Comparing Cortical Trajectory Transforaminal Lumbar Interbody Fusions Against Pedicle Trajectory Transforaminal Lumbar Interbody Fusions and Posterolateral Fusions: A Retrospective Cohort Study of 90-day Outcomes

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BACKGROUND: The cortical screw (CS) trajectory for pedicle screw placement is believed to require a smaller incision and less tissue dissection resulting in lower blood loss and faster healing; however, this has not yet been confirmed in clinical studies.

OBJECTIVE: To compare CS transforaminal lumbar interbody fusions (TLIF), traditional pedicle screw (TPS) trajectory TLIFs, and posterolateral fusion (PLF) without interbody for differences in operative characteristics and complications.

METHODS: We performed a retrospective cohort study (CS, TPS, and PLF) looking at patients who underwent lumbar fusion with 1 or 2 levels. Extracted data included demographics, comorbidities, estimated blood loss, transfusions, operative time, length of stay, discharge disposition (home vs rehabilitation), and complications within the perioperative, 30- and 90-d periods.

RESULTS: A total of 118 patients (45 CS, 35 TPS, and 38 PLF) were included with average age 62 and 90-d follow-up for 106 (90%) patients. CS had less average blood loss (231 ml) than either TPS (424, $P = .0023$) or PLF (400, $P = .0070$). CS had far fewer transfusions than either TPS or PLF ($P < .0001$). TPS had longer average operating room (OR) time (262 min) than either CS (214, $P = .0075$) or PLF (211, $P = .0060$). CS had the shortest length of postoperative stay (4.3 days) which was significantly shorter than PLF (6.2, $P = .0138$) but not different than TPS (4.8). There were no differences in discharge disposition, complications, perioperative, 30-d, 90-d, durotomy, or wound healing issues.

CONCLUSION: The CS trajectory is associated with less blood loss, fewer transfusions, reduced OR time, and shorter length of stay, with no difference in complications.

KEY WORDS: Transforaminal lumbar interbody, Pedicle screw, Cortical screw, Posterolateral fusion

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Cortical screw (CS) trajectory transforaminal lumbar interbody fusion (TLIF) is a newer technique developed to improve screw–bone interface in patients with poor bone quality.[1] In addition to increased biomechanical strength, several other clinical benefits may exist, improving patient postoperative outcomes over other fixation methods, but to date few studies have compared this technique against more traditional approaches.[2,3]

ABBRIVIATIONS: BMI, body mass index; **CS,** cortical screw; **EBL,** estimated blood loss; **LOS,** length of postoperative stay; **OR,** operating room; **PLF,** posterolateral fusion; **TLIF,** transforaminal lumbar interbody fusions; **TP,** transvers processes; **TPS,** traditional pedicle screw.

Over the last 30 yr, advancement of TLIF has focused on the modification of hardware and augmentation of the bone. The CS trajectory is a relatively new adaptation to this technique. This screw projection was developed to improve construct integrity by increasing bone screw purchase, particularly in patients with poor bone quality.[1,4] The CS technique offers an alternative technique to matchstick allograft, or bone cement augmentation in patients with low bone density. Both of these techniques can limit bone remodeling. Furthermore, cement can cause a large immunologic response, is toxic, and has poor fatigue performance.[5] While the standard pedicle trajectory aims along the pedicle axis and parallel to the end plate, the cortical trajectory projects caudal-cephalad and lateral.[1] The advantage of this technique is increased contact between the screw and cortical bone leading to improved implant bone interface. Biomechanical studies show a 30% increase in pullout load over traditional placed pedicle screws.[3]

In addition to biomechanical advantages of the CSs vs traditional pedicle screws (TPSs), both intra- and postoperative benefits may exist. In the preparation for CS placement, only the caudal medial aspect of the facets is exposed. This significantly reduces lateral muscle dissection compared to traditional TLIF and posterolateral fusion (PLF).[3] Currently, 2 studies have compared pedicle and cortical trajectories focusing on fusion and found no differences[2,3]; however, less is known about the secondary clinical benefits of the reduced exposure in placement of CSs over traditional TLIF and PLF.

The aim of this study to investigate differences in the operative and postoperative outcomes between CS TLIF, TPS TLIF, and PLF without interbody.

METHODS

Study Design and Selection

We conducted a retrospective study of consecutive patients undergoing posterior lumbar fusion and compared 3 cohorts: posterolateral fusion (PLF) using pedicle trajectory screws without interbody, TPS trajectory with transforaminal interbody fusion, and cortical trajectory screws with transforaminal interbody fusion (CS). Consecutive patients treated by author DR from October 2010 through August 2016 and by author FUA from May 2016 through January 2017 were included who underwent 1- or 2-level fusion for spondylolisthesis, scoliosis, or stenosis. Patients were excluded who underwent decompression and fusion for infection, tumor, trauma, or other pathological fractures. Patients were also excluded who had previous lumbar instrumentation (simple discectomy or laminectomy alone were allowed), who were undergoing both anterior and posterior fusion, or who had a spinal cord stimulator. This study was approved by our Institutional Review Board with a waiver of patient consent due to its retrospective design.

Surgical Technique

In all 3 techniques, an attempt is made to minimize surgical dissection with focus on maintaining appropriate hemostasis and exposing only the skeletal elements needed to perform the surgical procedure. The dissection requirements decrease from PLF, to TPS TLIF, to CS TLIF.

In PLF, muscle dissection progresses from medial to lateral with complete skeletonization starting at the spinous process continuing laterally over the pars and facet joints to the most lateral extent of transvers processes (TP). Two distal branches of the lumbar radicular arteries are often encountered during exposure and require coagulation at the lateral border of the pars, and the anterior-lateral margin of the facet. Proper identification and rapid coagulation of these arterial bleeding sources greatly reduces blood loss. Screws are placed freehand using anatomic landmarks for TPSs (Figure, left column). Laminectomy and decompression is then completed. The gutter produced from the removal of the paraspinal muscles posterior to the TP and lateral to the facet joint is decorticated and filled with graft as the fusion bed. Proper skeletonization and decortication of the TPs, pars, and facet joints are vital for adequate fusion given the lack of interbody in a PLF.

For TPS, the intraoperative dissection is carried out as described for that of PLF. Freehand pedicle screws are then placed using anatomic landmarks. Unilateral facetectomy, bilateral laminectomy, and foraminotomies are followed by discectomy and interbody placement (Figure, middle column). A standard posterolateral fusion is also included.

In CS, the muscular dissection is significantly reduced. Only the inferior-medial corner of the facet joint is exposed in screw placement. At our institution CT guidance with stealth navigation is the preferred method of screw placement. Fluoroscopy is an alternative, acceptable method for guidance, and was used prior to our acquisition of O-arm. Orientation of the CS trajectory follows a caudocephalad path in the sagittal plane and laterally directed in the transverse plane, as described in the original paper on the technique (Figure, right column).[1] Once pilot holes are drilled, pedicle screws on the contralateral side of the facetectomy are placed in the cortical trajectory. The laminectomy and facetectomy are completed from medial to lateral, limiting exposure and bleeding. Completion of the interbody arthrodesis is identical to that of the TPS. Next, the ipsilateral screws are placed. The contralateral facet and pars are typically decorticated and bone graft is packed into the recess of the hardware.

Data collection

Basic demographic details were collected including age at surgery, sex, and body mass index (BMI). Comorbidities included diabetes, osteoporosis, cancer, and smoking status. Osteoporosis was defined as any documented diagnosis, but actual bone mineral density was not available for analysis. Procedure data included levels fused, levels with interbody implants, in-room operating room (OR) time, estimated blood loss (EBL), transfusion record (any units of packed red blood cells or from cell saver autotransfusion), length of postoperative stay (LOS), discharge destination (home vs rehab determined by Physical Therapist prior to discharge). Complications within the perioperative, 30-d and 90-d time periods were recorded. Follow-up was calculated through most recent clinic visit, and any subsequent lumbar revision surgeries were recorded. All measurement data are reported as "mean ± standard deviation" while counts are reported as "count (percent)."

Statistical Analysis

Analysis showed the measurement data to be relatively normal in distribution; therefore, parametric tests were employed. For measurement data (EBL, OR time, and LOS), the standard analysis of variance was used to test for overall group differences in mean. If significant differences were detected, this was followed by Tukey's method to assess differences pairwise between each subgroup. For nominal data (fusion levels, transfusions, disposition, complications, and revisions), Fisher's exact test was used to test for overall group differences. Significance was set at $P < .05$ with correction for multiple comparisons during pairwise subgroup testing. Statistical analysis was performed using the JMP Pro v13 software package (SAS Institute Inc, Cary, North Carolina).

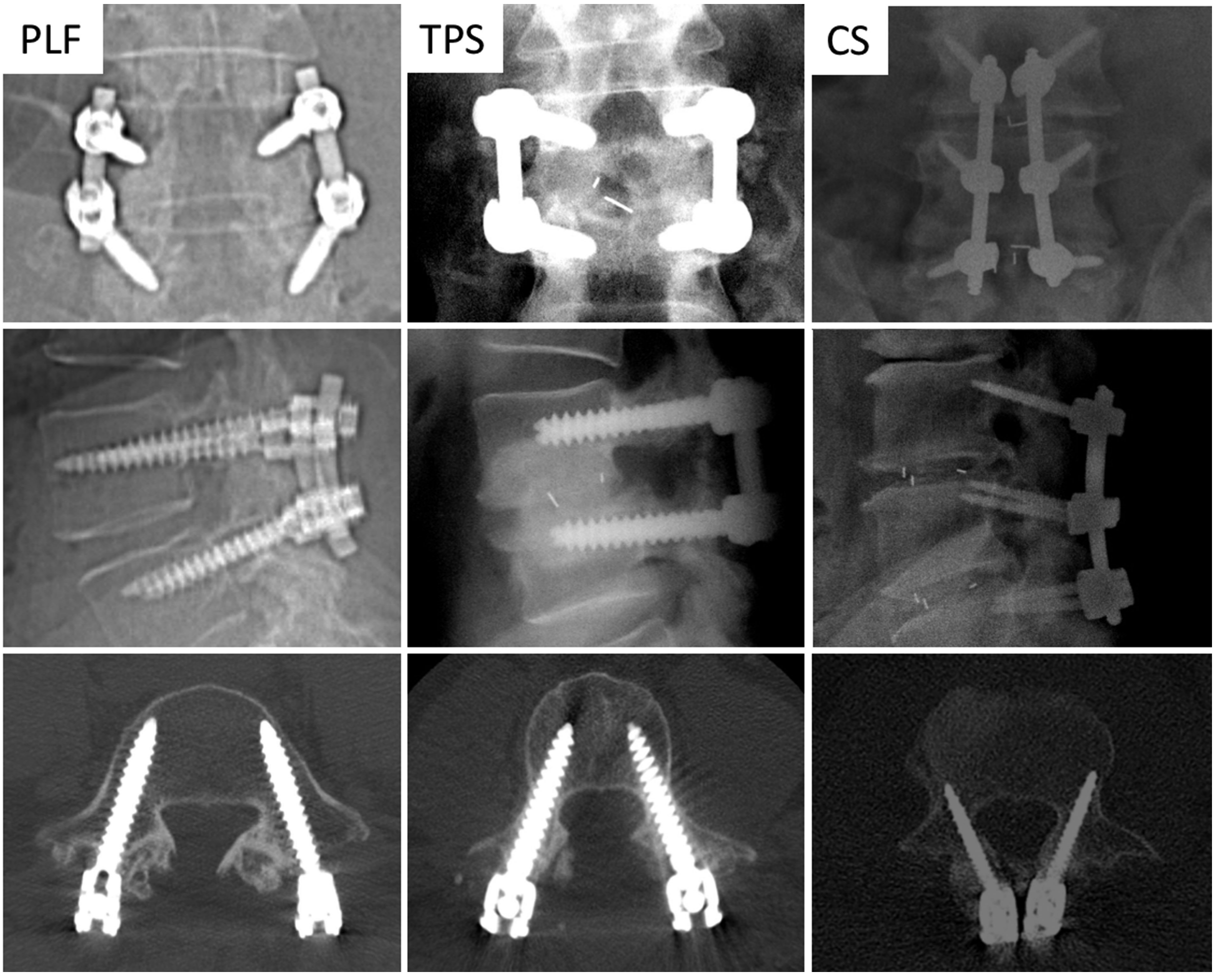

FIGURE. *Imaging for example patient from each cohort (columns). Anterior–posterior and lateral plain films (**top, middle rows**) show differences in screw trajectories. CT (**bottom**) shows cortical screw trajectory traveling medial-to-lateral through cortical bone.*

RESULTS

Patient Demographics

A total of 118 patients met inclusion criteria and were split into 3 cohorts: 45 cortical, 35 pedicle, and 38 posterolateral (Table 1). The patients included 71 females and 47 males with an average age of 62 ± 10 and average BMI of 28 ± 6. There were 16 patients who currently smoked tobacco, 14 patients with diabetes, 12 patients with a diagnosis of osteoporosis, and 8 patients with a history of cancer unrelated to the spine. Four patients had scoliosis as their indication while the remaining majority had spondylolisthesis and canal/foraminal stenosis.

Operative Characteristics

Table 2 provides details of the procedure and discharge destination. Most patients underwent arthrodesis at 1 level (88) versus 2 levels (30). Author DR performed the majority of cases (107, 91%). There was no significant difference between the proportions of patients undergoing 1- or 2-level fusion. EBL showed significant differences between groups ($P = .0009$). The cortical cohort (231 ± 186 ml) had less blood loss than either the pedicle (424 ± 315 ml, $P = .0023$) or the posterolateral (400 ± 241 ml, $P = .0070$). There were 22 transfusions (19%) with significant group differences ($P < .0001$). Only 1 member of the CS group (2%) was transfused, compared to 14 (40%) of the TPS and 7 (18%) of the PLF groups. Overall operative time showed significant group differences ($P = .0026$). The traditional pedicle cases (262 ± 71 min) took longer than either the cortical cases (214 ± 61 min, $P = .0075$) or the posterolateral cases (211 ± 77 min, $P = .0060$).

Postoperative length of stay (overall average 5.1 ± 3.2 days) showed significant differences between groups ($P = .0161$). The

TABLE 1. Patient Demographics, Comorbidities, and Previous Spinal Surgery

	Overall (n = 118)	Cortical (CS, n = 45)	Pedicle (TPS, n = 35)	Posterolateral (PLF, n = 38)
Demographics				
Patients (n)	118	45	35	38
Female/Male	71/47	25/20	28/7	18/20
Age (years)	62 ± 10	63 ± 9	57 ± 11	64 ± 10
BMI (kg/m^2)	27.9 ± 5.9	28.4 ± 5.3	27.3 ± 4.1	28.6 ± 6.2
Comorbidities				
Smoker (n, %)	16 (14%)	9 (20%)	3 (9%)	4 (11%)
Diabetes	14 (12)	7 (16)	1 (3)	6 (16)
Osteoporosis	12 (10)	5 (11)	3 (9)	4 (11)
Cancer	8 (7)	3 (7)	1 (3)	4 (11)

Data reported as "mean ± standard deviation" or "count (percent)."
BMI, Body Mass Index

TABLE 2. Operative Characteristics, Disposition, and Rehabilitation Needs

	Overall (n = 118)	Cortical (CS, n = 45)	Pedicle (TPS, n = 35)	Posterolateral (PLF, n = 38)	*P*-value
Operation					
One-level	88 (75%)	37 (85%)	23 (64%)	28 (72%)	>.05
Two-level	30 (25)	8 (18)	12 (33)	10 (26)	>.05
EBL (ml)	343 ± 261	231 ± 186[a,b]	424 ± 315[a]	400 ± 241[b]	.0009
Transfused	22 (19%)	1 (2)	14 (39)	7 (18)	<.0001
OR time (min)	228 ± 72	214 ± 61[c]	262 ± 71[c,d]	211 ± 77[d]	.0026
LOS (days)	5.1 ± 3.2	4.3 ± 1.6[e]	4.8 ± 1.7	6.2 ± 4.9[e]	.0161
Disposition					
Home	94 (80%)	49 (89)	28 (80)	26 (68)	>.05
Rehab	24 (20)	5 (11)	7 (20)	12 (32)	>.05

Data reported as "mean ± standard deviation" or "count (percent)."
EBL, estimated blood loss
OR, operating room
LOS, length of post-operative stay
Superscripts denote significance of pairwise comparisons within the row: [a]$P = .0023$; [b].0070; [c].0075; [d].0060; and [e].0138.

cortical cohort had the shortest postoperative stay (4.3 ± 1.6 days) that was significantly shorter compared to PLF (6.2 ± 4.9 days, $P = .0138$) but not different than TPS (4.8 ± 1.7 days, $P > .05$).

Considering discharge destination, while more CS patients went home (89%) compared to TPS (80%) and PLF (68%), there were no significant differences between groups.

Repeating the above analyses with patients only from surgeon DR found the conclusions unchanged.

Clinical Follow-up and Complications

Table 3 reports follow-up and complication data for each cohort. Overall average follow-up was 351 days and was significantly different between groups ($P = .0007$). The cortical subgroup had shorter average follow-up (247 days) compared to either the pedicle (379) or posterolateral (440). Since the cortical trajectory is a newer technique, those cases were more recent and had less follow-up. However, 106 of 118 patients (90%) had at least 90-day follow-up, sufficient to assess complications in this study. Complications were analyzed overall, perioperatively, within the 30-d period, within the 90-d period, and in categories including durotomy and wound healing. The most common complication was a durotomy, which we defined to be any tear to the dura even if there was no apparent cerebrospinal fluid leak requiring repair (CS 7, TPS 4, and PLF 3). Examples of common complications were wound dehiscence (n = 4, 3 treated with antibiotics alone, 1 requiring revision); urinary retention that resolved (n = 2); or infection (n = 1); and 1 case of a screw malpositioning causing radicular pain that resolved with steroids (TPS 1). There were no significant differences found among complications. Each cohort had approximately the same percentage of patients with at least 90-day follow-up (cortical

TABLE 3. Clinical Follow-up and Complications

	Overall (n = 118)	Cortical (CS, n = 45)	Pedicle (TPS, n = 35)	Posterolateral (PLF, n = 38)	*P*-value
Follow-up					
>90 days (n)	106 (90%)	39 (87)	33 (94)	34 (89)	
Average (d)	351 ± 240	247 ± 149	379 ± 183	440 ± 318	
Complications					
Overall	24	8	8	8	>.05
Perioperative	20	7	7	6	>.05
Durotomy	14	7	4	3	>.05
Within 30 d	3	1	1	1	>.05
Within 90 d	1	0	0	1	>.05
Wound healing	4	1	1	2	>.05
Revisions					
Count	7	1	1	5	>.05
Median interval (mo)	19	6	13	22	

Data reported as "mean ± standard deviation" or "count (percent)."

87%, pedicle 94%, posterolateral 89%). There were 7 revision lumbar surgeries with no group differences (CS 1, TPS 1, PLF 5, $P = .13$). One PLF revision was for nonunion, while the remaining 6 were all for continued degeneration at an adjacent level. While not reaching significance, we believe that the PLF group included more revisions because of its longer available follow-up.

DISCUSSION

Clinical factors that show significances in our series are intraoperative blood loss, operative time, and LOS. Factors that were found to be equivalent were postoperative complications, discharge destination, and readmission rates. These metrics are critical in determining the success of a surgical procedure, they can help infer patient intraoperative stress load, potential risks, postoperative recovery rates, and overall cost of the intervention to the system and the patient.

Blood loss and need for potential transfusion is a significant risk factor in patient undergoing surgical operations. In our study, CS patients had significantly less blood loss then other groups. Nationally, intraoperative blood loss is reported to cause increased risk for myocardial infarction, stroke, acute kidney injury, and death. Blood is highly immunogenic and is reported to cause hemolytic reactions in 1/1000 transfusion, acute respiratory distress syndrome in 1/5000 transfusions, and death in 1-4/1 million transfusions.[6] In our study, we found that blood loss for the CS population is approximately half that seen for the other 2 techniques. The mean blood loss for PLF was 400 ml, 424 ml for TPS, and 231 ml for CS.

Minimizing blood loss for patients decreases perioperative risks for complication. Increased blood loss in PLF and TPS can be attributed to increased surgical exposures, and operative time needed to complete these procedures. Risks of transfusions can be abated through the use of cell saver. Given the large blood losses seen in PLF, cell saver was used in these cases. However, this technology is not always available, has many contraindications, and is expensive.[7] With pressure to reduce intraoperative cost many institutions pressure physicians to forgo the request for cell saver placing patients at risk for transfusion with donor blood, or holding back transfusions placing patients at increased risk of perioperative complications. Of the 22 patients that underwent transfusion, only 1 was from the CS group, while 14 for TPS and 7 for PLF.

Reduced operative times were seen in CS and PLF relative to the TPS. Duration of surgery is a critical clinical consideration when selecting surgical intervention. Given the aging US population, prolonged anesthesia times increase surgical risk.[8] Additionally, operative time is expensive. Given clinical risk and expense of longer procedures, if surgical equipoise exists the shorter procedure should be considered first.[9, 10] In this series CS and PLF, operative times were roughly equivalent (214 vs 211 min). The reduced muscle dissection needed in placement of CS drastically reduced the intraoperative exposure time. However, preparation of the disc space, and acquisition of intraoperative imaging caused overall surgical time to be equivalent to PLF. With increased experience in image acquisition, operative times will continue to shorten and CS will become the faster surgery. The overall low operative times for PLF were multifactorial; staff familiarity, decreased technical difficulty, reduced imaging needs, and lack of disc space preparation all contribute. TPS was found to have the longest surgical time. Increased dissection needs relative to the CS, and the need for disc space preparation not required for PLF continue to make this a lengthy procedure.

Postoperative LOS showed significant benefit for the procedures that require less surgical dissection. The average LOS for CS was (4.3 ± 1.6 d) vs TPS (4.8 ± 1.7 d) vs PLF (6.2 ± 4.9 d). While no significant difference was seen between CS and TPS, with increased patient numbers a trend towards shorter LOS in the CS patient population may be seen. Between PLF and both the CS and TPS, there was a difference of almost 2 hospital days in LOS. Significant differences in discharge time are a reflection of recovery rate. In addition to LOS, reduced requirements at discharge directly reflect the extent of surgical dissection. Patients required inpatient rehabilitation in 32% of PLF and 20% of TPS vs 11% of CS cases. Although these proportions did not reach significance, there appears to be an association between extent of dissection and discharge needs. No significant differences were noted in readmission rates, reflecting consistency in timing and placement at discharge between groups. The reduced LOS and discharge requirements with CS suggest it may be a less costly option for lumbar surgery.

Limitations

Although this is one of the largest cohort studies of CS patients examined, several important limitations exist. First, the cortical trajectory technique is relatively early in its adoption with few studies available comparing it to more established techniques.[2,3] As such, our pool of patients with sufficient follow-up is limited in size that impacts our analysis. A larger cohort is necessary to explore confounding variables or attempt matching via propensity scoring or similar methods. Second, this is a single center study with the majority of patients operated on by a single surgeon. While this adds uniformity to the surgical procedures between patients at this institution, our experience might not apply to other surgeons. To address this, we repeated the analysis with only patients from DR and found the conclusions unchanged (all significant results remained so, and vice versa). Third, this cohort was accrued linearly over nearly 8 yr starting with PLF, and then later adding TPS, and most recently introducing CS as the primary technique. As with other professionals presumably skill increases over time, as would surgical speed. This may give an advantage to CS over TPS and PLF; however, all 3 techniques continue to be utilized to date so the operative skill in the last few years is comparable. This is especially at academic centers such as ours where residents and fellows rotate regularly, and so for example, the initial dissection and closure would be carried out by residents at roughly the same skill level year after year. Regardless, this is the only study available that compares all 3 techniques side-by-side.

To address some the limitations discussed, we make 2 primary recommendations for future studies. First, randomize between pedicle and cortical TLIFs alone, separating out PLF cases; this may draw a clearer picture between perioperative tradeoffs by reducing a dimension of choice in technique, and eliminate questions of evolving technique and surgeon skill over time. This may be especially important when comparing fusion rates. Second, match by number of levels; this should clarify questions of operative time and blood loss.

CONCLUSION

Numerous factors contribute in selecting the appropriate surgical intervention for patients. Over the last 70 years, the methods to decompress, fuse, and restore lordosis to the lumbar spine have evolved. In consideration for surgery, fusion rates have always been the paramount. Studies show fusion rates between TLIF and PLF show no statistically significant long-term difference in pseudarthrosis or adjacent level disease.[10,11] The CS TLIF offers a new technique developed for patients with poor bone quality. Evidence is emerging that this screw trajectory has increased strength over TPSs and equivalent fusion rates of either PLF or TLIF.[1,3] Therefore, when selecting optimal intervention for a patient, considerations beyond fusion construct must be made. In this series, CS patients had reduced operative time, blood loss, and length of stay.

Disclosures

Dr Refai has royalties with Stryker Spine. Dr Ahmad is a consultant for Stryker Spine and Medtronic. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

Cortical screw transforaminal lumbar interbody fusion is a technique designed to increase the biomechanical strength of a fusion construct in patients with poor bone quality. This retrospective cohort study describes operative characteristics and complications of cortical screw transforaminal lumbar interbody fusion compared to pedicle screw interbody fusion and pedicle screws alone. The authors found that patients who underwent cortical screw fusion had significantly less intraoperative blood loss, operative time, and postoperative hospital stay compared to both pedicle screw groups. The cortical screw group also did not have any significant differences in postoperative complications, discharge destination, and readmission rates at 30 and 90 days of follow-up compared to the other groups. The short-term implications of this study are meaningful, and suggest that cortical screw fusion is at least equivalent, if not better, than traditional pedicle screw fusion techniques using these parameters.

This study, however, is limited by a lack of significant follow-up. With a maximum 90-day postoperative period, it is difficult to assess the long-term viability of the cortical screw technique in terms of bony fusion and clinical outcome. Moreover, for a technique touted to be advantageous for patients with poor bone quality, it would be prudent to understand how this population, specifically, responds to treatment. Regardless, this study demonstrates early promise for cortical screw transforaminal interbody fusion, and we commend the authors on their excellent work.

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