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Original Article

Conventional vs. Universal Entry Point: A Postoperative Radiological comparison of Freehand Thoracic Pedicle Screw Placement

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Abstract:

Objective: To observe the difference of postoperative CT scan findings between using conventional and universal entry point for pedicle screw placement among the study subjects in all levels of the thoracic spine.

Methods: This interventional study was conducted in the Neurosurgery Department of Dhaka Medical College Hospital. A total of 43 samples were taken. 31 Patients were categorized as Group-A (universal entry point) and 12 patients as group-B (conventional entry point). Patients who had presented with compressive dorsal myelopathy due to either traumatic thoracic fractures or kyphotic deformity, Pott's disease or patients having neoplastic bony lesions requiring fixation were enrolled in this study. All patients underwent Magnetic Resonance Imaging for establishing diagnosis. CT scan of thoracic spine was done postoperatively within 1 week in all cases and pedicle violations were measured by Surgimap (version 2.3.2.1) software. Data was collected and compiled.

Results: Mean age of the patients was 44.9 ± 11.4 years. A total of 224 screws were inserted in both groups in different thoracic levels. Maximum screws were inserted in T10, T11 and T12 thoracic levels. Pedicle wall violation in universal entry point group was 17.1% and in conventional group it was 27.3%. 82.9% screws were fully contained within the pedicle wall in universal group and in conventional group it was 72.7%. Per-operative unintended durotomy was observed in 2 (6.5%) cases, screw in the fractured pedicle in 3 (9.7%) cases, CSF leak in 1 (3.2%) case, pulmonary complication in 1 (3.2%) case, nerve root irritation in 3 (9.7%) cases and no incidence of major vascular injury occurred in group-A. In Group-B, unintended durotomy was observed in 1 (8.3%) case and screw in the fractured pedicle in 1 (8.3%) case.

Conclusion: This study shows that there was no significant difference of pedicle wall violation and in post-operative CT scan between using the universal and the conventional entry points. Per-operative complications were also similar in both groups.

Introduction:

Pedicle screws are commonly used in spine surgery for rigid fixation1. They are used in a spinal fusion as a strong support for reconstruction by providing extra strength to the fusion while it heals, usually placed above and below the vertebrae that were fused. A rod is used to connect the screws which prevents movement and allows the bone graft to heal. Pedicle screws offer robust and quick stability. Pedicle screw placement for spinal stabilization was first described in 1950 and has since become a widely used technique among Spine surgeons2. However in the thoracic spine there are certain challenges due to the critical regional neurovascular anatomy as well as the narrow pedicular corridor that typically exists. Neurological complications that occur during or after instrumentation are more likely as a result of the spinal cord's presence throughout the thoracic segment and the spinal canal's small diameter.

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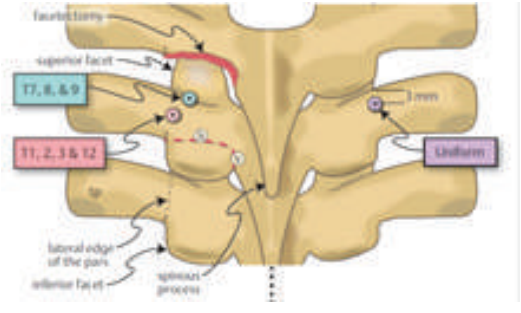
To achieve spinal fixation and fusion, pedicle screws have various biomechanical advantages3 but screw malposition can be devastating when it occurs in the proximity of neurovascular and visceral structures. In addition, there is a long learning curve associated with pedicle screws accurate placement4. Several techniques, including intraoperative C-Arm, image-assisted navigation, and intra-operative fluoroscopy have been developed to improve the accuracy of pedicle screw placement5, but these techniques increased radiation exposure and overall operative time for patients and surgeons6. To avoid harmful effects of radiation, Freehand pedicle screw placement hasbecome the preferred modality of fixation for various thoracic pathologies, such as trauma, degenerative spine disease, scoliosis, and tumors.

Fig 1: Entry points for thoracic pedicle screws. The left side illustrates level specific entry points, and the right side shows uniform placement (Ref: Handbook of Neurosurgery, 9th edition).



Kim et al outlined variety of entry points for freehand thoracic pedicle screw placement at various thoracic spinal levels. Later it was observed that existing published techniques and “thoracic pedicle screw charts” were cumbersome to adopt and teach given the variability of starting points and angulations4. Conversely, the universal entry point focuses on base of the superior articular process where the screws were inserted 3mm caudal to the junction of the lateral margin of the superior articulating process and the transverse processes7. In this study our experience with freehand pedicle screw placement in the thoracic spine using both the conventional and a uniform entry point for all levels was described. Post-operative radiological comparison was done using CT scan between both these groups to find out the accuracy of both the techniques. Specific attention was focused on the incidence and degree of cortical breakthrough within the various planes of thoracic vertebrae.

Materials and Methods:

This is an interventional study conducted at Dhaka Medical College & Hospital over a period of one and half year from July 2020 to January 2022 among the patients undergoing thoracic fixation. Patients were categorized as universal entry point group (Group-A) and conventional entry point group (Group-B). Total 43 samples were taken. Purposive sampling was done. Patients who had presented with compressive dorsal myelopathy due to either traumatic thoracic fractures or patients with degenerative causes of spinal fractures, e.g. kyphotic deformity, infective causes like Pott’s disease, or patients having primary or secondary bony lesions causing significant compression over spinal cord, patients with MRC muscle grading of lower limb from 0/5-4/5, with or without having bowel bladder incontinence due to the primary insult were included in both groups. Age range was between 20-66 years in universal entry point group and 22-62 years in conventional entry point group. Complete history of all patients pertaining to complaints, neurological assessment by clinical examination was obtained. Ethical clearance for the study was ob¬tained from the Ethical Review Committee. All patients underwent Magnetic resonance imaging (MRI) of the Dorsal or Dorso-lumbar region for establishing diagnosis and planning for fixation by thoracic pedicle screws. All the cases were performed by 5 neurosurgeons of Dhaka Medical College & Hospital and involved neurosurgical residents assisting with pedicle screw placement under direct supervision. Informed consent was taken after full explanation of risk, benefit of the study. All Patients underwent open procedure of thoracic fixation. In Universal entry point group, Pedicle screws were placed using a uniform entry point of 3 mm caudal to the junction of the lateral margin of the superior articulating process and transverse process. Level specific entry points were used in the Conventional entry point group of patients, that is, in T1, 2 & 3 levels even with the lateral edge of the pars, in T7, 8 & 9 levels just lateral to mid-position of the base of the SAF and finally in T11, 12 levels just medial to lateral edge of pars. In both groups the sagittal trajectory was orthogonal to the curvature of the dorsal spine. The following steps in screw insertion were same in both groups. After exposure, a high-speed electric drill or a pedicle owl was used to disrupt the cortical bone at the entry point described above. A sharp, straight gearshift is used to cannulate the pedicle to the desired depth based on preoperative CT measurements in some cases. A ball-ended feeler is used to assess for breaches. Markers were placed into the holes. The pedicle is then typically under-tapped and an appropriate size

poly-axial screws were placed. Final C-arm guided images were taken again after screw placement in all procedures. Postoperative CT scans were obtained on the 2nd postoperative day in all cases. The medical records were recorded the following variables: age, gender, presenting diagnosis, name of the procedure, thoracic vertebrae involved, and materials used for pedicle screw fixation. The violations of the screw trajectory using both the universal and conventional entry points were measured by calibrating the axial and sagittal JPEG images of postoperative CT scans into the Surgimap version 2.3.2.1software. The degree of pedicle violation was rated in the following two categories: 2-4mm violation (probable safe zone) and >4mm violation (questionable safe zone) where distances were measured either from the medial border (in case of medial violation) or from lateral border (when pedicle violation occurred laterally) of the pedicle8. The following events after thoracic fixation using universal entry point were recorded: screw trajectory, medial violation of the screw, lateral violation, superior and inferior violation, unintended durotomy, screw in the fractured pedicle, vascular injury, pulmonary complications, nerve root irritation etc.

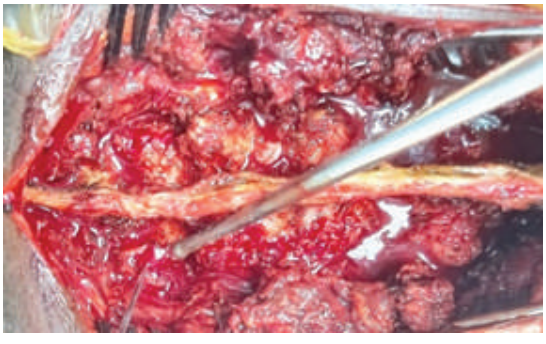


Fig. 2. Exposure of spine showing the lateral edge of SAP and TP

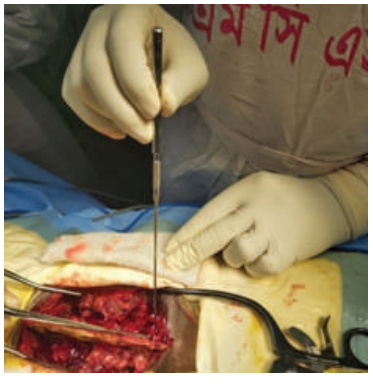


Fig. 4. Ball tipped sound probe is inserted to feel for all the quadrants of the canal for any breach

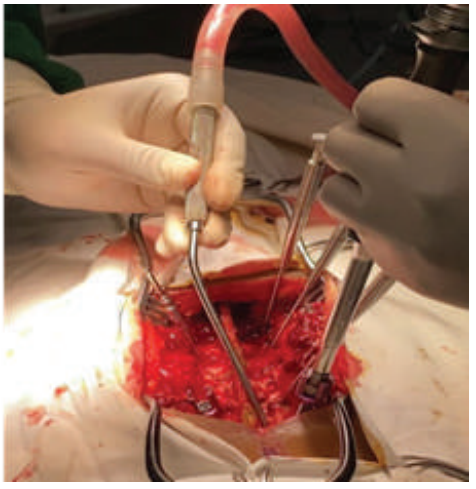


Fig. 6. Screw is inserted after C-arm confirmation

Fig. 3. Cannulation of the pedicle using a straight narrow gearshift

Fig. 5. Undertapping the pedicle tract

Fig. 7. Rod is placed along the screws making the correct curvature confirmation

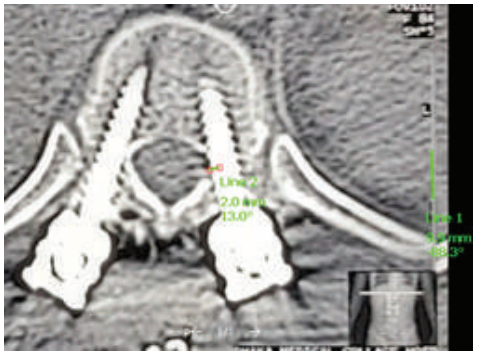


Fig. 8. 2 mm medial breach(Gr-I) on left side of T6 vertebra

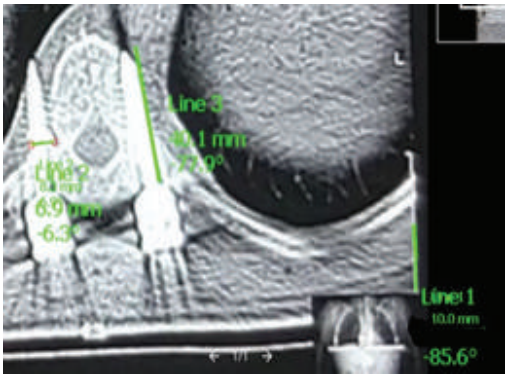


Fig. 10. A 6.9 mm lateral breach on right T8 vertebra

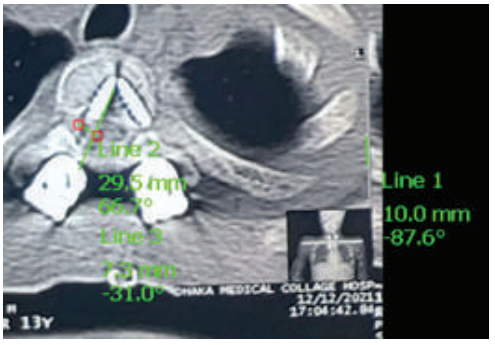


Fig. 9. A 7.3 mm(Gr-IV) medial breach on right side of T2 vertebra

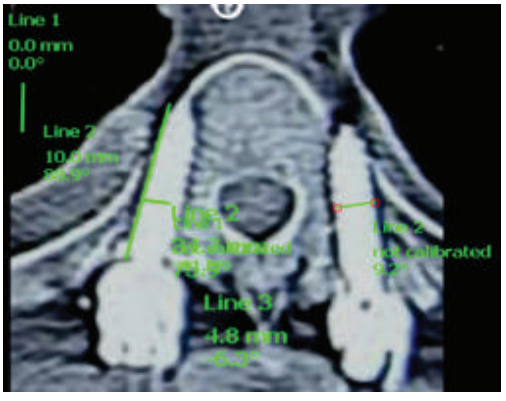


Fig. 11. 4.8 mm(Gr-III) lateral breach on left T2 vertebra

Fig. 12. 5.8mm(Gr-III) superior violation at T11 level

Fig. 13. Grade II(4.2mm) inferior violation at T7 level

A structured questionnaire was designed including all the variables of interest. It was finalized following pretesting and necessary modifications. Data were collected by the researcher. Collected data were checked and edited first. Then they were processed with the help of software SPSS (Statistical Package for Social Sciences) and analyzed. The test statistics used to analysis the data was descriptive statistics. A probability (p) value of < 0.05 was considered statistically significant and p<0.001 is considered highly significant but p > 0.05 taken as non-significant.

Results

Mean age of the patients was 44.9 ± 11.4 years with range from 18 to 66 years in Group-A and was 42.91 ± 12.57 years with a range from 22 to 62 years in Group-B. Male to female ratio was 4.1:1 in group-A and 3:1 in group-B. A total of 224 screws were inserted in both groups in different thoracic levels. Maximum screws were inserted in T10, T11 and T12 thoracic levels. Pedicle wall violation in universal entry point group was 17.1% and in conventional group it was 27.3%. 82.9% screws were fully contained within the pedicle wall in universal group and in conventional group it was 72.7%. Per-operative unintended durotomy was observed in 2 (6.5%) cases, screw in the fractured pedicle in 3 (9.7%) cases, CSF leak in 1 (3.2%) case, pulmonary complication in 1 (3.2%) case, nerve root irritation in 3 (9.7%) cases and no incidence of major vascular injury occurred in group-A. In Group-B, unintended durotomy was observed in 1 (8.3%) case and screw in the fractured pedicle in 1 (8.3%) case.

Table I

Distribution of subjects according to indication of surgery (n=43)

Indication for surgery	Group-A (Universal entry point) (n=31)	Group-B (Conventional entry point) (n=12)	P value
Trauma	19 (61.29)	6 (50.0)	0.579
Tumor	2 (6.45)	0 (0.0)	
Infection	4 (12.90)	3 (25.0)	
Degeneration	4 (12.90)	1 (8.3)	
Metastatic vertebral fracture	2 (6.45)	2 (16.7)	

Table II

Location and degree of pedicle wall violation (n=224)

Location	Grade	Group-A (Universal entry point) (n=158)	Group-B (Conventional entry point) (n=66)	p-value
Medial wall violation	2-4mm	5 (3.2)	3	0.120
	>4mm	3	2	
Lateral wall violation	2-4mm	8 (5.1)	5	
	>4mm	5	3	
Superior wall violation	2-4mm	2 (1.3)	2	
	>4mm	2	1	
Interior wall violation	2-4mm	2 (1.3)	2	
	>4mm	0 (0.0)	0	

Table III

Distribution of subjects according to complications (n=43)

Complications	Group-A (Universal entry point) (n=31)	Group-B (Conventional entry point) (n=12)	p-value
Unintended durotomy	2 (6.5)	1 (8.3)	0.522
Screw in the fractured pedicle	3 (9.7)	1 (8.3)	
CSF leak	1 (3.2)	0 (0.0)	
Pulmonary complication	1 (3.2)	0 (0.0)	
Nerve root irritation	3 (9.7)	1 (0.0)	
Vascular Injury	0 (0.0)	0 (0.0)	

Discussion

Pedicle screw stabilization have become commonplace in the treatment of traumatic and degenerative conditions of the thoracolumbar spine9. Among several techniques freehand pedicle screw placement has become the preferred modality of fixation for to avoid the harmful effects of sustained radiation and decrease the overall operative time. One of these freehand techniques is using the level-specific entry points for different levels of thoracic spine while another relies on a novel entry point for all levels in the thoracic spine, which is at 3mm inferior to the junction of the lateral edge of the superior articulating process and the transverse process. The ideal pedicle screw placement technology has the characteristics of constant needle entry points, little trauma, and high accuracy rates10. In this study both these techniques were used during insertion of pedicle screws in all thoracic vertebrae.

There was no significant difference in age between the Universal and conventional groups (p= 0.627).In this study, males were predominant than female. There was no significant difference in gender between the two groups (p= 0.683).

Indication of surgery in universal Group-A were 19 cases (61.29%) of traumatic vertebral fracture followed by infection (Pott's disease) 4 cases (12.90%), and Kyphotic degeneration 4 cases (12.90%), 2 cases of primary bone tumors (a case of Aneurysmal bone cyst and Ewing's Sarcoma requiring trans-pedicular fixation) constituting 6.45%, and metastatic vertebral fracture 2 cases (2.8%) in this study. In the conventional group, there were 6 cases of trauma (50.0%), infection 3(25.0%), degeneration 1(8.3%) and 2 cases of metastatic vertebral fracture (16.7%) in this study. No significant differences in indications found between these two groups. Majority of the cases were due to trauma in both groups. In a prospective cohort study on 28 patients, Kuntz et. al. also described trauma as the most common pathology11.

In our study, a total of 224 pedicle screws were placed in 43 subjects among which 158 screws in universal group and other 66 in conventional entry point group. In both the group highest number of screws were inserted in T11 level (38 in universal and 14 in conventional group). The reason behind this is trauma was the most common pathology in this study and as T11 and T12 are at the thoraco-lumbar junctional area they are the most vulnerable to traumatic thoracic fractures.

In this study, 82.9% screws were fully contained within the pedicle wall in universal entry point group and in conventional entry point group it was 72.7%. Karapinar et al showed that the pedicle breach rate in the 'thoracic level' is the highest of all the spinal segments12. Kim et al suggested that there was a consensus in all the studies of a "safe zone" from 2 to 4 mm for pedicle screw breach of the vertebral bodies4. This safe zone allows the medial or lateral wall breach by the screw without clinical consequences for the patient. Furthermore, they defined a breach of < 2 mm as a "definite safe zone", a breach of 2-4 mm a "probable safe zone", and a breach of 4-8 mm as a "questionable safe zone". In our study, the pedicle violations were classified according to 'Gertzbein Classification.' We found a total of 45 incidence of pedicle violations among 224 screws inserted in both the groups. Pedicle wall violation in universal entry point group was 17.1% and in conventional group it was 27.3%. No significant difference was found between these two groups.

A comparative study conducted by Sun et al postulated that the pedicle violation rate was 12.1% in the universal entry point group, and 15.1% in the traditional entry point group13. In our study, overall pedicle violation was 44.4% while according to Fisher et al in their prospective cohort study of 201 pedicle screws in 23 patients, 33.8% (68) screws were found to be in violation with the pedicle wall using both freehand and fluoroscopy guided techniques9. Of these, 52.9% were lateral and 39.7% were medial perforations. The breach rate of screw placement was relatively higher at the level of T4-T5 according to that study probably because these levels had smaller diameters, relatively thinner pedicles than other levels.

According to previous reports, mal-positioned screws in the sagittal plane are a rare occurrence in the thoracic spine (0–1.7% of screws). Such findings likely reflect the typical "kidney bean" morphology of the thoracic pedicle with a sagittal diameter greater than the transverse diameter. The common connection between all the studies is that a lateral breach is far more prevalent than a medial breach. As Parker et al discussed, this may be because the surgeon usually tries to avoid the medial wall to prevent spinal cord damage as well as the higher thickness of the medial wall of the pedicle14.

In this study, per-operative unintended durotomy was observed in 2 (6.5%) in universal entry point group vs 1 (8.3%) case in conventional group. CSF leak due to incidental durotomy was observed in 1 (3.2%) occasion in universal group while there was no CSF leakage occurred in the other. Also, there was pulmonary complication in 1(3.2%) case and nerve root irritation was observed in 3(9.7%) cases in universal group but no such incidence observed in conventional group and finally no incidence of major vascular injury occurred in either of these groups. There was no significant difference found in complications between the two groups (p=0.522). Vaccaro et al described the structures at risk with perforation of the anterior vertebral cortex. On the right side the azygos vein and the parietal pleura are at greatest risk, whereas on the left side the thoracic aorta and the esophagus can be injured15. In other related studies, erosion of the aorta by anterior spinal implants and migration of a broken pedicle screw into the retroperitoneal space have been reported.

The present study offers preliminary experience with thoracic pedicle-screw placement utilizing a uniform entry point in one group and conventional level-specific entry point in another group followed by C-arm guidance (after screw placement) in both the groups.

Some argue that, in the upper thoracic spine, the ideal entry point is typically more cranial. In our experience, the proposed entry point (3 mm caudal to the junction of the transverse process and lateral margin of the superior articulating process) is still effective in this region as long as a cranial-caudal orthogonal cannulation trajectory is used. However, there is no one single or uniform technique based on each surgeon's training and individual preferences, and significant variations exist among studies that may not provide easily reproducible parameters. There are certainly larger series in the literature and many of the existing techniques are effective and time tested.

Conclusion:

Our goal was to simplify and minimize variables of both these techniques in thoracic spinal fixations by comparing post-operative radiological (CT) findings. This study shows that there is no significant difference of pedicle wall violation in postoperative CT scan between using the universal and conventional entry points. Also no significant difference found in per/immediate post-operative complications

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