-1)
Indeterminate (A-3)	Fragmented (P-2)
Indeterminate (A-3)	Not fused (P-3)

1. Solid radiological fusion was defined as bridging bone in both anterior (at least 30% endplate surface) and posterior columns or anterior column alone
2. Partial radiological fusion: anterior column "probably fused" with any fusion status of posterior column
3. Inadequate radiological fusion: at least anterior column "not fused" or "probably not fused", with any fusion status posteriorly
4. Indeterminate radiological fusion: indeterminate anterior fusion status with any fusion status posteriorly

On this scale, "solid" and "partial" fusions were considered as adequate, as the anterior supporting column was definitely or probably fused. "Inadequate fusion" was considered as a non-union or pseudarthrosis. Some examples illustrating this CT fusion scale are shown in Fig. 1.

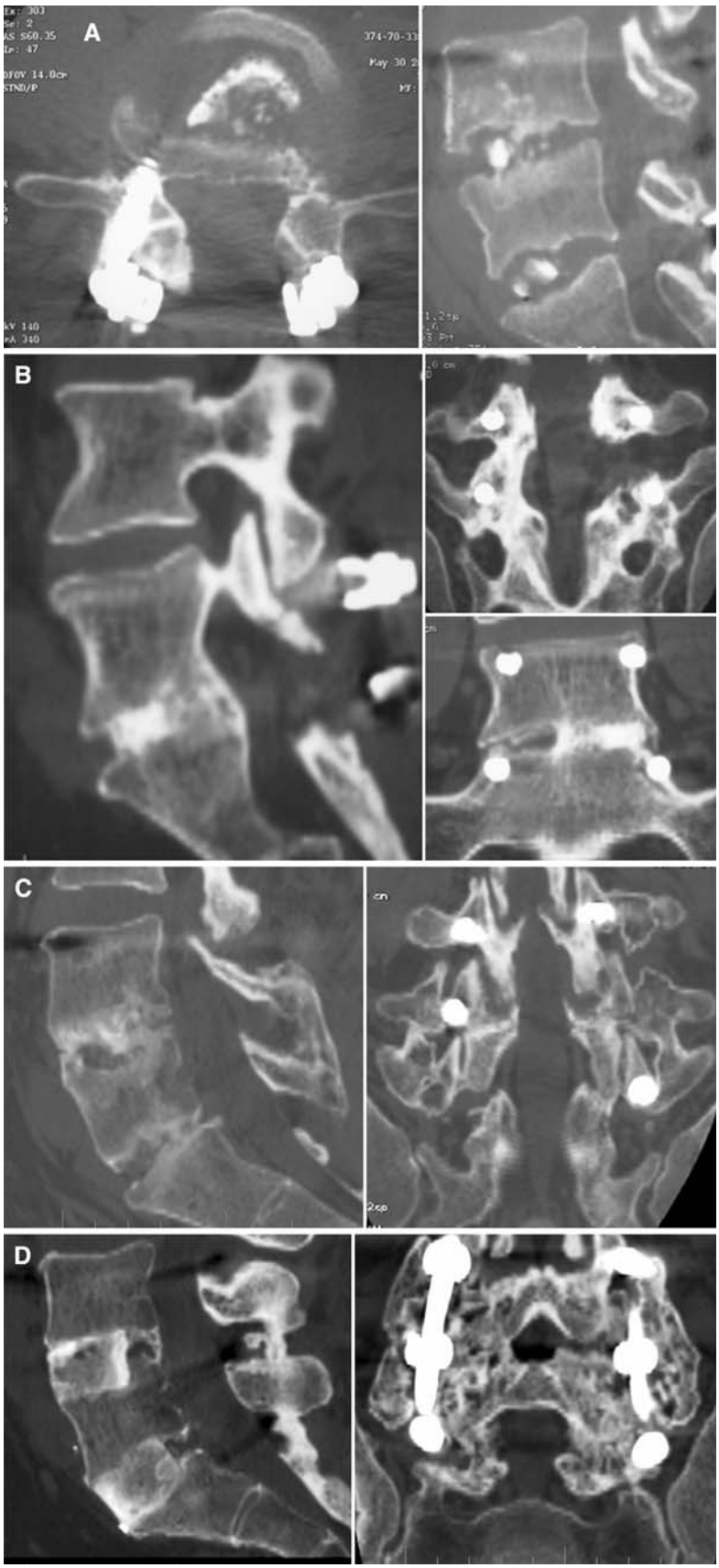

Fig. 1 **a** *TLIF* inadequate fusion. CT scan at 16-month FU. Fused right facet joint (P1), interbody pseudarthosis (A-5). **b** *TLIF* solid fusion. CT scan at 22-month FU. Fused right facet joint (P-1), interbody solid fusion (A-1). **c** *APF* inadequate fusion. CT scan at 33-month FU. L4–L5 posterior nonunion (P-3), interbody nonunion (A-5) L5–S1 posterior solid fusion (P-1), interbody nonunion (A-5). **d** *APF* solid fusion. CT scan at 35-month FU. L4–L5 posterior solid fusion (P-1), interbody solid fusion (A-1). L5–S1 posterior solid fusion (P-1), interbody solid fusion (A-1)

Statistical analysis

Student's T test was used to test for differences between treatment groups for continuous variables (Ex: Age) and dichotomous variables (ex: reoperation rate), assuming the normality assumption was met. For non-normally distributed continuous variables (ex: Blood loss), the nonparametric Wilcoxon–Signed Rank test was utilized. Fisher's Exact test was utilized to compare categorical variables (ex: fusion status, length of stay).

Statistical analysis was conducted with SPSS® 14.0, Chicago, IL. Statistical significance was set at $P < 0.05$.

Results

We identified 68 subjects who underwent a one or two level combined APF and 65 subjects who underwent a one or two level TLIF (Table 4). Mean age for the APF group was 42 years (range 17–67), and the mean age for the TLIF group was 44 (range 23–73, $P > 0.05$).

The primary diagnosis for all patients was SDD, but 38.2% of the patients in the APF group and 33.8% of the TLIF group had a concomitant diagnosis at the time of index surgery for this study, including arthritic stenosis (10% in APF group, 18.5% in TLIF), voluminous HNP (4% in APF, 7.7% in TLIF) or recurrent HNP (13% in APF, 8% in TLIF%). Prior spinal surgeries were noted in 45% of the patients in both groups, with the most common being decompression surgeries such as discectomies (19% in both groups) and laminectomies (13% in APF, 9% in TLIF).

There were three patients of the APF group enrolled in this study had a preoperative diagnosis of pseudarthrosis; there were none in the TLIF group.

Clinical and surgical parameters in each group and per number of levels are presented in Table 5. Only the mean OR time and the mean LOS were significantly shorter in the TLIF group ($P < 0.05$). The EBL showed a trend also in favor of TLIF with a median at 409 cc versus 480 cc for the APF group ($P > 0.05$).

Intraoperative complications were significantly less in the TLIF group ($P < 0.05$). In the APF group, complications were noted in eight patients (11.8%) during the anterior retroperitoneal portion of the procedure and included: six vein lacerations (five minors, one major with 1,200 cc EBL); one interbody graft displacement that occurred while flipping a patient for the second approach and was noticed on a lateral radiograph view during the posterior procedure; one posterior wall fracture of L4 with post-operative nerve root irritation in another patient. Both of these latter complications needed immediate revision surgery. Two additional complications (2.9%) were noted on the posterior procedure, both were minor dural tears.

In the TLIF group, intraoperative complications were noted in three patients (4.6%): one L5 root impingement due to a displaced fragment of a laminar fracture that was noticed early in the post-operative period and needed

Table 4 Study materials

	APF		TLIF	
	n	%	*n*	%
Enrolled	68	M: 56 F: 44	65	M: 43 F: 57
Clinic charts available	68	100	65	100
Hospital charts available	55	80.9	57	87.7
Returned questionnaires	44	64.7	41	63.1
Complete set of radiographic documents available for analysis (CT scans)	40	58.8	35	53.8

Table 5 Clinical and surgical data

Study group	OR time (mean, range)	EBL (mean, range)	LOS (mean, range)
APF one level ($n = 11$)	209 (100–350)	187 (20–450)	4.6 (3–6)
APF two levels ($n = 43$)	305 (214–550)	494 (100–2,500)	5.3 (3–11)
TLIF one level ($n = 31$)	152 (93–261)	248 (25–2,100)	3.9 (2–7)
TLIF two levels ($n = 27$)	216 (85–290)	387 (100–1,150)	4.8 (3–13)
Mean for APF group	285	430	5.1
Mean for TLIF group	181, $P < 0.05$	313, $P > 0.05$	4.3, $P < 0.05$

OR time operating room time, *EBL* estimated blood loss, *LOS* length of hospital stay

revision surgery; one L4 nerve root irritation with weakness due to pedicle screw malplacement that was also noticed immediately postoperatively; one inability to place an L4 pedicle screw after an attempted redirection.

The rate of early postoperative complications (<6 weeks) was statistically higher in the TLIF group ($P < 0.05$). Ten patients out of 65 (15.4%) underwent early revision surgery. Reasons for early revision surgery included wound incision and drainage (I&D) in six patients (9.2%) because of hematoma or *Staphylococcus aureus* infection, graft extrusion with neurologic symptoms in three patients (4.6%), an intraoperative laminar fracture with nerve root impingement that was not noticed in the immediate postoperative period in one patient (1.5%).

In the APF group, early revision surgery had to be performed in four out of 68 patients (5.9%): one patient needed additional surgery because of insufficient decompression, three patients needed wound I&D for a documented infection (*S. aureus*), all in the posterior wound.

We looked for a correlation between smoking status and risk of infection. Overall, 49 patients were smokers and 84 were non smokers. Six of the patients who smoked (12.2%) required wound I&D while only three of the non-smokers (3.6%) required I&D. Due to small patient sample size, statistical analysis did not reach significance (Fisher's exact test, $P = 0.061$).

Fusion results

Single-level fusions were done in 21% of the APF group and in 51% of the TLIF group ($P > 0.05$); the remaining had two level fusions. Levels fused were mostly located between L4 and S1 in both groups.

In the APF group, tricortical iliac crest allografts were used for interbody fusion in 41 patients (59.7%). Milled femoral ring was used in 12 patients (17.9%), patella allograft alone in 11 patients (16.4%), or a combination of patella allograft and iliac crest allograft in four patients (6%). Pedicle screws and rods were implanted in 55 subjects (80.9%), and translaminar facet screws in 13 subjects (19.1%).

In the TLIF group, a split femoral ring provided by a human bone bank was used for interbody fusion in 25 patients (38.5%) and a semilunar graft milled from a human femoral ring provided by an independent manufacturer in the remaining 40 patients (61.5%). Only pedicle screws were implanted in this group.

Only 58.8% of the APF and 53.8% of the TLIF subjects had a complete set of radiological documents for fusion analysis at the time of this study. However, all the subjects included in this study had a minimum of 2-year follow-up and all had their clinical charts available for review. From these, it could be determined that the remaining subjects did not undergo a surgical revision because of pseudarthrosis. For the remaining patients, the radiological report of other CT scan examinations were found in the clinical charts and clearly mentioned criteria that were compatible with "definitely" or "probably fused" interbody fusion. We thus decided to include these patients in the statistical analysis.

The average radiographic follow-up was 33 months (APF: 34 months; TLIF 32 months), with the maximum follow-up being 56 months. A total of 17.6% in the APF group and 23.1% in the TLIF group were diagnosed with pseudarthrosis ($P > 0.05$). Nine patients in the APF group (13.2%) and 12 in the TLIF group (18.5%, $P > 0.05$) underwent revision surgery for pseudarthrosis.The diagnosis of pseudarthrosis was comfirmed by the surgeon intra-operatively. Additionally, there were three patients (4.4%) in the APF group and three (4.6%) in the TLIF group with a radiologically documented pseudarthrosis (CT scan) that had not been surgically revised yet at their latest follow-up (>24 month). However, all of these six patients were being considered for possible revision because of symptoms.

The type of anterior graft appeared to have an influence on the occurrence of pseudarthrosis within the TLIF group. When a split femoral ring allograft from the bone bank was used, 10 out of 25 patients (40%) had a pseudarthrosis, while only 3 out of 40 patients (7.5%) had a pseudarthrosis when a milled semilunar allograft spacer was used ($P < 0.05$).

The data of the APF group was too sparse within anterior graft type to determine if there was an effect due to anterior spacer type. However, type of posterior instrumentation was noted as an influential factor on pseudarthrosis in the APF group, with 3 of 13 (23%) patients with translaminar facet screws having pseudarthrosis and 6 of 55 (11%) patients with pedicle screw instrumentation having pseudarthrosis ($P < 0.05$).

Clinical outcome

On average, 64% of the patients of this study returned the ODI, SF-36 and satisfaction questionnaires for follow-up (APF group: 65%; TLIF group: 63%). Due to changes in process and the retrospective nature of this project, baseline patient questionnaires for ODI were only available for a small number of patients and change from baseline could not be statistically analysed. Mean ODI score at latest follow-up was 33.5% for the APF group (0–76) and 39.5% for the TLIF group (0–76).

The change from baseline analysis was limited to SF36 and included only those patients with both baseline and follow-up questionnaires available. For this subgroup of

patients, the improvement was consistent for SF36. Statistically significant change from baseline in both APF and TLIF groups was observed for Physical Composite Score, Physical Function, Role Physical, Bodily Pain and Social Function; significant improvement for General Health was noted only in the APF group ($P < 0.05$).

Eighty percent of the APF and 71% of the TLIF group patients that had returned the self-rating satisfaction questionnaire elaborated in our clinic, rated their treatment results as good or excellent ($P > 0.05$).

Discussion

Amongst all the lumbar spinal fusion techniques, combined APF offers the highest mechanical stability and the best chances of bony fusion [30]. However, it is well recognized that the anterior approach may result in severe, sometimes life threatening intraoperative complications, because the surgeon has to work in proximity of major anatomical structures [4, 6, 19, 21]. Nevertheless, with the help of vascular or general surgeons that are familiar with these approaches, the incidence of major complications can remain very low [1, 27].

TLIF is an extracanalar variant of the PLIF technique described by Cloward in the 1950s [9]. PLIF has been associated with high incidences of neurological complications, up to 13.6% permanent neurologic lesions in Barnes' et al. study, in particular of the traversing nerve root [2, 12, 18, 26, 29]. This is due to the fact that a great amount of traction on the dural sac is required to implant the interbody fusion devices. With TLIF, a complete unilateral facetectomy allows the surgeon to decompress the intervertebral foramen and perform an extracanalar discectomy. However, the exiting nerve root is at risk for injury, especially at the L5–S1 foramen where the L5 nerve root is larger and crosses the foramen more obliquely [17].

TLIF has been retrospectively compared to instrumented PLIF by Humphreys et al. in 2001 [20]. They used one cylindrical mesh cage placed posteriorly and centrally. They found blood loss to be the only variable significantly lower in the two level TLIF procedure ($P < 0.01$) compared to two level PLIF. Several complications were reported for the two levels PLIF technique versus none for the two levels TLIF, but only postoperative radiculitis (four subjects in the PLIF group, 11.8%) could directly be related to technical issues with the former, dural traction for instance. The remainder of the complications was not specific to the PLIF technique. Two limitations of this study were the absence of detailed radiological and clinical outcomes.

To the best of our knowledge, only three studies have compared TLIF to APF [18, 34, 35].

In 2001, Hee et al. [18] retrospectively compared results between 53 subjects who underwent a single stage anterior–posterior fusion (APF) to 111 who underwent a TLIF with posterolateral instrumented fusion. Diagnoses and indications were multiple in both groups. The anterior–posterior fusion (APF) group was managed with three different types of anterior support. The TLIF group was managed with two different types of anterior support. Both groups received a posterior pedicle screw construct completed by interlaminar or intertransversary decortication and autogenous graft packing. Their rate of nonunion for a single level and for two levels APFs, were 11 and 17%, respectively, compared to 4 and 6% for the one and two level TLIF procedure, respectively ($P < 0.07$). This appears to be surprising, as one could expect higher pseudarthrosis rates with the TLIF technique which does not provide as much endplate surface for grafting. The authors make us aware of the fact that 40% of the APF subjects and 16% of the TLIF subjects had a preoperative diagnosis of pseudarthrosis. There were more heavy smokers in the TLIF group. The rate of postoperative persistent radiculopathy was similar for both groups, 8 and 9%. Finally, the rate of infection was higher in the APF group compared to the TLIF group, 11.3 versus 4.5% (not significant). The authors conclude that both techniques are demanding, but TLIF was their preferred technique because of shorter OR time (APF $= 279.6 \pm 65.4$ min, TLIF $= 172.5 \pm 48.7$ min; Wilcoxon's two sample test, $S = 0.0001$, significant), less blood loss ($S = 0.01$, significant) and lower incidence of complications ($P = 0.04$). As with other studies, the groups studied were not matched for diagnosis and surgical technique.

The same year, Whitecloud et al. [35] published a comparative financial analysis of APF versus TLIF. They reviewed the hospital charts of 40 subjects who had undergone an anterior–posterior fusion (APF) and 40 subjects who had undergone a TLIF procedure. Different variables were analyzed: OR time, blood loss, blood transfusion, intensive care unit stay and hospital stay. All these variables were in favor of the TLIF group, but statistical analysis was available only for blood loss ($P < 0.05$). No radiological or clinical outcomes were assessed. The authors concluded that the cost for an APF was in average $15,301 higher than for a TLIF procedure ($P < 0.05$). None of the subjects in either group had undergone a revision surgery at 1-year follow up.

More recently, Villavicencio et al. [34] also compared both techniques in patients treated for degenerative diseases of the lumbar spine. There were 124 patients in the TLIF group, 73 of which had a minimally invasive surgical (MIS) procedure and 51 a classic open procedure. In the APF group, there were 43 patients. Clinical and surgical parameters were compared for both TLIF groups (open and MIS)

and both had significantly shorter OR time ($P < 0.0001$), significantly less blood loss ($P < 0.05$) and significantly shorter hospital stay than APF. Complications were classified by the authors into minor (including allograft or pedicle screw malposition without reoperation) or major (including blood vessel lesion, deep venous thrombosis, pulmonary embolism) and were globally significantly higher in the APF group (76.7 vs. 35.3% in open TLIF, vs. 30.1% in MIS TLIF, $P < 0.001$ between APF and TLIF groups). They concluded that the APF technique should be reserved for patients with an extremely high risk of pseudarthrosis or other contraindication for posterior lumbar fusion.

In the study, we are presenting as in previous ones, the rate of intra-operative complications was significantly higher in the APF group (14.7%) and mostly related to the anterior portion of the surgical technique (11.8%). Most of these complications were considered minor. They nevertheless are potentially serious, and this type of surgical approach should be reserved to experienced surgeons.

Intraoperative complications in the TLIF group were all neurological and our rate (4.6%) was similar to previous publications describing complications after PLIF procedures [13, 20, 26]. Strikingly, there was a significantly higher rate of early revision surgery in the TLIF group. One-third of these were post-operative extrusion of cancellous allograft chips through the annulotomy. Although numbers were too small to draw definitive conclusions, we attributed this to a learning curve effect.

The pseudarthrosis rate was higher in both of our study groups than usually reported for APF and TLIF techniques [16, 24, 28, 32]. In fact, fusion assessment was based on a very strict and detailed scale resulting in a very critical look at fusion results.

Nevertheless, issues with the surgical technique appeared to have an influence on the rate of pseudarthrosis. Significantly higher rates of pseudarthrosis were found when a split bone bank femoral ring was used for TLIF. The quality of the bone bank allograft and its mechanical properties might have been in cause. Endplate preparation is critical with TLIF. Javernick et al. [23] found that only a 69% of disc volume can be excised through a unilateral transforaminal approach and about 80% with a bilateral approach. In addition, remaining disc material has been shown to interfere with interbody fusion healing in both clinical and basic science studies [2, 25]. TLIF technique has been subsequently modified at our institution: the interbody fusion is now done using a straight anatomical polyether ether ketone (PEEK) cage filled with autologous bone graft and placed obliquely across the disc space. Additional bone graft is packed in front and besides the cage, not behind it anymore. Bone Morphogenic Protein type 2 (BMP-2) is systematically used in patients with high risk of pseudarthrosis (smokers, previous nonunion).

A particular subgroup of patients combining TLFS and iliac crest allograft as an anterior support was found to have the highest pseudarthrosis rate in the APF group. Again, quality of the bone bank iliac crest allograft was the suspected cause, as those patients showed early interbody height loss at follow-up (<3 month after surgery). The APF technique has also been modified subsequently and TLFS are now routinely combined to stronger milled femoral ring allografts. Most of our surgeons prefer to use pedicle screws however.

Conclusion

This study shows there are numerous, distinctive factors influencing results of each spinal fusion approach. Intraoperative complications were significantly less in TLIF. Early revision rate was significantly higher in TLIF.

Radiographic fusion was higher in APF but not statistically different from TLIF (82.4 vs. 76.9%, $P > 0.05$). Inferior fusion results were specifically related to a learning curve effect, vertebral endplate preparation technique and type of interbody implant in TLIF and were associated with weaker tricortical iliac crest allografts and translaminar screw fixation in APF. Clinical outcomes and patient satisfaction were similar in both study groups.

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