Posterior Lumbar Inter-body fusion with pedicle and screw fixation Guided by spinal Neuronavigation for the Treatment of Spondylolithesis. Advantage and disadvantage.

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Abstract: Background: To assess accuracy, time efficiency, safety, and outcome of using the neuronavigation system in posterior lumbar inter-body and pedicle screws fixation. **Methods**: This is a retrospective study which has been done between May 2009 and may2011. During this period, there were 20 cases with lytic or degenerative Spondylolithesis, which required posterior interbody and pedicle screws fixation. Pedicle screws were placed utilizing the image-guidance system in all 20 patients. The accuracy of screw placement was assessed by intraoperative neurophysiological monitoring, assisted fluoroscopy, postoperative computerized tomography, x rays and clinical follow up after 6 weeks 3, 6, 9 and 12 months. **Conclusion:** The accuracy of pedicle screws placement using neuronavigation was better than using fluoroscopy with reduction of fixation complications as implant failure, pedicle cortex violation, and neural injury. Navigated minimal invasive cases had faster recovery and shorter hospital stay because of less muscle retraction and less tissue damage.
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Abbreviations: NPLIF, Navigated posterior lumbar interbody fusion. **OPLIF**, open posterior lumbar interbody fusion. **PLIF**, posterior lumbar interbody fusion. DRA, dynamic reference arc. CNSS = computer-navigated spine surgery; 2D: Two dimensional, 3D: three-dimensional

1. Introduction

When lumbar radicular pain resulting from isthmic or degenerative spondylolisthesis in adults does not respond to conservative treatment, it can be effectively treated with posterior lumbar fusion.**(1)** The most established types of neuronavigation in spinal surgery are 2D navigation and 3D navigation, which differ in the modality of the imaging used for reference. Two dimensional navigation uses 2D imaging such as plain radiographs or fluoroscopic images, while 3D navigation uses multiplanar imaging, usually CT scanning, that can provide information in 3 dimensions.**(2)** Both modalities use either an infrared camera or an electromagnetic field to determine the exact location of a designated surgical instrument relative to registered reference points of the patient anatomy**(3)** accurate placement of pedicle screws can be technically challenging, and the incidence of screw misplacements can vary from anywhere between 6% and 40%. Misplacement can lead to iatrogenic damage to neural, vascular, or visceral tissues. **(4)** also several clinical and cadaveric studies have demonstrated a 10 to 50% rate of pedicle cortex violation during screw insertion in the spine guided by landmark anatomy and fluoroscopy.**(5)** Furthermore, radiation exposure of surgeon and operating room personnel, as well as young patients undergoing extensive instrumentation procedures related to intraoperative fluoroscopy, has raised concerns, especially at centers treating a high volume of complex disorders and deformities, revision cases, or minimally invasive procedures requiring frequent intraoperative radiographic assessment.**(6)**3D-image guidance or computer-assisted navigation allows for a multiplanar visualization of the spinal anatomy to facilitate the tracking of surgical instruments.**(7)** A recent meta-analysis found that the image guided navigation reduces the misplacement rate of pedicle screws from 15% to 6%.**(8)**

The potential benefits of spinal image guidance regarding the accuracy of pedicle screw placement in the lumbar spine, as well as reduction of intraoperative radiation exposure, have been outlined by previous investigations.**(9)** Traditional techniques for posterior spinal fixation required large incisions, extensive stripping and retraction of the paraspinal musculature, significant postoperative pain, and long recovery times, which are believed to be, at least in part, due to damage to the erector spinae muscle group. The operative exposure, however, remained the same or even increased the surgical dissection and muscle damage necessary to perform a lumbar fusion with instrumentation compared with non-instrumented techniques. Follow-up MR imaging studies have demonstrated fatty degeneration of the paraspinal musculature after such exposures, which, in theory, could lead to worse clinical outcomes in terms of strength, pain scores, and lost work days. **(10)**

2. Patients and Methods

Between May 2009 and may2011 retrospective study was performed of 20 patients who underwent posterior lumbar interbody fusion using neuronavigation. Patients were included in the study if they had lytic or degenerative spondylolisthesis with radicular pain and or claudicating pain that had persisted for at least 6 months despite treatment with physical therapy, analgesic medications, and transforaminal or epidural injection of corticosteroids. Before surgery, all patients were assessed radiologically with plain x-rays, computed tomographic scanning, and magnetic resonance imaging. All patients were instrumented following a single automated registration sequence with the dynamic reference arc (DRA) uniformly attached to L5 or L4 or S1. With Paired point matching combined with surface matching technique. The ability of surgeons to undertake precise navigation with image guidance is directly dependent on the quality of registration. This step allows correlation between the exposed operative anatomy and the image-based anatomy displayed on the computer workstation. The process is begun by selecting a minimum of three distinct landmarks, termed fiducials, on the computer workstation. A stereotactic registration probe is then used to touch the anatomical points that correspond to those selected on the workstation. The computer workstation generates a registration error, which serves as an estimate of the accuracy of registration. This measurement is determined by multiple factors and represents the error in the localization of the exact geometrical position of the registered fiducial markers.**(11)** This step can be refined through surface matching, a process in which multiple random points on the exposed surface are chosen after an initial paired point registration. Surface matching designed to provide the computer with additional topographic information in an effort to reduce the CRE. **(12)** The mean CRE (the minimal error that determines the proper transformation). In our study, the CRE ranged from 1.5 to 0.3.

14 patients were female (70%), and 6 patient were male (30%), 5 patient(25%) below 45 years old,and 15 patient (75%) above 45 years old, range from 30-70 years),all patient were complaining of chronic lower back pain with different intensity, bilateral leg pain were in 17 patients (85%),2 patients (10%) were complaining of unilateral leg pain, and 1 patient (5%)was complaining of low back pain without leg pain, 9 patients (45%)with L4-L5 spondylolisthesis, 9 patients(45%) with L5-S1 spondylolithesis, and 2 patients(10%) with L3-L4sponylolithesis, 10 patients(50%) were grad 1, and 10 patients (50%) were grade 2 to 3 underwent transpedicular screw instrumentation.

Number of screws were 80 screws: (L3): 4 screws(5%), L4:22 screws(27.5%); L5: 36 screws(45%) and sacral:18 screws(22.5%)) were inserted via conventional open midline access in14 patients (70%) and paramidline through the muscles using tubes and dilators in 6 patients of patients(30%).

A single-level fusion was performed in 16 cases (80%), and in the remaining cases, two levels were involved. Decompressive procedures were performed, including partial facetectomies in 18 patients (90%), and unilateral total facetectomies in rest of patients, with discectomies, laminectomy with cages in all patients. The most common cage size was peek size 8/22. In all tubular or minimal invasive cases, we did not give blood to the patients and most of traditional open surgery we transferred one or two units of blood. times of surgery duration were collected and ranged from 6-8 hours, and hospital stay ranged from 3 - 30 days depending on back and leg improvement after surgery and physiotherapy assessment. one of our patient his wound get infected and stayed on the hospital for 30 days tell he improved and the organism was Gram negative bacilli, another patient had bleed post-operative and reopened again and hemostasis is done, the last complications was hardware failure and repositioning is done. So the net result were (85%) without complications and (15%) with complications one patient only with hardware failure (5%) which go with other researches using neuronavigation for instrumentations

Patient Positioning

After routine induction and intubation in prone position in a spinal surgery foam cradle placed on a completely radiolucent carbon-fiber composite operating table. The patient's arms, respirator tubing, and intravenous and arterial lines were secured in armrests alongside the foam cradle, so as not to interfere with the mobile scanner gantry (Figure1). A padded headrest was used; patients were positioned prone on a support to ensure that the abdomen was not compressed.

The orientation of the pedicles was determined using an image intensifier. A 4-6-cm midline incision was made, and the midline muscle attachments were divided along the incision to facilitate muscle retraction using traditional way in 14 patients. And Subcutaneous dissection were cared laterally with incision of muscle sheath about 2 -3 cm parallel to paraspinal muscles in 6 patients then the dynamic reference arc (DRA) attached exclusively to the L5 or L4 or L3 spinous process depending on fusion level. With automated registration of CT scanner and DRA (Brain Lab). Within the scanning volume, using the standard navigation pointer tool. Instrumentation was performed only after obtaining a near-perfect registration.

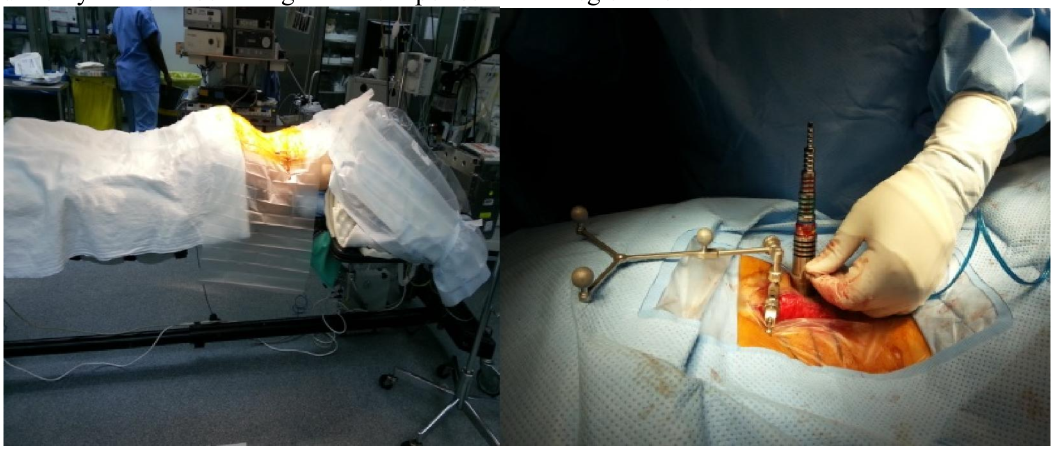

Fig. 1 (a) patient positioning and ((b) using tubular system with neuronavigation arc

The dorsal aspect of the pedicle was decorticated and then gradually perforated using a drill. After a hole was made, screws were inserted into the pedicles, which were confirmed by neuronavigation and neurophysiological monitoring the diameter of the screws that were used ranged from 3.5 to 4.5 mm. All of the implants used in this study were made entirely of titanium. The Screw placement was considered correct when the screw was surrounded by the pedicle and no portion of the screw perforated outside the cortex. No screws were modified after the confirmatory spin or after neurostimulation. Adequate neural decompression, cages filled with local bone chips were introduced into the cleaned-out space. Next, the screw heads, and extension sleeves were attached using the application tool, and the appropriate rod length was determined using the point-to-point measurement. Postoperative CT was performed in all cases to evaluate implant position The CT scan was performed within 48 hours after surgery, before patient mobilization.

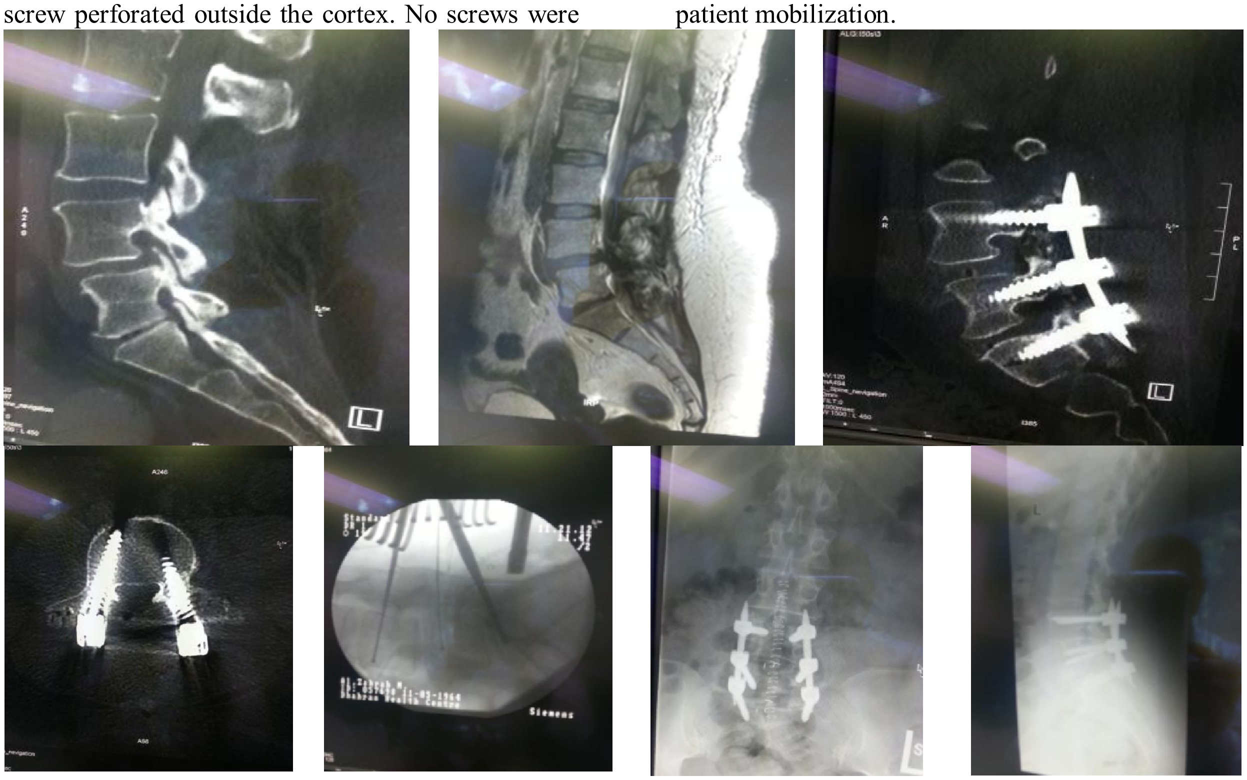

Fig 2: shows fluoroscopy and CT lumbar spine of female patient with bilateral leg pain and claudication pain with L4-L5 spondylolysis: shows the accuracy of neuronavigation in pedicular screw insertion in both fluoroscopy and CT lumbar spine intraoperative and post operative.

The duration of the operation was recorded (range from 6-8 hours), together with the requirement for blood transfusion and any procedural complications. Patients received the same postoperative management. With a patient-controlled analgesia device on the first postoperative day. Orally administered analgesia was introduced on the second postoperative day and replaced the patient-controlled analgesia device. Patients were encouraged to walk, beginning on the 2-3 postoperative day. Patients were discharged when the therapists deemed that the patient was able to manage in his or her own home. The number of days before initial mobilization out of bed and the number of days before independent ambulation, as well as the length of hospital stay, were recorded. Routine clinical follow-up, checking for complications and recovery, was conducted at 6 weeks, 3 months, 6 months 9 months and 12 months radiography was repeated, CT and x rays were performed to evaluate fusion, disc height, and the extent of reduction of the listhesis. Disc height was assessed at the midpoint of the anteroposterior length of the vertebral body, and was expressed as a proportion of the height of the overlying vertebral body.

3. Results:

During the study period, 20 patients underwent PLIF for the treatment of radicular pain attributable to isthmic or degenerative spondylolisthesis using neuronavigation. Before surgery, physical function and social function were recorded. All patients were similar in demographic and baseline clinical features before surgery. At 6 weeks 3 6-9-12 months postoperative follow up were measured for both improvement of leg pain and back pain depending on numerical pain score scale, and radiologically by the degree of reduction of spondylolisthesis, restoration of disc height, accuracy of fixation and fusion assessment.

Clinically:

All patients exhibited clinically significant improvements in leg pain 96% and back pain without motor deficits. This was corroborated by improvements in social and physical functioning, which were similar for all patients. All clinical outcomes data were collected by asking the patients to rate low-back pain and leg pain independently on a 10-point numeric rating scale (back pain and leg pain numeric rating scales), ranging from 0 (no pain) to 10 (worst possible pain). 96% were low back pain free and 40% of our patient was complaining of low back pain with score 6-8 for about 3 months then the pain decreased in intensity after 3 months but did not improve completely except after 9 months, also96% of the patient with no leg pain and 4% of our patient complaining of radicular pain for 3 months and improved completely after that and4% still complaining of leg pain for 6 months and improved after extension of fixation one level above.

Table 1: showed the pain scale for low back pain and leg pain (10 point numeric rating scale).

Pain	Back pain	leg pain
Score after 3 months	40% (6-8)	4% (4-6)
Score after 6 months	40% (4-6)	2 %(4-6)
Score after 9 months	40% (4_6)	0%
Score after 12 months	0%	0%

Radiologically:

Restoration of disc height in all patients by using cages, the rate of frank pedicle screw misplacement was 0%. The rate of minimal or questionable pedicle wall violation was 2%.

Complications:

The complications not related to screw malposition: Superficial wound infection was noted in one diabetic patient (2%) and healed after 4 weeks postoperative. No late hardware failure occurred tell time of doing the research. One patient 2% developed adjacent segmental instability and required additional surgery to extend the fusion and she improved from radicular pain but back pain persisted, and one patient with post operative bleeding and reopened and hemostasis was done

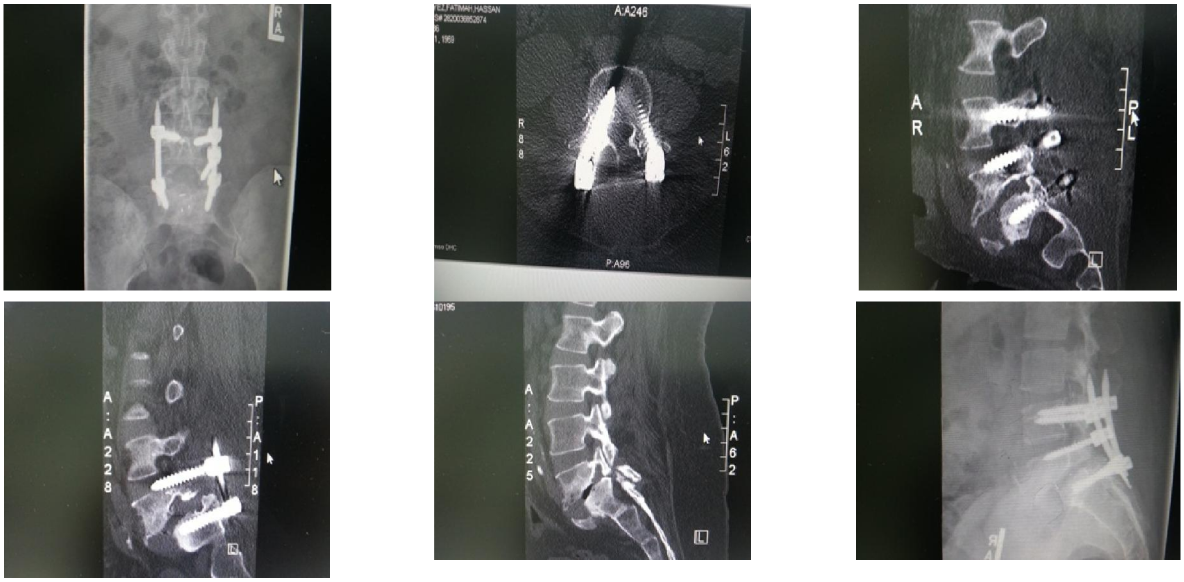

Fig 3: shows x rays of a woman 53 years old presented by chronic low back pain and bilateral leg pain and claudication pain with L5 –S1 Grade II Spondylolithesis underwent fixation of L5-S1 guided by neuronavigation and after 2 days the same complain as preoperative persist then CT lumbar spine done and showed avulsion of L5 pedicle with disc space L4-L5, she underwent reopening and fused again with level above,also we can see the difference between the finding of plain xray and CT for diagnosis of pedicular avulsion, in CT the screw inside the disc space while in x rays looks at the cortical endplate not in disc space.

Fig 4: shows accuracy of neuronavigation of pedicular screws insertion of L3-L4 spondylolysis of a female patient 44 years old with low back pain and bilateral leg pain as shown in post operative MRI,CT and fluoroscopy of lumbar spine

4. Discussion

The rate of neurological injury related to improper screw positioning has been reported to be as high as 11% and as low as 2%.**(13), Weinstein et al. (14)** found that neurological dysfunction was associated with spinal canal penetrance of > 6 mm. many clinical studies reported some cases of patients with screw misplacement of < 6 mm (or even < 2 mm) who demonstrated neurological deficits. In our study, the incidence of neurological injury, defined as the presence of sensory and/or motor deficits, was 0%, and the incidence of radicular pain without sensory or motor deficits, 2%.

The average distance from the pedicle to the dural sac medially has been reported to be in the range of 0.9–2.1 mm, and the average distance to the nerve root inferiorly has been reported to be in the range of 0.8–2.8 mm. **(15)**

Spinal navigation is an effective and accurate means of achieving instrumentation of the lumbosacral spine. Its use improves the accuracy of instrumentation placement and decreases the risk to adjacent neurovascular structures. Furthermore, with CT-based image guidance, the operating room staff is spared the radiation exposure of traditional procedures that use fluoroscopy The use of image guidance software also allows not only for placement of instrumentation within the boundaries of the pedicles but also with the desired axial and sagittal angles required to maximize construct strength. Surgical correction of spinal deformity requires that implants withstand the force necessary to achieve the correction. Increasing biomechanical stiffness will lead to higher arthrodesis rates **(16).** The surgeon may maximize convergence, as well as screw size, via surgical planning on the axial images provided by the navigational software. Further strength may be added to the construct by choosing an optimal sagittal trajectory. Screw position was classified as correct when the screw was surrounded by the pedicle cortex in all boundaries, (questionable violation) if the pedicle cortex could not be visualized in all boundaries, and as “frank penetration” when the screw was outside the pedicular boundaries.

Table 2: shows number of screws used in each level with no cortical breaches, no facet violations, and only one patient with single screw causes pedicle and disc space violation.

Pedicle (no. of screws)	Cortical Breaches	Spinal Level	Disc Space Violations	Facet Violations	Pedicle violation
L3(4)	0	L2-3	0	0	0
L4(22)	0	L3-4	0	0	0
L5(36)	0	L4-5	1	0	1
S1(18)	0	L5-S1	0	0	0

Conclusions

In comparison with traditional lumbosacral fixation and lumbosacral fixation with neuronavigation, the accuracy of fusions of pedicle screw placement is improved with the use of neuronavigation. It allows the surgeon to visualize the pedicle and the surrounding structures that are normally out of the surgical field of view. The surgeon, however, must be aware of the limitations of an image-guidance system and have a sound basic knowledge of spinal anatomy to avoid causing serious complications. An image-guidance system provides multiplanar views of the pedicle, allowing the surgeon to select the optimum point of entry and trajectory to traverse the pedicle without perforating the wall.

OPLIF involving a wide exposure to gain access to the vertebral column. This involves detachment and retraction of the paraspinal lumbar musculature from the midline structures, which is associated with immediate postoperative morbidity. With minimal invasive technique less muscle retractions and less, back pain postoperative.

With neuronavigation there are significantly reduction or even absent radiation exposure to surgeons, staff and patient, But the main disadvantage of using neuronavigation are difficult registration due to problems associated with surface-matching technique, time and money consuming.

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