Open lumbar pedicle screw technique

- Novel Mini-open Transforaminal Lumbar Interbody Fusion
- A Prospective Study on the Functional Outcomes of Surgical Management of Lumbar and Lumbosacral Spondylolisthesis Using Pedicle Screw Fixation and Posterolateral Fusion
- Risk factors for facet joint violation in minimally invasive and open lumbar interbody fusion: a systematic review and meta-analysis
- Application of oblique lateral interbody fusion channel technique in lumbar infection
- Current Trends and Future Directions in Lumbar Spine Surgery: A Review of Emerging Techniques and Evolving Management Paradigms
- Effect of Supplemental Fixation on Fusion and Subsidence After Lateral Lumbar Interbody Fusion
- Realistic 3D-Printed Lumbar Spine Model for Non-cadaveric Surgical Training: A Proof of Concept Study
- Percutaneous pedicle screw placement with a mini-open decompression versus open surgery in the treatment of lumbar spondylolisthesis: one-year results of a randomised controlled trial

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There are at least 4 screw placement techniques

1. intraoperative fluoroscopy: biplane fluoro facilitates this technique

a) PROS:

● allows percutaneous screw placement

● generally good accuracy in screw placement

b) CONS:

● imaging may be difficult in some parts of the lumbar spine, especially in larger patients. In these cases, the Steinman pin method below can be used to supplement

● may increase radiation exposure to the surgery team and patient

2. Steinman pin method: Steinman pins are placed at the estimated entry points for the screws, and AP (and often lateral) fluoro is used to fine-tune the position so that the screw enters the pedicle at the desired location

3. freehand placement based on anatomic landmarks. Usually with X-ray verification, after all, screws are placed. Greatly facilitated at levels where a laminectomy has been performed since the medial pedicle is exposed and is easily palpated

a) PROS: likely reduces radiation to the surgical team and the patient

b) CONS: requires somewhat more experience than the other methods; distortion of landmarks e.g. by previous surgery can preclude using this method; since the methodology uses averages in anatomy, it can be unreliable for patients whose anatomy differs from average

4. image guidance using instruments that are fitted with specialized markers that are tracked in real-

time by “cameras” that project the drill and/or screw location on a CT or X-ray image viewed in the O.R.

a) PROS:

● reduces intraoperative radiation to the surgical team, and to a lesser extent to the patient

● allows percutaneous screw placement

b) CONS: accuracy may be compromised by the movement of spinal segments relative to the registration array, or by technical errors. The surgeon must be vigilant for screw placement that does not look appropriate based on the anatomy.

Cortical bone trajectory screw fixation

A total of 60 human cadaveric lumbar pedicles were studied. Three different screw insertion techniques were compared: (A) Jamshidi needle and Kirschner wire without tapping; (B) Jamshidi needle and Kirschner wire with tapping; and (C) sharp-tipped screw insertion. Pullout tests were performed at a displacement rate of 10 mm/min recorded at 20 Hz. Mean values of these parameters were compared using paired t-tests (left vs right in the same specimen): A vs B, A vs C, and B vs C. Additionally, 3 L1-L5 spine models were used for timing each screw insertion technique for a total of 10 screw insertions for each technique. Insertion times were compared using a 1-way analysis of variance.

Results: The mean pullout force for insertion technique A was 1462.3 (597.5) N; for technique B, it was 1693.5 (805.0) N; and for technique C, it was 1319.0 (735.7) N. There was no statistically significant difference in pullout force between techniques ($P > 0.08$). The average insertion time for condition C was significantly less than that for conditions A and B ($P < 0.001$).

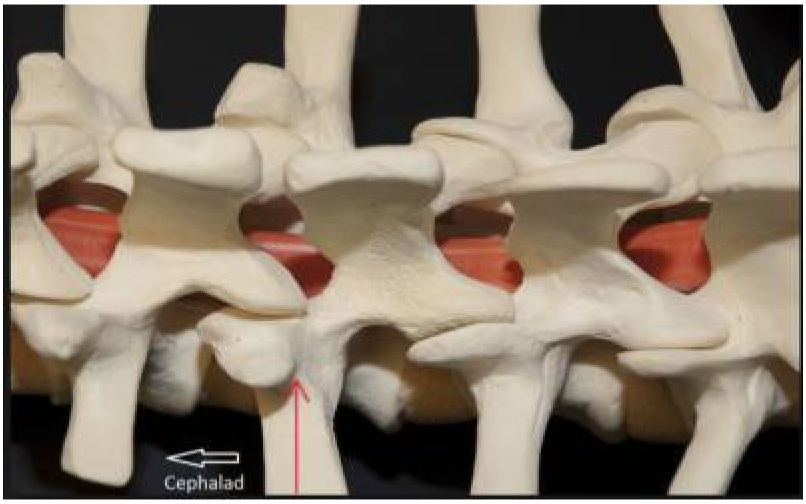
Conclusions: The pullout force of the novel sharp-tipped screw placement technique is equivalent to that of traditional techniques. The sharp-tipped screw placement technique appears biomechanically viable and has the advantage of saving time during insertion.

Clinical relevance: Single-step screw placement using high-resolution 3-dimensional navigation has the potential to streamline workflow and reduce operative time [1].

The aim of a study was to compare the accuracy, safety, and usefulness of percutaneous pedicle screw placement for lumbar fixation using a multi-axis angiography unit (MAU) and an electronic conductivity device (ECD) with a cannulated Jamshidi needle with that using a conventional C-arm. Of 65 cases that underwent lumbar fixation (region between L1-S1) during April 2013 to March 2019, 57 cases that could be followed up for more than 12 months after the procedure were included. Among them, 31 patients (150 screws) received treatment with MAU and ECD (MAU+ECD group), and 26 (117 screws) were treated with the conventional C-arm. We performed a retrospective study of the surgical techniques used in each group at our institute by assessing the accuracy of PPS using Gertzbin-Robbins classification and the Japanese Orthopedic Association (JOA) score for recovery. There was no significant difference in surgery outcome based on the JOA recovery rate. There was a significant difference between the two groups in terms of Accuracy-1 (Group A indicating accuracy and Groups B-E indicating inaccuracy), where the rates were 85.3% and 72.0% in the MAU+ECD group and C-arm group, respectively (P = 0.008). There was also a significant difference between the two groups in terms of Accuracy-2 (Groups A-B indicating accuracy; Groups C-E indicate inaccuracy), where the rates were 98.0% and 92.4% in the MAU+ECD and C-arm groups, respectively (P = 0.036). A combination of MAU and ECD is a safe and accurate method for inserting screws into the pedicle [2].

Entry point

At the base of the transverse process, at the intersection of the center of the transverse process (in the rostral caudal direction) and the sagittal plane through the lateral aspect of the superior facet



If a lumbar laminectomy has been performed at that level, the location of the pedicle is then verified by palpation using a probe within the spinal canal, otherwise fluoroscopy is used.

Trajectory

Dickman et al., published in 1992, that the approximate mediolateral trajectory equals the lumbar vertebral number multiplied by 5 º for each level from L1 to L5 [3].

The angle of the screw in the rostro-caudal direction is determined by fluoroscopy, maintaining a course that is paralell to the vertebral end plate.

S2 screws are oriented laterally and superiorly and can be as long as 60 mm.

Screw length

Cross 2/3 of the vertebral body (typical 40-55 mm). S1 usually 35-40 mm long.

Rod Diameter

Rod diameter typically 5-6.5 mm.

X-Ray verification

On AP view if the screw tip crosses the midline to the contralateral side, there is likely to be a breach of the medial pedicle (sensitivity 0.87, specificity 0.97, and accuracy 0.98), and if the screw does not pass medial to the medial pedicle wall there is likely to be lateral pedicle/VB violation (sensitivity 0.94, specificity 0.90, and accuracy 0.96) [4].

Complications

Pedicle screw misplacement

see Pedicle screw misplacement.

Facet joint violation

see Facet joint violation.

Kim et al., from the Department of Orthopaedic Surgery, Washington University School of Medicine, Shriners Hospitals for Children, St. Louis, developed an accurate and reliable method to detect Pedicle screw misplacement during thoracic and lumbar spinal deformity operations using intraoperative plain radiographs.

A total of 789 pedicle screws, including 632 thoracic and 157 lumbar, inserted from T1 to L4 in 49 patients with spinal deformity with postoperative computerized tomography (CT) data were investigated. According to the diagnoses, the number of screws placed was 683 for scoliosis in 43 patients and 106 for kyphosis in 6 patients. The position of the pedicle screw inserted was graded with CT as an acceptable screw (n = 724) versus violated screw (n = 65), defined as the central axis of the inserted pedicle screw out of the outer cortex of the pedicle wall. There were 3 plain radiographic criteria used to judge the accuracy of screw position after minor screw tip position adjustment according to the relative length of the screws in the lateral radiograph: (1) violation of the harmonious segmental change of the tips of the inserted screws with reference to vertebral rotation using the posterior upper spinolaminar junction in the posteroanterior (PA) radiograph (medial or lateral out); (2) no crossing of the medial pedicle wall by the tip of the pedicle screw inserted with reference to the vertebral rotation using the posterior upper spinolaminar junction in the PA radiograph (lateral out); and (3) violation of the imaginary midline of the vertebral body using the posterior upper spinolaminar junction in the PA radiograph by the position of the tip of the inserted pedicle screw (medial out).

Comparative analysis of these pedicle screws using postoperative CT and intraoperative plain radiographs confirmed 65 violated pedicle screws, including 15 medial violations and 50 lateral violations. Of 15 pedicle screws with medial wall violation, 13 showed a loss of harmonious segmental change in the screw tips and violation of the imaginary midline of the vertebral body (sensitivity 0.87, specificity 0.97, and accuracy 0.98). One case showed only a loss of harmonious change in the screw tip, and the other one case did not show any significant plain radiograph findings. Of the 50 pedicle screws with lateral wall violation, 47 cases showed a loss of harmonious segmental change in the screw tips and no crossing of medial pedicle wall by the pedicle screw inserted (sensitivity 0.94, specificity 0.90, and accuracy 0.96). Two cases did not show any significant plain radiograph findings, and the other one case showed only violation of the harmonious segmental change in the screw tips.

Intraoperative plain radiographs alone using 3 radiographic criteria were very sensitive to detect lateral wall pedicle screw violations, specific for assessing for medial wall violations, and highly accurate for both. This result confirms the ability of careful intraoperative plain radiographic assessment after pedicle screw insertion to detect malpositioned screws, to allow for possible revision during the index operation [5].

Atlas

An algorithm for automatic spinal pedicle screw planning was reported and evaluated in simulation and first clinical studies.

A statistical atlas of the lumbar spine (N=40 members) was constructed for Active Shape Model (ASM) registration of target vertebrae to an unsegmented patient CT. The atlas was augmented to include “reference” trajectories through the pedicles as defined by a spinal neurosurgeon. Following ASM registration, the trajectories are transformed to the patient CT and accumulated to define a patient-specific screw trajectory, diameter, and length. The algorithm was evaluated in leave-one-out analysis (N=40 members) and for the first time in a clinical study (N = 5 patients undergoing cone-beam CT (CBCT) guided spine surgery), and in simulated low-dose CBCT images.

ASM registration achieved (2.0 ± 0.5) mm root-mean-square-error (RMSE) in surface registration in 96% of cases, with outliers owing to limitations in CT image quality (high noise/slice thickness). Trajectory centerlines were conformant to the pedicle in 95% of cases. For all non-breaching trajectories, automatically defined screw diameter and length were similarly conformant to the pedicle and vertebral body (98.7%, Grade A/B). The algorithm performed similarly in CBCT clinical studies (93% centerline and screw conformance) and was consistent at the lowest dose levels tested. Average runtime in planning five-level (lumbar) bilateral screws (10 trajectories) was (312.1 ± 104.0)s. The runtime per level for ASM registration was (41.2 ± 39.9)s, and the runtime per trajectory was (4.1 ± 0.8)s, suggesting a runtime of ~(45.3 ± 39.9)s with a more fully parallelized implementation.

The algorithm demonstrated accurate, automatic definition of pedicle screw trajectories, diameter, and length in CT images of the spine without segmentation. The studies support translation to clinical studies in free-hand or robot-assisted spine surgery, quality assurance, and data analytics in which fast trajectory definition is a benefit to workflow [6].

Pedicle screw placement is a common procedure. It has a great developing technique that is used for fixation and fusion in spine surgery. It was firstly introduced by Harrington and Tullos in 1969 and then in late 1980′s developed by Roy Camille et al., Louis, and Steffe. It had already become the leading instrumentation in spinal surgery until nowadays. It could be applied in degenerative, trauma, neoplastic, infectious and malformation cases that had a problem with axial instability [7].

Placement

The fixation is performed in conjunction with spinal fusion surgery to secure the vertebrae of the treated area in a fixed position.

The main purpose of the procedure is to achieve a solid arthrodesis and without this, any form of internal fixation may eventually fail [8] [9] [10].

The utilization of pedicle screw fixation as an adjunct to posterolateral lumbar fusion (PLF) has become routine, but demonstration of a definitive benefit remains problematic. The medical evidence indicates that the addition of pedicle screw fixation to PLF increases fusion rates when assessed with dynamic radiographs. More recent evidence, since publication of the 2005 Lumbar Fusion Guidelines, suggests a stronger association between radiographic fusion and clinical outcome, although, even now, no clear correlation has been demonstrated. Although several reports suggest that clinical outcomes are improved with the addition of pedicle screw fixation, there are conflicting findings from similarly classified evidence. Furthermore, the largest contemporary, randomized, controlled study on this topic failed to demonstrate a significant clinical benefit with the use of pedicle screw fixation in patients undergoing PLF for chronic low-back pain. This absence of proof should not, however, be interpreted as proof of absence. Several limitations continue to compromise these investigations. For example, in the majority of studies the sample size is insufficient to detect small increments in clinical outcome that may be observed with pedicle screw fixation. Therefore, no definitive statement regarding the efficacy of pedicle screw fixation as a means to improve functional outcomes in patients undergoing PLF for chronic low-back pain can be made. There appears to be consistent evidence suggesting that pedicle screw fixation increases the costs and complication rate of PLF. High-risk patients, including (but not limited to) patients who smoke, patients who are undergoing revision surgery, or patients who suffer from medical conditions that may compromise fusion potential, may appreciate a greater benefit with supplemental pedicle screw fixation. It is recommended, therefore, that the use of pedicle screw fixation as a supplement to PLF be reserved for those patients in whom there is an increased risk of nonunion when treated with only PLF [11].

Findings in the Department of Neurosurgery, Clinical Neurosciences Center and Huntsman Cancer Institute, University of Utah, Salt Lake City, indicate that electromyography may not be a highly reliable tool in determining an anatomical breach during lumbar pedicle screw placement. O arm may be better for detecting either medial or lateral breaches than electromyography stimulation if there are concerns about screw placement or for confirmation of placement prior to leaving the operating room [12].

Cortical Bone Trajectory for Lumbar Pedicle Screw Placement

Cortical Bone Trajectory for Lumbar Pedicle Screw Placement

Case series

A total of 104 patients underwent transpedicular spinal instrumentation in the Department of Neurosurgery, University of Florida College of Medicine, Gainesville, using the Cotrel-Dubousset (71 cases) or the Texas Scottish Rite Hospital rod instrumentation (33). Surgery was performed for lumbar vertebral column instability secondary to fractures (28 cases), spondylolisthesis (29), tumors (four), vertebral osteomyelitis (two), or postoperative causes (41). Pseudoarthrodesis due to failure of a prior fusion was present in 37 cases. The 55 men and 49 women (mean age 47 years, range 18 to 87 years) all presented with severe back pain. Signs or symptoms of neural compression were noted in 96 patients. Surgery consisted of neural decompression, internal fixation, and autogenous iliac bone grafting. Spondylolistheses were fused in situ, without reduction; otherwise, major spinal deformities were corrected. A total of 516 pedicle screws were placed. The mean extent of fusion was 2.7 motion segments (range one to six motion segments). A 96% fusion rate was obtained with a mean follow-up period of 20 months. There were no operative deaths. Major complications included one spinal epidural hematoma, three isolated nerve root deficits (two transient, one permanent), and three wound infections (two deep, one superficial). Instrument failure eventually developed in 18 patients; nine were asymptomatic with a solid fusion and did not require further treatment and the other nine were symptomatic or had a pseudoarthrosis and required operative revision. Pedicle screw-rod fixation offers biomechanical advantages compared to other forms of internal fixation for the lumbar spine. It enables short-segment fixation with preservation of lumbar lordosis and adjacent normal motion segments. This technique provides a highly successful method to obtain arthrodesis, even with prior pseudoarthrosis [13].

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