Journal of Cardiovascular Disease Research

ISSN: 0975-3583, 0976-2833 VOL 12, ISSUE 03, 2021

ACCURACY OF LUMBAR PEDICULAR SCREWS INSERTION AND CLINICAL CORRELATION OF PATIENTS UNDERGOING LUMBAR PEDICULAR FIXATION AT ZAGAZIG UNIVERSITY HOSPITAL

Samy Hassanin Mohammed Salem[1], Atef Kelany Abdelwanees[1], Mansour Abdelmageed Makia[1], Mahmoud Hamed Abdelkhalek[1]
[1]Department of Neurosurgery, Faculty of Medicine, Zagazig University, Egypt

Corresponding author: Mahmoud Hamed Abdelkhalek, **Mobile:** (+20) 01062492544,
E-Mail: mahmoudabdelkhalek15889@gmail.com

ABSTRACT
Background: Pedicle screw instrumentation is generally utilized in the lumbar spine as a method for adjustment to improve arthrodesis. Signs for pedicle screw instrumentation remember adjustment for the setting of injury, deformation, tumors, diseases, degenerative conditions and recreation. Pedicle screw instrumentation is widely used in the lumbar spine as a means of stabilization to enhance arthrodesis. For accuracy, pedicle screw instrumentation may be guided by anatomic landmarks, preoperative imaging, and intraoperative imaging tools such as plain radiography, fluoroscopy, and, more recently, image-guided technology. This study aimed to improving accuracy of lumbar pedicular screws insertion and clinical outcome of patients undergoing lumbar pedicular fixation. **Patients and Methods:** Site of the investigation: Neurosurgery division at alexandria military emergency clinic and neurosurgery office in Zagazig college. Kind of the investigation: accomplice study. Test size: expecting that participation pace of patients for lumbar pedicular obsession is 3 patients for every month, the example size is 36. All patients will be taken as a far reaching test. patients affirmed to have been undrwent transpedicular lumbar obsession .All patients were taken as a comprehensive sample. Patients confirmed to have been underwent transpedicular lumbar fixation. **Results:** In assessing 153 pedicle screws inserted in 36 patients. Out of 51 misplaced screws; lateral screw misplacement was observed in 28 screws (54.9 %) and medial pedicle wall violation in 22 screws (43.1 %) and inferior misplacement in one patient. The remaining 102 screws (67.55 %) were judged as correctly inserted. Of the 51 misplaced screws, 34 misplaced screws were classified as minor (cortical perforation ≤ 2 mm), 15 screws moderate (2–4 mm), and 2 screws severe penetration (> 4 mm). **Conclusion:** Pedicle screw insertion carries risk of pedicular wall violation even in experienced hands even though intraoperative fluoroscopy is used. However; most violations are minimal with no clinical consequences and can be evaluated best by CT scan not plain X-ray. Minor displacements don't require corrections, while screws causing symptoms must be redirected.
Keywords: Correlation- Postoperative Computed Tomography- Assessment-Lumbar Pedicular Screws Insertion.

Introduction:

Pedicle screw instrumentation is generally utilized in the lumbar spine as a methods for adjustment to improve arthrodesis. Signs for pedicle screw instrumentation remember adjustment for the setting of injury, deformation, tumors, diseases, degenerative conditions and recreation. It is obligatory, regular in numerous signs and still not without confusions including lost screws. Since the presentation of pedicle screws, exactness of arrangement has been the subject of numerous investigations, where a wide scope of screw malposition rates have been accounted for [(1)].

The primary issue at medical procedure is that a visually impaired strategy is utilized; the specialist doesn't see the pedicle [(2)]. The danger of iatrogenic damage must be limited as essential anatomic structures encompass the pedicle: the dural sac medially, the nerve roots superiorly and poorly, and the vascular structures anterolaterally. Further, the exactness of pedicle screw inclusion is pivotal for the productivity and strength of the surgery. For exactness, pedicle screw instrumentation might be guided by anatomic milestones, preoperative imaging, and intraoperative imaging apparatuses, for example, plain radiography, fluoroscopy, and, all the more as of late, picture guided innovation [(3)].

The advancement of instrumentation procedures to balance out and address the harmed or ailing thoracolumbar and lumbar spine has gained huge ground during ongoing years. Analysts have detailed

that transpedicular screw obsession is better than front instrumentation and back snare bar obsession on the grounds that the pedicle offers a solid purpose of connection [3].
Concerns in regards to wellbeing, potential inconveniences if screws are lost, and loss of mechanical preferred position with pedicle divider interruption, have concentrated consideration on screw arrangement procedures [4]
The pace of lost screws still might be significant and has been accounted for to go up to almost 40% [5] Many more removals happened however went imperceptibly [6]. In an audit of the writing, noticed a 28.1% to 39.9% pedicle screw malposition rate in clinical investigations and a 5.5% to 31.3% malposition rate in body thinks about.
The level of malpositioned screws might be higher when ordinary anatomic milestones have been darkened, similarly as with modification medical procedure in the setting of a posterolateral combination [7].
Despite the fact that it is for the most part accepted that CT imaging is more precise than customary radiography in deciding pedicle screw area, especially in the setting of average and sidelong pedicle puncturing, a scope of correctnesses for both radiographic and CT surveyed holes has been accounted for [8]. Nonetheless, no unmistakable information as of now exist on the affectability or the particularity of utilizing CT pictures in distinguishing proof of pedicle screw arrangement [9].

This study aimed to improving precision of lumbar pedicular screws addition and clinical result of patients experiencing lumbar pedicular obsession

Patients and Methods

Specialized Design:

1. Site of the investigation: Neurosurgery division at alexandria military emergency clinic and neurosurgery office in Zagazig college

2. Kind of the investigation: accomplice study.

3. Test size: expecting that participation pace of patients for lumbar pedicular obsession is 3 patients for every month, the example size is 36. All patients will be taken as a far reaching test.

4. Subjects: patients affirmed to have been undrwent transpedicular lumbar obsession.

Incorporation criteria:

Incorporation criteria incorporated any patient experiencing lumbar spine pedicle screw obsession for degenerative, awful, or neoplastic sores. No age or sex confinements will be applied

Prohibition criteria

deformation

Withdrawal criteria:

Refusal of patients to take part in the examination.

Devices and Instrument:

• Full history taking.

• General assessment, back assessment.

• Neurological assessment.

• lumbar radiographs and postoperative CT filter.

Operational Design :

All cases will be exposed to clinical and radiological assessment

clinical assessment

A)full individual history taking

counting name, age, sex and symptomatology including back agony and lower appendage torment.

B) Examination

The patients are inspected for

•Vital signs

•Sensory shortages.

•Motor shortages.

•Back assessment and deformation.

•Straight leg raising test.

•Examination after exertion

C) Investigations:

1-Routine research center examinations:

During preoperative readiness of the patients, all cases were exposed to finish blood picture, blood glucose, liver and kidney capacities, draining profiles and serum electrolytes.

2-Radiological examinations:

a) Plain x-beam of lumbosacral spine:

•Anteroposterior see.

•Lateral see.

•Both slanted perspectives.

•Dynamic flexion and augmentation sees.

b) Computed tomography of lumbosacral spine:

c) Magnetic reverberation imaging

III) Technique:

Medical procedure:

The screw passage point will be recognized by utilizing anatomical tourist spots finding the crossing point of the transverse procedure with the relating aspect and the direction of the screw will be affirmed by intra employable radiographs.

Preoperative arrangement:

This incorporates history taking, clinical assessment, research facility and radiological examinations, determination for medical procedure, , fasting of the patient at the evening of medical procedure, prophylactic anti-infection agents, shaving of skin at the usable field and legitimate sanitization utilizing betadine clean arrangement

Postoperative administration:

•Preoperative anti-toxins were proceeded for 10 days postoperative.

•Narcotic analgesics were utilized in the initial 24 hours.

•Non steroidal mitigating drugs were utilized for seven to ten days.

•Corticosteroids were utilized now and again

•Oral diet plentiful in protein, nutrients and calcium was begun in the subsequent day.

•Patients were ambulant in the second postoperative day without props aside from in corpulent patients.

Post employable assessment:

Postoperatively all patients were assessed neurologically to evaluate new radicular torment or deficiencies if present.Postoperative routine anteroposterior and sidelong plain radiographs will be performed inside 48 hours after medical procedure. C.T. Output with 2 mm hub cuts with bone window will be performed in all cases to assess embed position 2 weeks after medical procedure. These pictures will be investigated for proof of pedicle infringement and the screws will be grouped by their situation inside or outside the pedicle.Pain will be evaluated by VAS score 2 weeks after medical procedure. Connection between's clinical side effects and radiological infringement will be accounted.

Statistical analysis: Recorded data were analyzed using the statistical package for the social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean± standard deviation (SD),

median, and range. Qualitative data were expressed as frequency and percentage. Independent-samples t-test of significance was used when comparing between two means. Chi-square (X^2) test of significance was used in order to compare proportions between two qualitative parameters. P-value <0.05 was considered significant. P-value <0.001 was considered as highly significant. P-value >0.05 was considered insignificant.

Results

The total number of patients included in this study was 36 patients 23 males and 13 females. The age distribution of the patients ranged from 21years old to 60 years old with mean age of 45 years old. The indications for surgical fixation in our cases were as follows, 19 patients with spondylolythesis , 6 patients with traumatic fracture, 5 patients with recurrent disc prolapsed , two patients with disc prolapse and 4 patients with lumbar canal stenosis.

The surgical indication for operation is shown in table 1.

Table no. 1 (Indication of surgical fixation)

Surgical indication	Spondylolythesis	Traumatic fracture
Number of patients	42	8

The total number of used screws for fixation in our patients was 153 screws . All screws were inserted under C-arm guidance .

The number of screws inserted in each vertebral level shown in table 3.

Table no. 2 (Screws inserted in each level)

Vertebral level	Number of inserted screws
L1	8
L2	7
L3	22
L4	58
L5	58

The accuracy of pedicle screws was assessed using thin slice C.T scan bone window to evaluate even minimal cortical breaching.

The number of totally accurate screws within the pedicle was found to be 102 screws (66.67%).

The number of screws breaching the cortex was 51 screws (33.33%). We have classified the degree of pedicle cortical breach according to the following classification:

A: minordisplacement < 2mm

B: moderate displacement 2~4mm

C: severedisplacement > 4mm

The degree of screw displacement as assessed by C.T scan in terms of millimeters were found to be 34 screws displaced less than 2mm (minor displacement), screws displaced between 2mm and 4mm were found to be 15 screws (moderate displacement),and those with more than 4mm displacement were found to be 2 screws (severedisplacement).

The data regarding degree of screw displacement as assessed by C.T scan.

Table no. 3 (Degree of screw displacement)

Number of screws	Displacement in mm	Degree
34	<2mm	Minimal
15	2~4mm	Moderate
2	>4mm	Sever

The direction of displacement of pedicle screws were also assessed by C.T. scan and described as superior, inferior, medial or lateral if any.

There were no cases with superior pedicular displacement.The number of screws laterally deviated were 28 screws (55.26%) and those with medial perforation were 22screws (44.74%) and those with inferior perforation were only one screw.

Table no. 4 (Direction of cortical perforation)	
Direction of perforation	Number of screws
Superior	0
Inferior	1
Medial	22(
Lateral	28

The numbers of screws found to breach the cortex of the pedicle were evaluated in terms of each vertebral level, the results were as follow:

In L1 level a total of 8 screws were inserted with no displaced screws on follow up, In L2 level a total 7 screws were inserted and 3 were found displaced from which one minor displaced screw, 2 moderate displaced screws. In L3 level a total of 22 screws were inserted and 12 screws were found displaced from which 10 screws were displaced less than 2mm and 1 screw was displaced between 2-4 mm and one screw was displaced more than 4mm

In L4 level a total of 58 screws were inserted and 22 were found displaced as follows: 16 screws displaced less than 2mm , 5 screws displaced between 2-4mm and one screw was displaced more than 4mm.

In L5 level a total of 58 screws were inserted, 14 screws found displaced as follows: 7 screws displaced less than 2mm, 7 screws displaced between 2-4mm

The data representing pedicular breach by screws are presented

Table no. 5 (Pedicular breach by screws)		
Vertebral level	Number of inserted screws	Number of breaching screws
L1	8	0
L2	7	3 (
L3	22	12
L4	58	22
L5	58	14

C.T.assessments of the direction of displacement of screws were also assessed in cases where screws found to breach the pedicular cortex.Those cases were as follow: In L2 level one screw was displaced laterally and 2 scews were displaced medially, In L3 level, 6 screws were displaced medially and 6 laterally , In L4 level 8 screws were displaced medially and 14 laterally , In L5 level 6 screws were displaced medially and 7 screws laterally and one screw inferiorly .

Table no. 6 (Direction of displacement)		
Vertebral level	Direction of displacement	
	Medial	Lateral
L2	2	1
L3	6	6
L4	8	14
L5	6	7
Total (51)	22	28

The degree of displacement as assessed by C.T scan was as follow: In L2 level one screw was displaced less than 2mm (minor displacement), In L3 level, 7 screws were found displaced less than 2mm (minor displacement) and 2 screws were displaced between 2~4mm (moderate displacement), In L4 level,23 screws were found displaced less than 2mm (minor displacement),12 screws were found displaced between 2~4mm (moderate displacement) and 2 screws were found displaced more than 4mm (severe displacement), In L5 level,12 screws were found displaced less than 2mm (minor

displacement),14 screws were found displaced between 2~4mm (moderate displacement)and 3 screws were found displaced more than 4mm (severe displacement).

Table no. 7 (Degree of displaced screws in relation to vertebral level)

Vertebral level	Degree of displacement		
	Minor < 2mm	Moderate 2~4mm	Sever > 4mm
L2	1	2	0
L3	10	1	1
L4	16	5	1
L5	7	7	3

The post operative clinical development of new symptoms related to displaced screws were evaluated. There were no cases of newly developed cauda equine injury.
In one patient with L5 medially displaced screw, new onset of sciatica and foot drop occurred which improved after surgical correction .
In one patient with L5 medially displaced screw , new onset sciatica developed without weakness which improved after surgical correction .
In another patient with L3 medially displaced screw, new onset of pain and occurred, after surgical correction of screw position, pain improved.
In one case with bilaterally laterally displaced screws of L4 surgical correction for L4 screws was done for good fixation.

Table no. 8 (Correlation between clinical, surgical, radiological data and displacement in lower lumbar levels)

Clinical , surgical, radiological data	L4	L5
Direction of displacement	Medial	Medial
Degree of displacement	> 4mm	> 4mm
Technique of insertion	Open	Open
New onset of symptoms	Pain weakness	Pain Weakness
Outcome after repositioning	Pain improved Weakness persist	Pain and weakness improved

CASE PRESENTATION

Case no 3 :

• Male patient, 51 years old, army officer and father of 2, 178 cm height, 79 kg weight.
• Presented with low back pain, sciatica, neurogenic claudication and parasthesia of left leg.
• On clinical examination, motor power of left leg was full motor power and L5 hyposthesia on left leg. Leg raising test on left leg was 30º while on right leg was 90º. There was muscle spasm and palpable step. There was no scoliosis or sphincteric disturbances.
• Radiologically: plain x-rays showed L4-5 spondylolisthesis , there was instability at dynamic views. Slip angle of 24º and lumbar index of 78%.
CT lumbosacral spine showed lumbar canal stenosis at L4 and L5 levels.

MRI lumbosacral spine showed central herniated disc of L4-5.

• He tried conservative treatment for 3 months. But there was no relief of pain or claudication.

• Surgery was indicated because of the intractable pain, neurological deficits, and presence of spondylolithesis and foraminal stenosis at 2 levels. Besides, he is active with instable spondylolisthesis with high incidence of progression.

• He was operated upon by decompression at L4-5

Posterolateral fusion and fixation using transpedicular screws and rods at L4-5.

• Postoperative: the patient was evaluated both clinically and radiologically and revealed new sciatica , neurogenic clausication , parasthesia of right leg . there was partial right foot drop grade 2 .

When assessed by multislice axial C.T 2mm cuts bone window, revealed medially displaced screws, that were correlated clinically.

- Revision operation was done to correct medially displaced screws of l4 and l5 at right side and to improve correlated clinical neurogenic pain and weakness .

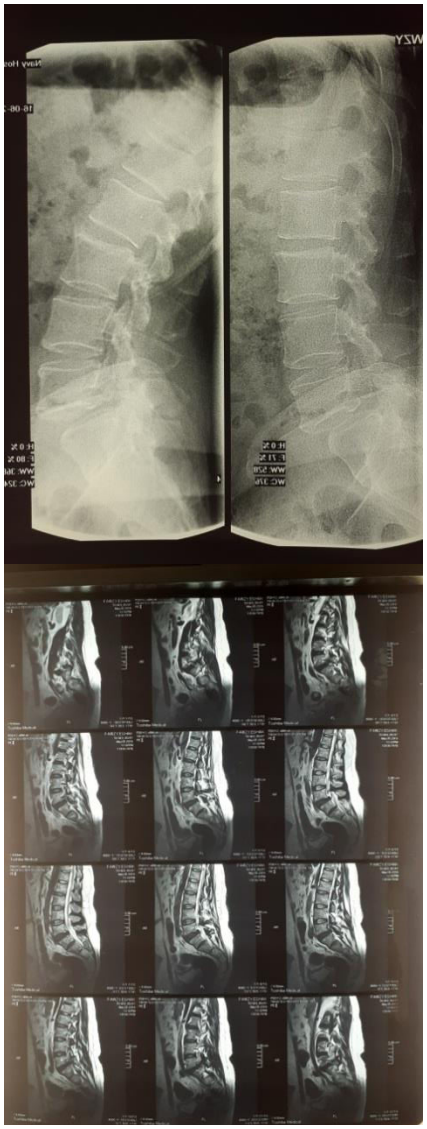

Fig. 1: Demonstrates pre-operative MRI and plain x-ray showing spondylolythesis.

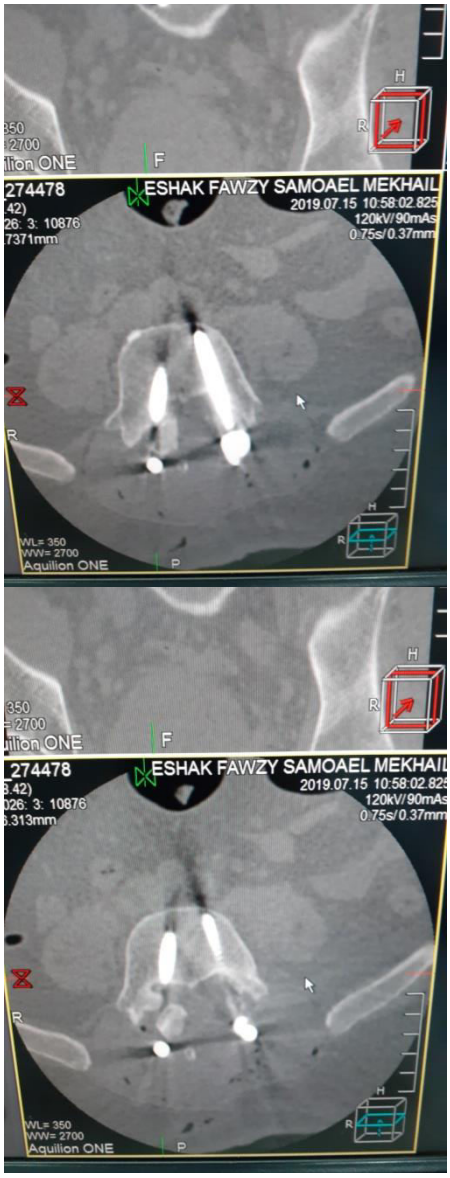

Fig. 2 : Demonstrates post operative C.T assessment for inserted pedicular screws showing medially displaced screws moderate degree .

Case no.25 :

•Male patient, 46 years old, retired officer and father of 3. 178 cm height, 86 kg body weight.
•Presented with low back ache, sciatica and parasthesia of left leg.
•On clinical examination: there was weakness grade IV on dorsiflexion of left foot and L5 hypoesthesia of left leg, leg raising test on left leg was 45º while on right side was 90º. There was muscle spasm.
•Radiologically: plain X-rays showed L4-5 minimal instability on dynamic views.
MRI lumbosacral spine showed L4-5 disc prolapsed lateralized to left and old L5 left hemilaminectomy, herniated disc encroaches on the left lateral recess and left foramen at L5.
•He tried conservative treatment for 6 months.
•Surgery was indicated due to intractable pain, failure of conservative treatment, and presence of neurological deficits, together with the presence of instability.
•He was operated upon by wide decompression of L4 and L5. Transpedicular screw insertion at L4 and L5 fixation.
•Postoperative: : the patient was evaluated both clinically and radiologically and revealed no new neurological symptoms or signs.
When assessed by multislice axial C.T 2mm cuts bone window, revealed medially displaced screws, however there are no correlated symptoms and signs.

Fig.3: Demonstrates pre operative MRI showing recurrent L4-5 disc prolapse.

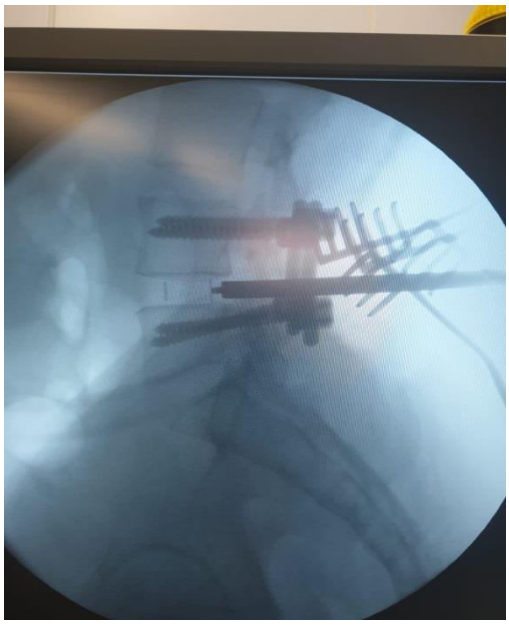

Fig. 4: Demonstrates intra operative plain x-ray assessment for inserted pedicular screws.

Fig. 5: Demonstrates post operative C.T assessment for inserted pedicular screws showing medially displaced screw minor degree.

Discussion

Concerning most clinicians practically speaking, intra employable and post usable evaluation of pedicle screw inclusion are chiefly dependant on plain x-beam.

C.T appraisal might be saved for assessment of patients with clinical uncertainty of screw pedicle infringement or side effects of new neurological pressure. In any case, for appraisal of screw position for inquire about, this evaluation must be finished utilizing C.T assessment to recognize even minor rupture of cortical bone and not simply major mal positions [(9)].

Legitimate position of pedicle screw in addition to the fact that it protects neural structures from damage it is a significant capacity which assurance long haul endurance of metallic develop which permits better combination and forestalls haul out or breakage of metallic inserts [(1)].

Despite the fact that lumbar pedicle screw obsession is progressively utilized in avariety of signs by specialists of neurological and orthopedic specialities , these additions are not without confusions including malposition which may be answerable for advancement of new neurological side effects and signs [(3)] ,[10), (11).

While considering the frequency of removal of lumbar pedicle screw, a wide audit of writing has uncovered inconstancy of announced rate rates to differ 28.1% and 45% in clinical examinations [(7)]. The pace of removal was lower in cadaveric examinations extending somewhere in the range of 5.3% and 31.3% [(7)].

It has been our training to embed lumbar pedicle screws for quiet with normal signs in writing including awful, fiery and degenerative signs.

The absolute no. of patients in this examination included 36 patients and an absolute 153 screws embedded by 2 specialists for a similar office.

The procedure utilized for inclusion of pedicle screws was the standard careful method as portrayed for open medical procedure [(12)]

Assessment of screw arrangement was performed by the criteria distributed by **Learch et al.** [(13)].

Screw arrangement was viewed as right when the screw was totally encompassed by the pedicle and no bit of the screw punctured outside the cortex. Infiltration of the pedicle screw was estimated in millimeters utilizing the scale on the CT picture. On the off chance that the infiltration of the pedicle screw was 2 mm or more along the pedicle poorly, superiorly, horizontally, medially, or anyplace from the corpus, it was evaluated as lost. Infiltration was additionally subdivided—in light of estimation of

the separation that the edge of the screw string stretched out outside the pedicle cortex—into minor (≤ 2.0 mm), moderate (2.1–4 mm), and serious (> 4 mm). Contingent upon the heading of the pedicle infringement, the screw removal was noted as parallel, average, second rate, or prevalent, and right or left. The rate of intra and postoperative inconveniences not identified with screw position just as equipment disappointments were likewise enrolled, with a base follow-up span of 6months [(1)].

While checking on our outcomes, the occurrence of lost screws were assessed utilizing C.T. sweep to distinguish cortical rupture even under 2mm was 33.33 %.

This general rate of lost tightens our investigation is as per most distributed writing results assessing rate of removal of pedicle screws following lumbar inclusion [(3) ,(10), (8)].

Farber et. al embedded 76 pedicle tightens 16 patients and assessed the affectability of radiographic appraisal of cortical aperture utilizing C.T. as the highest quality level in their investigation 21/74 28% of pedicle screws ruptured the average pedicle cortex on postoperative C.T. assessment, despite the fact that they have done intraoperative palpation of pedicles however midline laminectomies during screw inclusion [(8)].

In a perfect world, pedicle screw ought to be totally inside the pedicle and the spinal waterway nor foramina ought not be disregarded [(8)]. Average and second rate infringement are bound to cause neurological shortfalls than unrivaled and sidelong infringement being more toward the dura and existing nerve root [(3) , (8)].

When looking at the rate of scattering in x-beam in our investigation, we don't locate a solitary instance of screw disregarding the pedicle or considered as lost, nonetheless, when appraisal is finished utilizing the C.T. examine postoperatively, we have discovered 51 screws have broken the cortex.

Ahlgren et al. [(8)] has likewise thought about C.T. output and plain radiographicy of lumbar pedicle screw exactness and has archived multiple times clear infringement than did plain x-beam.

We certainly credit this to the way that we embed all screws under fluoroscopic imaging by which sinks rostral caudal direction are unmistakably envisioned, be that as it may, postoperative C.T. filter portion envision additionally mediolateral entrances which are not obviously distinguished intraoperatively.

This reality is concurred by creators who led cadaveric investigations as pedicle screw addition utilizing fluoroscopy [(4).]

As we center around the anatomical occurrence of C.T. evaluated entrance of the pedicle by embedded tightens our investigation, we have discovered that the rate of horizontal divider infiltration was more typical than average infiltration. Where sidelong divider infiltration had happened in 28 screws. While average divider infiltration has happened in 22 screws

Our elucidation for this occurance is the way that specialists while embeddings screws know that average infiltration is bound to cause neurological wounds, accordingly they will in general remember section and direction, in order to limit probability of average entrance. Likewise, most cases are finished up by laminectomies through which the specialist assesses the comparing pedicles for conceivable sentiment of screw sensation utilizing careful instruments, as additionally been portrayed by different creators [(14)].

In **Li et al.** [(15)] while directing a morphometric study utilizing reproduced automating tomography of pedicular isthmic screws additionally found that frequency of parallel apertures were more typical than average puncturing.

The primary enthusiasm for leading such examinations is to assess the clinical effect of screw positions on the patients symptomatology.

In clinical practice, the frequency of neurological shortage coming about because of pedicle screw inclusion may result from puncturing of cortex and pressure or damage of neurological structures nearby the pedicle including nerve establishes or thecal sac in the focal channel.

Anatomically, the pedicle is isolated from the dura by thin layer of epidural fat of about 2mm thickness. In this way damage is almost certain with average aperture [(3), (8)].

While assessing our outcomes, we found that patients who grew new indications identified with screw inclusion are nearly nothing.

Just 3 patients had created side effects that can be clarified by cortical infringement and nerve root bothering.

Lower lumbar levels were the spot of the most elevated cortical puncturing, in L4 is 22 screws, L5 is 14 tightens our investigation contrasted with L1 is with no uprooted screws, in L2 has just 3 dislodged screw and in L3 is 12 screws.

We and others concur that it is bound to abuse the pedicle when more pedicular tendencies are available [(10)]

We had no instances of focal channel infringement causing cauda equina sore. Nonetheless, we had just 3 patients who created agony and shortcoming following obsession that had radicular indications and could be identified with screw position. In those 3 cases, screws had done average aperture, and required adjustment. They had improved after rectification.

In every single other situation where radiological C.T. has exhibited pedicle divider punctures, these cases were asymptomatic aside from one case with reciprocal relocation L4 screws that was reoperated for good obsession. At last patient side effects are presumably the most affected factor in deciding adequate situating of the screw [(3)].

Conclusion:

Pedicle screw insertion carries risk of pedicular wall violation even in experienced hands even though intraoperative fluoroscopy is used. However; most violations are minimal with no clinical consequences and can be evaluated best by CT scan not plain X-ray. Minor displacements don't require corrections, while screws causing symptoms must be redirected.

References:

1. **Albert T, Grauer J, Vaccaro A *et al.* (2004):** Evaluation of a novel pedicle probe for the placement of thoracic and lumbosacral Pedicle screws. Spinal Disord Tech., 17: 492-497.
2. **Castro WH, Halm H, Jerosch J, Malms J, Steinbeck J, Blasius S:** Accuracy of pedicle screw placement in lumbar vertebrae. Spine 21: 1320-1324 **(1996).**
3. **Akyildiz F, Söyüncü Y, Yildirim F *et al.* (2005):** Anatomic evaluation and relationship between the lumbar pedicle and adjacent neural structures an anatomic study. Spinal Disord Tech., 18: 243-246.
4. **Robertson P, Stewart N (2000):** The radiologic anatomy of the lumbar and lumbosacral pedicles. Spine, 25: 709–715.
5. **Grauer JN, Vaccaro AR, Brusovanik G, Girardi FP, Silveri CP, Cammisa FP, Kwon BK, Beiner JM, Albert TJ, Hilibrand AS, Scuderi GJ:** Evaluation of a novel pedicle probe for the placement of thoracic and lumbosacral pedicle screws.J Spinal Disord Tech 17: 492–497 **(2004).**
6. **Glossop ND, Hu RW , Randle JA:** Computer-aided pedicle screw placement using frameless stereotaxis. Spine 21: 2026-2034 **(1996).**
7. **Austin MS, Vaccaro AR, Brislin B, Nachwalter R, Hilibrand AS, Albert TJ:** Image-guided spine surgery;a cadaver study comparing conventional open laminoforaminotomy and two image-guided techniques for pedicle screw placement in posterolateral fusion and nonfusion models. Spine 27: 2503–2508 **(2002).**
8. **Ahlgren B, Learch T, Massie J *et al.* (2004):** Assessment of pedicle screw placement utilizing conventional radiography and computed tomography: A proposed systematic approach to improve accuracy of interpretation. Spine, 29(7): 767–773.
9. **Yoo JU, Ghanayem A, Petersilge C, Lewin J:** Accuracy of using computed tomography to identify pedicle screw placement in cadaveric human lumbar spine. Spine 22: 2668-2671 **(1997).**
10. **Attar A, Ugur H, Uz A *et al.* (2001):** Surgical anatomic evaluation and relationships. Eur Spine J., 10: 10–15.
11. **Roy-Camille, R., Saillant, G., and Mazel, C**.: Internal fixation of the lumbar spine with pedicle screwplating. Clin. Orthop. 2037, **1986**.
12. **Haid RW, Morone MA:** spondylolisthesis and spondylolysis. In: George T. Tindall, Paul R. Cooper, Daniel L. Barrow (eds):The practice of neurosurgery. Williams and Wilkins. Baltimore, Meryland. volume 6,ch167,p.2541-2563**,(1997)**
13. **Learch T, Massie J, Pathria M *et al.* (2004):** Assessment of pedicle screw placement utilizing conventional radiography and computed tomography: a proposed systematic approach to improve accuracy of interpretation. Spine, 29:767–773.

14. **Gonzalez-Cruz J, Karim A, Mukherjee D *et al.* (2006):** Accuracy of pedicle screw placement for lumbar fusion using anatomic landmarks versus open laminectomy: A comparison of two surgical techniques in cadaveric specimens: Operative Neurosurgery, 1: 13-19.
15. **Li B, Jiang B, Fu Z, Zhang D, Wang T:** Accurate determination of isthmus of lumbar pedicle: A morphometric study using reformatted computed tomographic images. Spine 29: 2438–2444, **2004**