

Evaluation of clinicoradiological outcomes of lateral vertebral notch referred pedicular screws entry point in subaxial cervical spine by freehand technique

ABSTRACT

Purpose: Cervical pedicle screws (CPSs), though associated with complications and steep learning curve, have significantly increased strength and stability as compared to any other posterior instrumentation methods. Using anatomical referral techniques, pedicle screws can be inserted safely with a high accuracy rate obviating the need for anterior stabilization. Our present study aims to investigate the safety and outcomes of lateral vertebral notch (LVN) referred entry point for subaxial CPSs by freehand technique.

Materials and Methods: We retrospectively studied 22 patients who underwent CPS fixation. Computed tomography (CT) scan with angiography was done in each case to know the anatomy, characteristics, and anomalies of each pedicle. Postoperative CT scan was done to look for any breach in cervical pedicles. We used free hand technique for insertion of subaxial cervical pedicles taking LVN as a reference point. The authors used the medial wall of the cervical pedicles as a safe guide for the probes that walked along it.

Results: Eighty screws were inserted in total in the study group. Mean angle of screw with sagittal axis of vertebrae was $23.43^\circ \pm 9.279^\circ$. Range of angle used was 6° – 40° . Perforation occurred in 11 pedicle screws: C3 (2 out of 8, 25%), c5 (3 out of 20, 15%), and c4 (4 of 22, 18%). Out of 11 perforations, four were complete and seven were partial perforations. One complete medial perforation was associated with radiculopathy that required revision.

Conclusion: The technique described in the study can be considered relatively safe, easy, and reliable method of inserting cervical pedicle screws with high accuracy (86.25%) and low complication rates (1.25%). However, meticulous preoperative planning is required.

Keywords: Cervical pedicle, freehand technique, lateral vertebral notch, perforation, subaxial cervical spine

INTRODUCTION

Various pathologies can destabilize the cervical spine and result in neural compression and/or spinal instability.^[1,2] While the most frequent indication for posterior stabilization is instability secondary to traumatic injury,^[3] posterior stabilization is also utilized in treating nontraumatic causes including congenital, multilevel, and more complex reconstructive needs^[1,2] such as ossification of posterior longitudinal ligament, degenerative cervical myelopathy, and tumors.

Pedicle screw fixation of the cervical spine has a long history of clinical use. In 1985, Roy Camille described the surgical

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technique, and use of cervical pedicle screws (CPS) in Hangman fracture at C2, and Abumi reported the first clinical use in 1994.^[2] In 1991, Punjabi published a three-dimensional anatomic study of the human cervical spine which showed the capacity of human cervical pedicle to accept transpedicular fixation.^[2] In 1994, Kotani demonstrated that pedicular screws offered increased stability over conventional anterior and/or posterior constructs when used for 2 column or 3 column instability.^[2-4] Ludwig (1999) noted that 3 column fixation with pedicle screws increased the stability and strength and that the pedicle offered the strongest point of attachment to the cervical spine.^[2,5]

Pedicular screws in the cervical spine have been shown to have significantly higher pull-out strength and higher primary stability than lateral mass screws.^[1,5-8] With the use of pedicular screws, it is possible to create sufficient short-distance dorsal instrumentation and fusion without the need for ventral stabilization.^[1,7-9] Although appealing, this procedure is associated with an inherent risk of vascular and neurological damage and has a long learning curve.^[1-11]

Various insertion techniques have been reviewed and practiced for CPSs. These include anatomical landmark-referred techniques, pedicle exposure-referred techniques through laminectomy or laminoforaminotomy, or computer-assisted navigation techniques. All these techniques have variable success rates with its own advantages and disadvantages. The pedicular exposure through laminoforaminotomy may destabilize the posterior arch of cervical spine. The computer-assisted navigation techniques are more accurate but are time consuming with cost constraints.^[12] Furthermore, not all centers have access to computer navigation. The anatomical-referred techniques, though require a steep learning curve, are the most preferred and practiced widely. Lateral vertebral notch (LVN) is a reliable and the most constant anatomical landmark in cervical vertebrae for insertion of pedicle screws. Thus, the present study was conducted with an aim to investigate the safety and outcomes of LVN-referred entry point for subaxial CPSs by freehand technique.

MATERIALS AND METHODS

This study was conducted at a tertiary care hospital with a duration from January 2016 to December 2018. Approval from the institutional review board was taken before the commencement. We retrospectively studied 22 patients who underwent CPS fixation by two consultant spine surgeons at a tertiary care center. Computed tomography (CT) scan with angiography was done in every patient preoperatively

to know the sagittal angulation of pedicle with midline, pedicle width, size of screw, angle with end plate, the angle of insertion with the sagittal axis, dysplastic pedicles, and vertebral artery anomaly. In our study, CPS fixation was done for patients with cervical myelopathy, ossification of posterior longitudinal ligament, trauma, tumors, and infection.

Patients with anomalies of the vertebral artery on side of CPS insertion, small size pedicle with diameter <3.5 cm and restricted direction for screw insertion, and dysplastic pedicles were excluded. Written informed consent was obtained from all the study participants for sharing of their clinical and radiological data. Postoperative CT scan was done in all patients to look for any breach in cervical pedicles. We classified perforations as complete perforation (CP): deviation of screw from pedicle by more than half of screw diameter, partial perforation (PP): deviation less than half screw diameter, and NP (no perforation): screw did not violate pedicle cortex.

Surgical technique

Several techniques that have been described for CPS fixation. We used free hand technique for insertion of subaxial cervical pedicles taking LVN as a reference point.^[12,13] The authors used a distinct characteristic of the cervical pedicles – the medial wall is thicker than the lateral wall.^[14] The authors used the medial wall of the cervical pedicles as a safe guide for the probes and were walked along it. All screws were inserted by the same surgical team.

The patient was placed in prone position with the neck in slight extension and kept on traction with Gardner-Wells Tongs. A midline incision was made at the desired levels. After exposure, we identified the LVN on lateral mass. With 4 mm burr, a hole was made 2 mm medial and inferior to notch which exposes the cancellous bone of lateral mass (superolateral part of lateral mass). This is in accordance with Lou *et al.*,^[15] who found out from a cadaveric study that entry points from C3 to C6 are approximately 2.2 mm medial and 1.4 mm lower to LVN, but for C7, the entry point is 2.2 mm medial and 1.2 mm higher to LVN. The cephalocaudal inclination of the screws was decided by lateral fluoroscopic images to make it parallel to the end plate. Medial angulation was decided preoperatively using the CT scan according to individual pedicle.

After entry point was made, slight extension of this hole was made on medial side to make a key hole or a gutter through which medial wall could be palpated with probe [Figure 1]. Under fluoroscopic guidance, 2 mm cervical probe was used to advance into the pedicle with medial angulation

in a predetermined direction and keeping probe parallel to superior end plate by a free hand technique [Figure 2]. By this technique, it can be seen that the screws were along the axis of pedicle with minimal angulation axially, thus minimizing the chances of perforation in all directions. Probing parallel to superior end plate gives hold at entry point of pedicle and at the junction of pedicle with vertebral body [Figure 3]. Medial wall is thicker and stronger than lateral wall. While probing, pedicles were walked along the medial wall. We were able to palpate medial wall of pedicle for breach with probe

inserted through prong of key hole. If perforation was found intraoperatively, new trajectory was made, other posterior fixation such as lateral mass was employed or the segment was skipped completely. We measured the size of screw with the help of probe. Tract was tapped and again palpated with probe to search for perforation. In case of sclerotic pedicles, we used the 1 mm high-speed diamond burr to make a tract with a medial angulation as determined by preoperative planning. Appropriate size 3.5 mm screw was inserted and occupied at least two-thirds of the anteroposterior vertebral body depth. Screw position was checked with fluoroscopy [Figure 4].

RESULTS

Of the 22 patients included in the study, 18 were males and 4 were females. Age of patients ranged between 14 years and

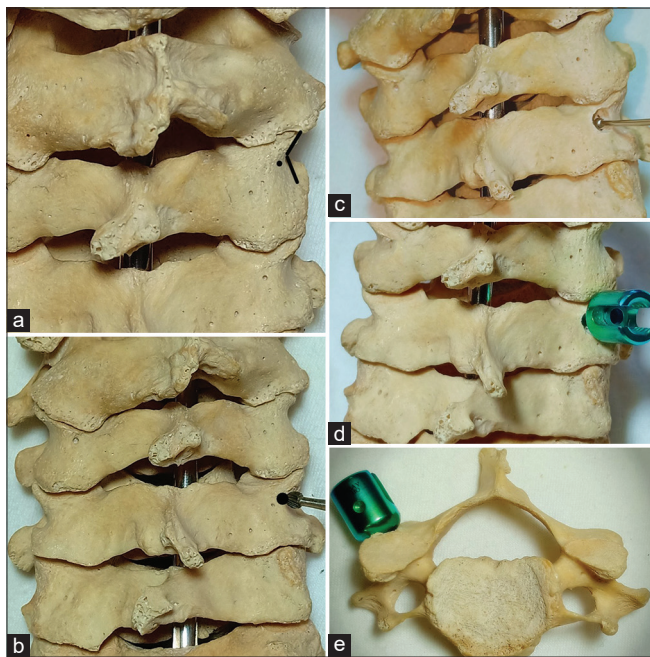


Figure 1: Illustrations showing the insertion of cervical pedicle screws through lateral vertebral notch entry point using bone models: (a) Subaxial spine with marked lateral vertebral notch; (b) Pilot hole made 2 mm medial and inferior to the notch using burr tips; (c) Free hand insertion of the cervical probe parallel to superior end plate for inserting pedicle screws; (d) lateral vertebral notch-referred pedicular screws after insertion viewed from posterior aspect; (e) lateral vertebral notch-referred pedicular screws viewed axially

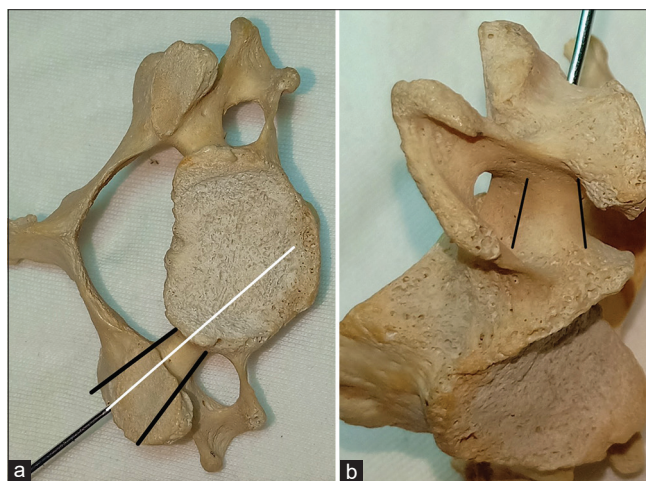


Figure 2: (a and b) Subaxial cervical pedicle viewed axially and laterally. Note the direction of lateral vertebral notch referred pedicle screws is along the direction of the pedicle without any breach



Figure 3: Intraoperative fluoroscopy image showing cervical pedicle probe



Figure 4: Anteroposterior image showing instrumented cervical pedicle screws using lateral vertebral notch referred technique

62 years with a mean of 49 years and median of 55 years. The mean duration for follow-up was 17 months (12–22 months). Eighty CPS were done in 22 patients that include C3 to C7 level [Table 1]. Of these 80 screws, 42 CPS were on left and 38 were on right.

Mean screw length for subaxial CPS was 21.05 ± 3.493 mm with a minimum length of 16 mm and maximum of 28 mm at C7 being used [Table 2]. 3.5 mm diameter screws were used for all levels of fixation. Although larger diameter screw increases purchase, 3.5 mm screws were adequate for all pedicles. The mean angle of screw with sagittal axis of vertebrae was $23.43^\circ \pm 9.279^\circ$. The range of angle used was 6° – 40° [Table 3].

Perforation occurred in 11 pedicle screws [Table 4]. C3 (2 out of 8, 25%), C5 (3 out of 20, 15%), and C4 (4 of 22, 18%) have maximum chances of perforation because the pedicle width and height are smaller at these levels.^[2,5,16]

Out of 11 perforations, 4 were CP (36%) and 7 (64%) screws were PP [Table 5]. Of all the CPs, 2 were present laterally and inferiorly, 1 medially and inferiorly, and 1 medially. Most of the PPs were into lateral wall. Lateral wall is the thinnest wall

of pedicle, so it is more liable for perforation.^[11,15] There were no superior perforations [Figure 5].

Out of 22 patients, one patient with CP developed radiculopathy [Table 6]. He had complete medial pedicular perforation of screws impinging on the C6 nerve root. This coincided with neurological examination postoperatively with pain and sensory deficit in the C6 dermatome. Revision surgery was done, and the screw was removed. The patient was symptom free at the end of 1-year follow-up. As neural



Figure 5: Lateral image showing cervical pedicle screws using lateral vertebral notch-referred technique in one of our case series

Table 1: Level wise pedicular screws

	Count	n in (%)
C3	8	10
C4	22	27.5
C5	20	25
C6	8	10
C7	22	27.5
Total	80	100.0

Table 2: Size of screw

Level	Mean	n	SD	Minimum	Maximum
C3	19.75	8	0.500	19	20
C4	20.27	22	1.794	18	24
C5	19.80	20	3.824	16	26
C6	19.00	8	1.155	18	20
C7	24.18	22	3.920	16	28
Total	21.05	80	3.493	16	28

SD - Standard deviation

Table 3: Angle with sagittal axis

Level	Mean	n	SD	Minimum	Maximum
C3	32.25	8	7.848	25	40
C4	27.55	22	10.367	12	40
C5	22	20	7.226	10	30
C6	9.5	8	4.041	6	13
C7	22.45	22	5.241	10	28
Total	23.43	80	9.279	6	40

SD - Standard deviation

Table 4: level-wise perforation

	Perforation (%)	NP (%)
C3	2 (25.0)	6 (75)
C4	4 (18.2)	18 (81.8)
C5	3 (15.0)	17 (85)
C6	1 (12.5)	7 (87.5)
C7	1 (4.5)	21 (95.5)
Total	11 13.75	69 (86.25)

NP - No perforation

Table 5: Perforation according to wall

Perforations	CP	PP	Total
Medially	1	2	3
Laterally	0	3	3
Laterally and inferiorly	2	2	4
Medially and inferiorly	1	0	1
Total	4	7	11

CP - Complete perforation, PP - Partial perforation

Table 6: Neurodeficit/radicular symptoms

	n	Neurodeficit/radicular symptoms (%)
Patients	22	1 (4.5)
Perforations	11	1 (9.1)
Medial perforations (medial+medial and inferior)	4	1 (25)
Pedicles	80	1 (1.25)

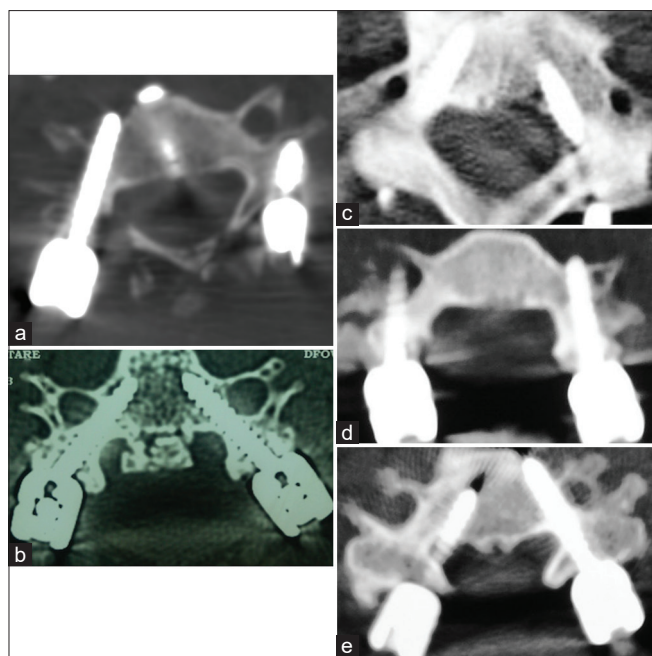


Figure 6: Types of breaches in our study. (a) CP – Lateral wall (left); (c) PP – Medial wall (left); (d) CP – Lateral wall (right) with the violation of vertebral canal and PP (Lateral wall); (e) CP – Medial wall. (b) CT scan showing normal pedicular screws bilaterally without any breach (NP). CP – Complete perforation; PP – Partial perforation, NP – No Perforation, CT – Computed tomography

Table 7: Vertebral artery compression and syndrome

	n	Vertebral artery compression (%)	Vertebral artery syndrome
Patients	22	2 (9.1)	0
Perforations	11	2 (18.2)	0
Lateral perforation (lateral + lateral and inferior)	7	2 (28.5)	0
Total (CPS)	80	2 (2.5)	0

CPS - Cervical pedicle screws

Table 8: Perforation in sclerotic pedicle

Pedicle	NP (%)	Perforation (%)	Total
Sclerosis	19 (86.4)	3 (13.6)	22
No sclerosis	50 (86.3)	8 (13.7)	58
Total	69	11	80

NP - No perforation

structure (cord and roots) is superior and medial to cervical pedicle; medial and/or superior perforations are associated with neurodeficit/radicular pain.

All patients compulsorily underwent CT angiography to know vertebral artery anatomy. All those with anomaly were excluded from CPS insertion. Seven CPS (63.6%) violated laterally, of which only 2 (28.5%) with complete breach compressed the vertebral artery. Two out of 22 patients (9.1%) had vertebral artery compression. None of the patients developed signs and symptoms of vertebral artery syndrome and hence not included in the clinical complication rate [Table 7].



Figure 7: Broad sclerotic pedicle

Overall clinical complication rate came out to be 1.25% (neurodeficit/radicular symptoms). One patient required revision surgery. All patients were studied with CT scan, and sclerotic pedicles were specifically looked for. Sclerotic pedicles make insertion difficult. Hence, pedicles were divided into broad sclerotic [Figure 6] and narrow (hour glass) sclerotic [Figure 7]. Sclerotic and broad pedicles were used for CPS fixation [Figure 8]. Out of 80 pedicles, 22 (26.1%) were broad and sclerotic. Out of 22, 3 were perforated (13.6%) [Table 8].

DISCUSSION

Pedicular screws offer the best biomechanical stability among all the other posterior fixation methods. They provide 3 column fixation to the spine. Advantages of such fixation are that it reduces the need for long segment fixation, it obviates the need for simultaneous anterior fixation to augment the construct, and they have the highest pull out strength. This has been verified with various cadaveric, biomechanical, and case studies, one of which is the biomechanical study conducted by Johnston *et al.*^[1] in 2006. Furthermore, pedicular screws with its 3 column fixation provide a strong construct, which is essential in conditions such as ankylosing spondylitis and fixation postneoplastic decompression of mass lesion to avoid catastrophic complications. Various pedicle screw insertion techniques have been described in literature. These include the use of anatomical landmarks, pedicle exposure referred techniques through laminectomy or laminoforaminotomy, or computer-assisted navigation techniques. All these techniques have variable success rates with its own advantages and disadvantages. The pedicular exposure through laminoforaminotomy may further destabilize an already unstable cervical spine by

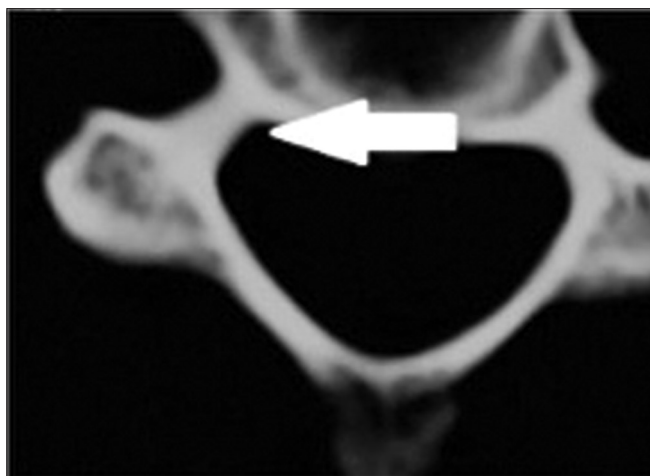


Figure 8: Hour glass sclerotic pedicle

damaging the posterior elements. Very few centers have navigation-assisted systems to help the surgeons. While these advanced navigation systems may improve the accuracy of CPS placement, they are not available on site at all hospitals due to cost constraints. In addition, movement of an adjacent segment of the spine or misalignment of the registration frame and optical array during surgery may lead to errors. Hence, we believe CPS insertion using anatomical landmark holds the most promise.

Safer transpedicular screw placement in the cervical spine depends on appropriate diameter, accurate length, and proper angulation of the screw to be inserted. Pedicle height and width are the factors, which help in determining the screw diameter. Koller *et al.*^[17] in their study showed increased safety with screw diameter adapted to pedicle diameter during posterior cervical pedicle screw fixation, achieving correct placement in 90%–100%. We used 3.5 mm screws in subaxial pedicles. This prevented us from the increasing bias that might have produced due to different diameters and we were sure that perforation was definitely not due to proportionately larger diameter screw. Although pedicle screws with larger diameters have been shown to provide greater holding strength,^[16] construct with 3.5 mm screws in our case proved stable enough construct for fusion.

Abumi *et al.*^[18,19] suggested screw lengths in their study, which was 20, 22, 24, and 28 mm. Almost similar findings were observed by Bozbuga *et al.*,^[20] who suggested screw length varying from 22.2 to 27.7 mm. Ludwig *et al.*,^[21] in their study, observed comparatively higher values of screw length ranging from 35.5 to 37.4 mm. In our study, mean screw length was 21.05 ± 3.5 with minimum used 16 mm and maximum used was 28 mm. A wide range of length of screws suggests the need for preoperative calculations of screw length based on CT scan.

In studies by Karaikovic *et al.*^[8] and Koller *et al.*,^[17] the highest value of pedicle angle with the sagittal axis (transverse pedicle angle) observed to reach up to 60° and 61°, respectively. Studies by Reinhold *et al.*^[22] and Ruofu *et al.*^[23] observed this angle ranging from 30° to 50°. These entire angles were calculated based on the anatomy of pedicle on CT scan. In our study, we measured the angle of the screw not the pedicle with the sagittal axis that came out to be $23.43^\circ \pm 9.279^\circ$. The range of angle used was 6°–40°. Importance of this observation is that medial angulation of screw is 10°–15° less compared to medial angulation of pedicle in the Indian population. The range of 36°–44° is difficult to achieve because of soft tissue. This will need an excess of retraction and extensive elevation of soft tissue.

Abumi *et al.*^[18,19] suggested the intended angle of screw insertion in the sagittal plane should be parallel to the upper endplate in the c5–c7 pedicles and was slightly cephalad in c2–c4 because of pedicle angle of c2 in the sagittal plane. In Abumi and Kaneda study, it was 93%,^[19] and in Kast *et al.* study, it was 70%.^[1] Yoshimoto *et al.*^[6] and Yukawa *et al.*^[24] reported the entire perforation rates were 11.1% (15 out of 134 screws) and 14.3% (59 out of 417 screws), respectively. Following chart is taken from reclassification petition filed by Orthopedic surgical manufacturers association (OSMA) in August 2012 [Table 9]. In our study, 86.25% of screws were placed completely inside pedicle with 5% CP and 8.75% PP.

In these studies, the satisfactory placement includes both nonperforated pedicles and those partially perforated pedicles, in which screw is not encroaching on the nerve root, not violating dura, and not causing any compression of the vertebral artery. In our studies, 86.25% of screws were completely inside the pedicle, but the satisfactory placement rate was 95% (69 NP and 7 PP).

The most obvious risk factor for screw misplacement in our series was the level of the pedicle. Most of the perforations were at c3, c4, and c5 (50%, 30%, and 27%, respectively). This was mostly due to the fact that the diameter of these pedicles is small.^[5,8,15] Kast *et al.*^[1] also showed maximum perforations at c3–c4 level.

Reinhold *et al.*^[22] stated that, for cervical spine, the tendency for a lateral pedicle wall perforation was higher than medial wall perforation. Reason for this may be the fact that the lateral pedicle wall is thinner and therefore less resistant. Gupta *et al.*^[5] stated that, in the Indian population also, lateral pedicle wall is thinner than medial. In our study, 70% of perforations were in the lateral wall.

Table 9: Orthopedic Surgical Manufacturers Association Chart: Systematic review of literature for the complications. Reclassification petition (2012): Lateral mass and pedicle screw spinal systems (cervical spine uses) SPONSOR: Orthopedic surgical manufacturers association (OSMA)

Author/Year	Number Subjects	Number Screws	Screws		CT Screw Placement Assessment: Satisfactory	Subjects Adverse Clinical Event*
			Pedicle	Lateral Mass		
Alosh/2010	93	170	C2	--	74.7% (127/170)	1.1% (1/93)
ElMiliqui/2010	15	30	C2	--	93.4% (28/30)	6.7% (1/15)
Goel/2002	160	NS	--	C1-C2	--	2.5% (4/160)
Harms/2001	37	NS	C2	C1	100%	0.0%
Mueller/2010	27	47	C2	--	83.0% (39/47)	3.7% (1/27)
Ondra/2006	79	150	C2	--	99.3 (149/150)	2.5% (2/79)
Parker/2009	70	161	C1-C3	--	93.2% (150/161)	1.4% (1/70)
Sciubba/2009	55	100	C2	--	98.0% (98/100)	0.0%
Stulik/2007 lateral mass	28	56		C1	100% (56/56)	0.0%
pedicle		56	C2		94.6% (53/56)	
Wang/2010 lateral mass	319	638		C1	95.5% (609/638)	0.0%
pedicle		638	C2		92.8% (592/638)	
Abumi/2000	180	669	C2-C7	--	93.3% (624/669)	1.7% (3/180)
Cornefjord/2005	19	67	C2-C7	--	94.0% (63/67)	5.3% (1/19)
Djurasovic/2005	26	148	C7	C3-C6	94.6% (140/148)	NS
Inoue/2012	94	457	--	C3-C6	90.4% (413/457)	0.0%
Ishikawa/2011	21	108	C2-C7	--	97.2% (105/108)	0.0%
Ishikawa/2010 Fluoroscopy	30	126	C2-C7	--	87.3% (110/126)	3.2% (2/62)
3D-Fluoro	32	150	C2-C7	--	96.7% (145/150)	
Ito/2008 pedicle	50	176	C2-C7	--	97.2% (171/176)	0.0%
lateral mass	50	58		C2-C7	100% (58/58)	
Kim/2007	65	486	C2, C7	C1, C3-C6	97.5% (474/486)	1.5% (1/65)
Kotil/2012	45	210	C3-C7	--	97.6% (205/210)	0.0%
Lee/2012	48	205	C3-C7	--	85.2% (174/205)	0.0%
Liu/2009	25	150	C3-C7	--	96.0% (144/150)	0.0%
Muffoletto/2000	35	146	--	C3-C6	98.6% (144/146)	0.0%
Nakashima/2011	84	390	C2-C7	--	95.9% (374/390)	6.0% (5/84)
Neo/2005	18	86	C2-C6	--	86.0% (72/86)	5.6% (1/18)

One patients out of 22 developed complications in the form of radiculopathy and sensory deficit due to complete medial pedicular perforation of screws impinging on the neural structures. Revision surgery was done, and screw was removed. He recovered completely at 1-year follow-up. Two other patients had vertebral artery compression which was asymptomatic and hence not included in the overall complications. Abumi *et al.* showed the complication rate of only 2.7%^[18] with revision in 1%. Kast and *et al.* showed a complication rate of 8% and revision in 4%.^[1] The clinical complication rate in our study came out to be only 1.25% with 1 revision. In the above chart from the reclassification petition, the clinical complication rate varies from 0% to 7%. Due to small sample size (22 patients), even 1 or 2 complications were reflected as higher complication rate. To assess the clinical complication rate accurately, the study has to be conducted on a larger population.

Mechanical complications such as implant failure, misplacement, screw loosening, breakage, and screw back out did not occur. This is attributed to fact that pull-out strength of CPS is greater and CPS construct is biomechanically more stable than any other construct.^[7-11,25] We recommend this procedure to be used in highly selective patients with the

selection of each vertebra on the basis of preoperative CT scan and angiography. In our series, we had used CPS fixation specifically for complex fixation for deformities, ankylosing spondylitis, tumor, and high energy trauma where stiff construct is required for biomechanical stability as recommended by Abumi *et al.*^[26]

However, our study is not without limitations. These are small sample size, absence of a control group comparing other fixation modalities, and the retrospective nature of the study. A prospective multicentric analysis with a large sample size is needed to further validate our findings. Second, CPS insertion it requires a steep-learning curve to master the technique. We recommend that, for training purposes, an inexperienced surgeon should master placement of the thoracolumbar pedicle screw in real practice and practice CPS insertion using cadavers. Heo *et al.*^[27] in his study on learning curve for cervical pedicle screw insertion showed that minimum of thirty patients is required for safe technique. Initial CPS should always be inserted under supervision in order to avoid a surgical catastrophe. Furthermore, a long-term multicentric comparative trial should be conducted comparing the effects of lateral mass screws versus CPS to see if the

fixation method has any impact on the long-term outcome considering the difficulty and steep learning curve of LVN-referred CPS insertion.

CONCLUSION

We performed cervical pedicle screw insertion with the free hand technique using LVN as a reference for entry point, with 86.25% accuracy and 1.25% complication rate. This technique can be considered relatively safe, easy, and reliable method of inserting CPS with meticulous preoperative planning.

Consent

All patients included in the study have given a written informed consent for sharing of their clinical and radiological data.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Kast E, Mohr K, Richter HP, Borm W. Complications of transpedicular screw fixation in the cervical spine. *Eur Spine J* 2006;15:327-34.
- RECLASSIFICATION PETITION. Lateral Mass and Pedicle Screw Spinal Systems (Cervical Spine Uses) SPONSOR: Orthopedic Surgical Manufacturers Association (OSMA); 2012.
- Uehara M, Takahashi J, Hirabayashi H, Hashidate H, Ogihara N, Mukaiyama K, *et al.* Perforation rates of cervical pedicle screw insertion by disease and vertebral level. *Open Orthop J* 2010;4:142-6.
- Liu Y, Hu JH, Yu KY. Pedicle screw fixation for cervical spine instability: Clinical efficacy and safety analysis. *Chin Med J (Engl)* 2009;122:1985-9.
- Gupta R, Kapoor K, Sharma A, Kochhar S, Garg R. Morphometry of typical cervical vertebrae on dry bones and CT scan and its implications in transpedicular screw placement surgery. *Surg Radiol Anat* 2013;35:181-9.
- Yoshimoto H, Sato S, Hyakumachi T, Yanagibashi Y, Kanno T, Masuda T. Clinical accuracy of cervical pedicle screw insertion using lateral fluoroscopy: A radiographic analysis of the learning curve. *Eur Spine J* 2009;18:1326-34.
- Dunlap BJ, Karakovic EE, Park HS, Sokolowski MJ, Zhang LQ. Load sharing properties of cervical pedicle screw-rod constructs versus lateral mass screw-rod construct. *Eur Spine J* 2010;19:803-8.
- Jones EL, Heller JG, Silcox DH, Hutton WC. Cervical pedicle screws versus lateral mass screws. Anatomic feasibility and biomechanical comparison. *Spine (Phila Pa 1976)* 1997;22:977-82.
- Karakovic EE, Kunakornsawat S, Daubs MD, Madsen TW, Gaines RW Jr. Surgical anatomy of the cervical pedicles: Landmarks for posterior cervical pedicle entrance localization. *J Spinal Disord* 2000;13:63-72.
- Johnston TL, Karakovic EE, Lautenschlager EP, Marcu D. Cervical pedicle screws vs. lateral mass screws: Uniplanar fatigue analysis and residual pullout strengths. *Spine J* 2006;6:667-72.
- Karakovic EE, Daubs MD, Madsen RW, Gaines RW Jr. Morphologic characteristics of human cervical pedicles. *Spine (Phila Pa 1976)* 1997;22:493-500.
- Luo J, Wu C, Huang Z, Pan Z, Li Z, Zhong J, *et al.* The accuracy of the lateral vertebral notch-referred pedicle screw insertion technique in subaxial cervical spine: A human cadaver study. *Arch Orthop Trauma Surg* 2017;137:517-22.
- Tomasino A, Parikh K, Koller H, Zink W, Tsiouris AJ, Steinberger J, *et al.* The vertebral artery and the cervical pedicle: Morphometric analysis of a critical neighborhood. *J Neurosurg Spine* 2010;13:52-60.
- Farooque K, Yadav R, Chowdhury B, Gamanagatti S, Kumar A, Meena PK. Computerized tomography-based morphometric analysis of subaxial cervical spine pedicle in asymptomatic Indian population. *Int J Spine Surg* 2018;12:112-20.
- Panjabi MM, Shin EK, Chen NC, Wang JL. Internal morphology of human cervical pedicles. *Spine* 2000;25:1197-205.
- Wu WL. Biomechanical evaluation of an expansive pedicle screw in calf vertebrae. *Eur Spine J* 2006;15:321-6.
- Koller H, Acosta F, Tauber M, Martin MH, Forstner R, Augat P, *et al.* Cervical anterior transpedicular screw fixation (ATPS) Part II – Accuracy of manual insertion and pull-out strength of ATPS. *Eur Spine J* 2008;17:539-55.
- Abumi K, Shono Y, Ito M, Taneichi H, Kotani Y, Kaneda K. Complications of pedicle screw fixation in reconstructive surgery of the cervical spine. *Spine* 2000;25:962-9.
- Abumi K, Kaneda K. Pedicle screw fixation for nontraumatic lesions of the cervical spine. *Spine* 1997;22:1853-63.
- Bozbuga M, Ozturk A, Ari Z, Sahinoglu K, Bayraktar B, Cecen A. Morphometric evaluation of subaxial cervical vertebrae for surgical application of transpedicular screws. *Spine* 2004;29:1876-80.
- Ludwig SC, Kramer DL, Balderston RA, Vaccaro AR, Foley KF, Albert TJ. Placement of pedicle screws in the human cadaveric cervical spine. *Spine* 2000;25:1655-67.
- Reinhold M, Magerl F, Reiger M, Blauth M. Cervical pedicle screw placement: Feasibility and accuracy of the new insertion technique based on the morphometric data. *Eur Spine J* 2007;16:47-56.
- Ruofu Z, Huilin Y, Xiaoyun H, Xishun H, Tiansi T, Liang C, *et al.* CT evaluation of cervical pedicle in a Chinese population for surgical application of transpedicular screw placement. *Surg Radiol Anat* 2008;30:389-96.
- Yukawa Y, Kato F, Yoshihara H, Yanase M, Ito K. Cervical pedicle screw fixation in 100 cases of unstable cervical injuries: Pedicle axis views obtained using fluoroscopy. *J Neurosurg Spine* 2006;5:488-93.
- Kotani Y, Cunningham BW, Abumi K, McAfee PC. Biomechanical analysis of cervical stabilization systems. An assessment of transpedicular screw fixation in the cervical spine. *Spine (Phila Pa 1976)* 1994;19:2529-39.
- Tukkapuram VR, Kuniyoshi A, Ito M. A review of the historical evolution, biomechanical advantage, clinical applications, and safe insertion techniques of cervical pedicle screw fixation. *Spine Surg Relat Res* 2019;3:126-35.
- Heo Y, Lee SB, Lee BJ, Jeong SK, Rhim SC, Roh SW, *et al.* The learning curve of subaxial cervical pedicle screw placement: How can we avoid neurovascular complications in the initial period? *Oper Neurosurg (Hagerstown)* 2019;17:603-7.